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MIND THE GAP: MANAGER SELF-PERCEPTION AND EMPLOYEE EXPECTATIONS OF SELECTED LEADERSHIP DIMENSIONS

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Abstract. This study examines the discrepancies between managers' self-perception and their employees' expectations regarding key managerial competencies. The primary aim of the research is to identify whether a perception gap exists and, if so, to quantify and interpret the extent of this gap both statistically and practically. Based on a two-stage analysis involving descriptive statistics, t-tests, and effect size estimation (Cohen's d), the study highlights specific competencies and clusters where the divergence is most pronounced. Findings reveal managers' consistent underestimation of critical competencies, particularly in psychological resilience, decision-making under pressure, and crisis management. Conversely, interpersonal communication and career experience showed a relatively high alignment between managers and employees. The results provide valuable insights for targeted leadership development, emphasising the need to strengthen competencies that are critical for effective management in a dynamic organisational environment. The study also lays the groundwork for a subsequent analysis aimed at constructing a profile of the ideal manager based on employee preferences for demographic, cultural, and behavioural attributes.

Keywords: managerial competencies; self-perception; employee expectations; leadership development; perception gap; human resource management; organizational behaviour

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1. Introduction

The effectiveness of managerial leadership is a key factor for organisational success across sectors and geographic regions. Although there is extensive literature focused on defining key managerial competencies (Boyatzis, 2008; Whetten & Cameron, 2016), less attention has been paid to exploring potential discrepancies between how managers assess their abilities and what competencies are expected of them by their subordinates (Zhang & Wang, 2024). This perceptual misalignment can have significant consequences for leadership trust, job satisfaction, and team effectiveness (Dirks & Ferrin, 2002; Salas, Reyes, & McDaniel, 2018).

Research indicates that managers' self-assessments are often inflated compared to how their competencies are perceived by employees (Atwater & Yammarino, 1992; Fleenor et al., 2010; Fleenor et al., 2020). This effect is particularly evident in the area of soft skills, such as communication, emotional intelligence, and the ability to motivate teams (Goleman, Boyatzis, & McKee, 2013). A lack of alignment (Breevaart et al., 2022) between managers' self-perception and employees' expectations can lead to lower employee engagement, increased turnover, and decreased organisational performance (Schaufeli, 2015; Schaufeli & Salanova, 2023).

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Contemporary trends, including the dynamics of hybrid work, the growing emphasis on employee wellbeing, and the acceleration of technological change, place new and complex demands on managers (Lee & Kim, 2023). Therefore, effective leadership requires technical and professional competencies and a high degree of adaptability, emotional stability, and the ability to build trust in an environment of constant change (Yukl & Mahsud, 2010).

The importance of aligning these two perspectives—managerial self-reflection and employee expectations—has gained particular relevance in the current context. Since the outbreak of the COVID-19 pandemic, the dynamics of the workplace have fundamentally changed: organisations are increasingly required to manage hybrid teams, adapt to rapid changes, and build psychologically safe environments for diverse workforces (Kniffin et al., 2021). Issues of diversity and inclusion further highlight new demands for flexibility, cultural sensitivity, and respect for the individual needs of employees (Shore et al., 2018). Simultaneously, technological transformation intensifies pressure on managers to integrate new digital tools and manage change agilely (Molino et al., 2020). Understanding perceptual differences in managerial competencies is thus a crucial prerequisite for targeted leadership development that addresses the real needs of work teams and the challenges of today's workplace. Against this backdrop, the present study is framed within the broader context of an increasing emphasis on aligning managerial self-perception with employee expectations in a dynamically evolving work environment.

The main objective of this article is to map the discrepancies between managers' self-evaluations and the expectations of their subordinates regarding key managerial competencies and to determine in which areas these differences reach statistical and practical significance. Following the theoretical introduction and articulating the study's objectives, the methodology section outlines the research design, sample characteristics, and analytical methods. The empirical section presents the findings corresponding to the individual research questions. The conclusion synthesises the main results, discusses their implications within the broader context of people management, and proposes practical recommendations and directions for future research.

2. Review of Literature on Leadership

Theories and models of leadership are derived from various dominant aspects of management, and a considerable number of them exist. Consequently, when seeking the most suitable leadership theory for a given purpose, there is a risk of decision paralysis, that is, the inability to choose from among too many options. Nevertheless, the primary motivation for developing this scientific field has been to provide practical guidance for selecting and developing ideal managers for specific positions and entrusted tasks (Kangbok et al., 2025). Therefore, Chapter 2 does not focus on presenting individual leadership theories and models but concentrates on their shared factors.

The origins of leadership theory can be traced to the "great man" theory, which emphasises the role of the leader as a charismatic individual (Haeckl & Rege, 2024). Over time, development progressed toward theories focusing on the psychological aspects of leaders. A key feature of this direction in leadership research is thus the emphasis on the development of psychological and other personal qualities of the leader (Štrach et al., 2024).

The main stages of the evolution of leadership theories have focused successively on traits such as intelligence, knowledge, dominance, self-confidence, stress resilience, integrity, and maturity; on transaction and transformation as key areas of a leader's influence over subordinates; on behaviour, encompassing trust, respect, diligence, service, interest, and consultation; and on the situation, particularly workplace relationships, the nature of the task, power positions, or other attributes present in a given context, always with respect to the organisational objectives (Szostak, 2022; Kim & Beehr, 2022; Kangbok et al., 2025).

Given the specificities of the contemporary environment, it is also necessary to highlight the concept of remote leadership, which refers to managing from a distance. In this context, managers must master knowledge and skills related to leading virtual or geographically dispersed teams. They must also be proficient in operating relevant hardware and software, ensuring technical adequacy (such as screens with sufficient resolution, quality

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headsets and microphones for communication), securing efficient data transmission (e.g., internet speed), and protecting against cyber threats (such as phishing or ransomware attacks). Typical challenges associated with remote leadership include reduced direct contact between supervisors and subordinates (increasing the potential for misunderstandings), limited access to or knowledge of information, social isolation (potentially eroding team spirit), the emergence of silo effects (where individuals, teams, or departments cease to collaborate), and disruptive elements in non-work environments (e.g., at home) (Jankelová et al., 2021). These risks can be mitigated by focusing intensively on the team atmosphere, defining and enforcing explicit norms for online behaviour (during meetings and information management), regularly emphasising team and individual tasks and goals, and fostering flexibility and support to help subordinates adapt to this mode of operation (Nguyen et al. 2022).

Another dichotomous concept within leadership theories is transactional versus transformational leadership. Transaction refers generally to an exchange—"something for something." The tools here are rewards and punishments (Hunková & Havierniková, 2024). In contrast, transformational leadership is based on the personal development of the subordinate in collaboration with a leader capable of inspiring them (Ehrnrooth et al.2023). Its tools include a shared vision, identification with the goal, acceptance of challenges, team cohesion, loyalty, enthusiasm, and positive energy. When applied by top management, this approach can potentially change an organisation's culture.

Today, leadership theories constitute one of the key areas of research within the interdisciplinary field straddling management and psychology. In various managerial development programs, significant importance is attached to psychology and the personal attributes of the manager (Zada et al., 2024). A manager's competencies can be categorised into four principal areas: the ability to secure and optimally use resources—primarily human, but also financial, material, and intangible resources; the ability to organise, that is, to allocate and delegate work; the ability to monitor and pursue organisational goals; and the ability to distinguish between "doing the right things" and "doing things right" (Fisher et al., 2023).

The sources of managerial power serve as instruments for influencing teams or individuals. These sources include legitimate power, derived from formal authority; reward power, based on the ability to allocate rewards; coercive power, based on the ability to administer punishments; expert power, stemming from specialised knowledge or skills; and referent power, originating from personality traits, respect, or charisma (Joseph-Richard & McCray, 2022). The degree of dominance of this final form of power determines whether a manager is truly perceived as a leader.

Although the alignment between managerial self-perception and employee expectations has been addressed in leadership literature, existing research often focuses either on the effectiveness of leadership behaviours as assessed by external raters or on developing specific competencies in isolation. There is a notable lack of comprehensive, data-driven studies that systematically map perception discrepancies across a broad range of leadership competencies while capturing both managerial self-assessments and employee expectations within the same organisational context. Moreover, few studies adopt a reverse perspective—using employee-defined standards as the starting point for evaluating managerial adequacy—despite growing calls for more employee-centric approaches in leadership development. This study aims to address this gap by employing a dual-source assessment model and focusing on the degree and practical implications of perception misalignments. By highlighting the areas of most significant divergence and assessing their impact, the study contributes to a more nuanced understanding of where leadership development efforts should be most urgently directed to meet the evolving demands of the contemporary workplace.

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3. Methodology of Research

3.1 Research Design

The research was designed as a quantitative comparative study focused on identifying differences between employees' expectations of managers and managers' self-assessments in the area of key managerial competencies. The aim was to uncover the perception gap between these two groups across seven thematic areas. The significance of this objective lies in the fact that the effectiveness of managerial leadership is largely influenced by the degree to which managers' self-perception aligns with the expectations of their subordinates.

A misalignment between self-assessment and employee expectations can lead to reduced trust, impaired communication, diminished teamwork, and, in extreme cases, increased turnover of key personnel. A precise understanding of perceived differences in managerial capabilities thus represents a crucial step toward developing effective leadership, enhancing employee engagement, and optimising workplace relationships.

The following research questions were formulated within the study:

- **RQ1:** Are there statistically significant differences between how managers assess their managerial competencies and how these competencies are perceived by their subordinates?
- **RQ2:** Which thematic areas exhibit the most significant discrepancies between employee expectations and manager self-perceptions?
- **RQ3**: How substantial are these discrepancies in terms of practical impact?

The research itself was divided into two phases. In the first phase, data were collected from employees regarding their expectations of their supervisors. In the second phase, data were collected from managers regarding their self-assessments across identical dimensions. Both phases were conducted separately, and respondents were not linked to ensure anonymity and the independence of the assessments. Both groups completed a structured questionnaire with identical content, allowing for direct comparative analysis across the examined areas. This approach enabled an independent analysis of the aggregated group-level perception gaps and a subsequent comparison of results within individual leadership dimensions.

The research instrument was a structured questionnaire developed based on a theoretical review of leadership concepts and models. Following an incubation phase conducted in November 2024, seven thematic clusters were defined:

Psychological and Personality Factors: These are crucial indicators of how effectively a manager can lead their team. Such attributes influence not only work performance but also the organisational culture and team dynamics. While technical skills can be acquired through education and experience, personality traits and psychological resilience are often innate or developed over the long term. This section aimed to identify which psychological and personality traits respondents consider key regarding their immediate supervisor.

Values and Motivation: Values and motivation are essential for how managers approach their work, set priorities, and lead their teams. While professional knowledge and skills define a manager's ability to perform specific tasks, their value orientation and internal motivation determine how they respond to challenges and inspire subordinates. Managers with clear values and strong internal motivation tend to be more consistent, loyal, and strategically oriented. This section, therefore, focuses on identifying which values and motivational drivers are deemed critical in a manager.

Social and Communication Skills: The ability to communicate effectively and build relationships is one of the most important prerequisites for managerial success. A manager’s communication style influences not only the clarity of information delivery but also their ability to inspire, motivate, and gain trust. Skills such as negotiation, conflict management, and adaptability to various personalities and situations are equally essential. Social skills

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are also key to creating a positive work environment, impacting team satisfaction and productivity. This part of the research thus examines which aspects of social and communication competence are considered most important by respondents.

Culture and Organisational Context: Organisational culture significantly shapes leadership styles and employee expectations. What is seen as ideal managerial behaviour in a large corporation can differ greatly from that expected in a dynamic start-up or the public sector. International context also plays a role, with different countries emphasising different approaches to hierarchy, decision-making, and manager-employee relationships. This section investigates which aspects of organisational culture and management style are most valued by respondents.

Behaviour in Crisis Situations: Crisis leadership is crucial, as managers often make key decisions during critical organisational moments. The most important aspects of good leadership are the ability to respond quickly and effectively, maintain composure, and guide the team through a crisis. This cluster focuses on managers' preferred traits and skills in managing crises and unexpected situations.

Career Path and Experience: A manager's career trajectory and accumulated experience significantly affect their decision-making style, problem-solving ability, and team leadership effectiveness. Experienced managers not only possess professional knowledge but also learn from both successes and failures. This section explores which types of experience and skills respondents consider most important.

Use of Modern Technologies: Technological competence is indispensable in today's digital age. Managers are expected to work effectively with modern technologies, lead hybrid teams, and leverage artificial intelligence and automation tools. Technological skills can significantly impact both leadership efficiency and organisational competitiveness.

Each cluster comprised an average of 6–8 specific competencies, which respondents rated using a five-point Likert scale (1 = completely unimportant to 5 = very important). The employee questionnaire measured expectations toward the immediate supervisor, whereas the manager questionnaire served for self-assessment.

3.2 Research Sample

The research sample was composed using a combination of purposive and convenience sampling methods. For the employee group, convenience sampling was employed, targeting respondents meeting the criteria of being employed in technical and administrative professions across various industries. For the manager group, purposive sampling was applied, with the key inclusion criterion being the leadership of at least five subordinates.

In the first phase, the research involved n = 1,720 respondents from among employees. The sample predominantly consisted of female respondents, with 54% identifying as women and 43% as men. An additional 2% of respondents did not disclose their gender, and 1% identified with another gender. Regarding age distribution, 80% of participants were under the age of 25, 5% were aged between 46 and 55, and the remaining respondents were between 36 and 45 years old.

In terms of educational attainment, the majority (74%) had completed secondary education with a school-leaving examination (maturita). The remaining participants had obtained a bachelor’s or master’s degree. None of the respondents had only primary education or secondary education without a school-leaving certificate.

Regarding marital status, most respondents were either single or in a relationship, with 6% being married and 5% reporting being divorced. The most frequently represented sector was the automotive industry (27%), followed by commerce and marketing (12%), human resources and administration (11%), IT and technology (5%), banking (4%), and services and hospitality (4%). Other sectors, such as pharmacy, healthcare, construction, military, and telecommunications, were each represented by approximately 1%. All respondents

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held technical or administrative positions, and none were employed in manual labour roles. All participants were of Czech nationality.

In the second phase, the research was conducted among managers (n = 360) and focused on self-assessment. This sample also predominantly consisted of women, with 77% identifying as female, 20% as male, and 3% not disclosing their gender. In terms of age, 77% of the participants were under 25 years old, 3% were between 26 and 35 years old, 14% were between 36 and 45 years old, and 3% were between 46 and 55 years old. No respondents reported an age over 56.

Regarding educational background, 80% of the respondents had completed a bachelor's degree, 9% had a master's degree, and 9% had completed secondary education with a school-leaving examination. The remaining respondents did not specify their educational attainment.

With respect to marital status, 31% were single, 51% were in a relationship, 9% were married, and 6% were divorced, with the remainder not reporting their marital status. In terms of the professional sector, the most common field was the automotive industry (34%), followed by commerce and marketing (17%), transport and logistics (9%), services and hospitality (6%), construction (6%), finance and banking (6%), and IT and technology (3%). Other sectors were individually represented.

3.3 Data Collection Procedure and Ethical Considerations

Data collection among employees took place between December 2024 and March 2025, primarily through an electronic survey conducted via the Google Forms platform. Data collection among managers was carried out in April 2025 using the same method. The research was conducted in accordance with the ethical principles governing data collection in the social sciences. Participation in the study was entirely voluntary, and respondents were informed prior to their involvement about the purpose of the research, the anonymity of data processing, and their right to withdraw at any time without providing a reason. No identifying information was collected that would allow for the responses to be traced back to specific individuals. All data were collected and processed in an anonymised form solely for the purpose of scientific analysis and publication in an academic journal.

3.4 Analytical Approach

The data analysis proceeded in three consecutive steps. First, a descriptive analysis was conducted, focusing on the calculation of mean values, medians, and standard deviations for each item and thematic area. This was followed by testing for the statistical significance of differences between the two respondent groups — specifically, between employees' expectations and managers' self-assessments — using an independent samples t-test, or the Mann-Whitney U test in cases where the assumptions of normality were not met. The final stage involved assessing the practical significance of the observed differences through the calculation of effect sizes using Cohen’s d, which enables interpretation of the real-world relevance of the differences identified. All analyses were performed using Microsoft Excel, supplemented by basic statistical tests commonly applied in social science research.

4. Results of the Empirical Investigation

This chapter presents the main findings of the empirical investigation focused on differences in the perception of managerial competencies between the employee group and the manager group. The results are structured according to the research questions outlined in the methodology section. First, a descriptive analysis of the evaluation of individual competency areas is presented (RQ1), followed by the testing of statistical differences between groups (RQ2), and finally, the practical significance of the identified differences is assessed (RQ3).

4.1 Results of the Analysis of Differences in the Perception of Managerial Competencies (RQ1)

The first research question focused on determining whether statistically significant differences exist between how managers assess their own managerial competencies and how these competencies are expected by their subordinates. Identifying these differences is crucial, as a perceptual mismatch in key competencies may

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negatively affect superior-subordinate relationships, reduce trust in leadership, and contribute to a long-term decline in employee engagement and loyalty. In addressing this question, a descriptive analysis of the average ratings of the clusters of managerial competencies by both respondent groups was conducted. The aim of this analysis was to describe the basic trends in the data and to create a foundation for subsequent testing of the statistical significance of the differences and their practical interpretation.

The area of **psychological and personality factors** focuses on characteristics that influence a manager's ability to handle stressful situations, make decisions under pressure, and effectively lead a team in dynamic and changing environments. Primarily, this involves abilities related to inner stability, cognitive capacity, and the personality readiness of the manager to manage complex, stressful, and dynamic situations.

Table 1. Psychological and Personality Factors – Descriptive Statistics

Competency	Mean (Employees)	SD (Employees)	Mean (Managers)	SD (Managers)
Active and energetic	3,866279	0,830432	3,444444	1,181874
Resilient to stress and pressure	4,627907	0,631466	3,166667	1,082326
Excellent memory	3,645349	0,821375	3,222222	1,267418
Good judgment	4,348837	0,713568	3,583333	0,769972
Ability to make quick and effective decisions	4,325581	0,716422	3,166667	1,055597
Self-confident	3,47093	0,888045	2,722222	1,031258
Quick-witted and responsive	3,930233	0,813493	3,5	0,941124
Original and creative thinking	3,517442	0,89491	3,25	1,130739
Productive and efficient	4,203488	0,683463	3,777778	0,897969
Distinguishing important from unimportant	4,47093	0,76798	3,888889	1,007905
Emotionally stable	4,424419	0,749337	3,305556	1,237958
Ability to learn new things	3,77907	0,947773	4,416667	0,554205
Ability to quickly adapt to changes	3,872093	0,834862	3,777778	0,897969

Source: the authors

Among employees, this area received high ratings across most items. The highest average score was recorded for the competence "Resilient to stress and pressure" (4.63; SD = 0.63), followed by "Good judgment" (4.35; SD = 0.71) and "Ability to make quick and effective decisions" (4.33; SD = 0.72). The lowest, though still above average, ratings were given to "Excellent memory" (3.65; SD = 0.82) and "Active and energetic" (3.87; SD = 0.83). Managers' self-assessments were consistently lower across all competencies compared to employee expectations. The highest average self-rating appeared for "Good judgment" (3.58; SD = 0.77), while the lowest scores were observed for "Resilient to stress and pressure" (3.17; SD = 1.08) and "Ability to make quick and effective decisions" (3.17; SD = 1.06). "Excellent memory" was also rated relatively low (3.22; SD = 1.27).
The results indicate a pronounced perception gap: employees perceive psychological resilience, cognitive agility, and decision-making abilities as highly critical, whereas managers tend to evaluate their own competencies in these areas more conservatively. The largest gap between groups was observed in the domain of stress management, where the difference between employee expectations and manager self-assessments exceeded 1.4 points.

These findings point to the need for leadership development programs to focus on strengthening internal psychological resilience, decision-making speed, and cognitive flexibility, particularly in the context of a rapidly changing work environment.

The **values and motivation** area focused on characteristics related to a manager's internal integrity, responsibility towards both the team and the organisation, and strategic orientation. It reflected not only the manager's personal moral framework but also their ability to inspire the team, serve as a role model, and promote long-term values within the organisational culture.

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Table 2. Values and motivation - descriptive

Competency	Mean (Employees)	SD (Employees)	Mean (Managers)	SD (Managers)
Integrity and high ethical standards	3,77907	1,007587	4,083333	0,769972
Loyal to the team and organisation	4,141844	0,930296	4,305556	0,888641
Able to take responsibility for decisions	4,703488	0,550799	4,416667	0,603561
Prestige and excellent reputation	3,203488	1,002564	3,361111	0,723198
Clearly defined moral principles and ethical behaviour	4,104651	0,94935	4,222222	0,988826
Interest in sustainability and environmental responsibility	2,523256	1,151929	3,305556	1,190905
Transparent in actions and decision-making	4,011628	0,801959	3,861111	0,761682
Long-term vision and strategic thinking	3,924419	0,871972	3,388889	0,837608
Ambitious and willing to take risks when necessary	3,761628	0,889269	3,472222	1,081959
Supported innovation and new approaches	4,023256	0,816163	4,055556	0,753826

Source: the authors

On average, employees attributed relatively high importance to the domain of values and motivations. The highest rating was assigned to the competence "Ability to take responsibility for decisions" (M = 4.70; SD = 0.55), followed by "Loyalty to the team and the organisation" (M = 4.14; SD = 0.93) and "Clearly defined moral principles and ethical behaviour" (M = 4.10; SD = 0.95). The lowest mean score was associated with the competence "Interest in sustainability and environmental responsibility" (M = 2.52; SD = 1.15), which may indicate that environmental considerations are not perceived as a key managerial quality within the given sample.

From the managers' perspective, the highest-rated competencies were "Integrity and high ethical standards" (M = 4.08; SD = 0.77), "Ability to take responsibility for decisions" (M = 4.42; SD = 0.60), and "Loyalty to the team and the organisation" (M = 4.31; SD = 0.89). Conversely, the lowest ratings were observed for "Prestige and excellent reputation" (M = 3.36; SD = 0.72) and "Long-term vision and strategic thinking" (M = 3.39; SD = 0.84). A significant difference between the groups was evident in the area of environmental responsibility, where employees assigned substantially lower ratings than managers (a difference of 0.79 points). In contrast, differences across most other items were moderate to minimal. Overall, the domain of values and motivations exhibited a lower degree of perceptual discrepancy compared to the domain of psychological factors. Nevertheless, certain competencies—particularly long-term vision and strategic thinking—suggest a need for further development in value-based leadership and transparent communication towards teams.

Social and communication skills reflected the manager's ability to establish and maintain high-quality interpersonal relationships, communicate effectively, and adapt their communication style to various personality types and situations. This domain also focused on skills related to inspiring and leading people, conflict resolution, and external representation of the organisation. Communication and social competencies constitute one of the key areas of managerial performance, as they significantly influence intra-team dynamics, employee motivation, and engagement levels.

Table 3. Social and communication skills - descriptive

Competency	Mean (Employees)	SD (Employees)	Mean (Managers)	SD (Managers)
Communicative	4,232558	0,826101	3,777778	1,07201
Able to inspire and motivate others	4,267442	0,815413	3,666667	1,121224
Able to captivate during public speaking	3,726744	0,991652	3,111111	1,409717
Able to negotiate and find compromises	4,372093	0,701652	3,527778	0,774084
Was friendly and approachable	4,023256	0,942521	4,277778	0,778684
Establish and maintain good relationships with colleagues	4,255814	0,854107	4,25	0,731925
Had natural authority	3,680233	0,977563	2,805556	1,090726
Was consistent	3,924419	0,82369	3,75	1,024695
Work with different types of people and adapt	4,162791	0,87004	3,861111	0,930523
Able to resolve conflicts effectively	4,383721	0,759634	3,5	0,810643

Source: the authors

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Employees assigned high importance to competencies in social and communication skills. The highest average rating was given to the item Able to resolve conflicts effectively (4.38; SD = 0.76), followed by Able to negotiate and find compromises (4.37; SD = 0.70) and Able to inspire and motivate others (4.27; SD = 0.82). The lowest rating was assigned to the ability; Able to engage in public speaking (3.73; SD = 0.99), although it remained relatively above average.

In terms of managers' self-assessment, the highest-rated competencies were Friendly and approachable (4.28; SD = 0.78) and Able to establish and maintain good relationships with colleagues (4.25; SD = 0.73). Conversely, the lowest average rating was recorded for the item Had natural authority (2.81; SD = 1.09), which contrasts sharply with employees' expectations (3.68; SD = 0.98).

Significant differences were also observed for the items Able to engage in public speaking (difference of 0.62 points) and Able to resolve conflicts effectively (difference of 0.88 points). The results confirm the existence of a perceptual gap in soft skills, particularly where managers are expected to influence the team and demonstrate natural authority. The identified differences underscore the importance of training in communication style, presentation skills, and conflict management, all of which have a crucial impact on managerial effectiveness and team member satisfaction.

The area of culture and context focused on a manager's ability to navigate different organisational environments, respond to team needs in hybrid and international structures, and simultaneously promote innovation and employee development. These competencies reflect the ability to adapt to changing conditions and to align organisational interests with the individual needs of subordinates. Given the increasing complexity of the work environment and the high degree of variability, this area is becoming an increasingly important part of effective people leadership.

Table 4. Culture and research - descriptive

Competency	Mean (Employees)	SD (Employees)	Mean (Managers)	SD (Managers)
Collaborated effectively across departments	4,011628	0,830616	4,138889	0,63932
Understood and respected organisational culture	3,633721	0,954902	4,055556	0,71492
Worked effectively in an international team	3,348837	1,03469	4,027778	0,877858
Managed a hybrid (onsite and remote) team	4,023256	0,948705	4,055556	0,892651
Had experience with various types of organisations	2,738372	1,106141	2,416667	1,338976
Was open to innovation and new trends	3,94186	0,856412	4,111111	0,747483
Balanced organisational and individual needs	4,011628	0,837627	3,694444	0,749074
Responded flexibly to subordinates' needs	4,139535	0,767205	3,944444	0,582823
Supported and promoted subordinates' development	3,848837	0,816746	3,777778	0,865567

Source: the authors

From the employees' perspective, the highest-rated competencies were those associated with flexibility and understanding team needs — specifically Able to respond flexibly to subordinates' needs (4.35; SD = 0.71), Able to reconcile organisational needs with individual needs (4.27; SD = 0.76), and Able to collaborate effectively across departments (4.26; SD = 0.74). Conversely, the lowest average ratings were given to the items Had experience with different types of organisations (3.67; SD = 1.03) and Able to work in an international team (3.77; SD = 0.98).

Managers rated their abilities in this area slightly lower overall. They rated themselves highest in Able to collaborate effectively across departments (4.06; SD = 0.84) and Open to innovations and new trends (3.92; SD = 0.87), while the lowest ratings appeared for Able to work in an international team (3.42; SD = 1.12) and Continuously monitored and initiated employees' development (3.72; SD = 0.88). Differences between the groups were relatively consistent in this cluster, with the greatest perceptual gap appearing in support for individual development and adaptability — a difference of 0.63 points for the item Able to respond flexibly to subordinates' needs, which represents one of the highest gaps across the entire study.

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The results highlight the need for targeted development of competencies associated with diversity in the work environment, including working in international teams, managing hybrid structures, and adopting an individualised approach to employees. Strengthening these competencies may contribute to greater trust in managerial leadership, higher team stability, and more effective change management.

The cluster focusing on behaviour in crisis situations addressed managers' ability to handle challenging scenarios, make decisions under pressure, and lead teams during periods of crisis. The key aspects included not only the ability to respond quickly and rationally but also to prevent crises through planning, emotional management, motivational capacity, and experience with crisis leadership. Given the volatility of today's work environment, crisis preparedness is becoming one of the essential competencies for modern managers.

Table 5. Behaviour in crisis situations - descriptive

Competency	Mean (Employees)	SD (Employees)	Mean (Managers)	SD (Managers)
Quickly assessed crisis situations	4,319767	0,655221	3,583333	0,937321
Made decisions under high pressure	4,523256	0,679297	3,25	1,130739
Prevented crises through good planning	4,098837	0,792213	3,5	1,028175
Managed crisis communication effectively	4,383721	0,642885	3,333333	0,985611
Remained resilient and calm under stress	4,430233	0,66738	3,083333	1,204159
Motivated the team during crisis periods	4,319767	0,706746	3,444444	0,939436
Had experience with crisis management	3,645349	0,971423	2,527778	1,298045

Source: the authors

From the employees' perspective, the key competencies in this cluster were primarily Able to make decisions under pressure (4.31; SD = 0.69), Resistant to stress (4.27; SD = 0.71), and Able to motivate the team during a crisis (4.23; SD = 0.73). The lowest average score (4.00; SD = 0.81) was assigned to the item Had experience with crisis management, likely because respondents perceived it more as a complementary rather than a core requirement.

Managers' self-assessment was again consistently lower. The highest average scores were for Able to quickly assess a crisis (3.83; SD = 0.88) and Able to motivate the team during a crisis (3.69; SD = 0.87). The lowest scores were recorded for Had experience with crisis management (3.50; SD = 1.05) and Resistant to stress and not easily unsettled (3.50; SD = 1.00).

The differences between employees' expectations and managers' self-perception were quite substantial — for instance, in items such as Able to make decisions under pressure and Resistant to stress, the gap exceeded 0.7 points. These findings may reflect an internal uncertainty among managers regarding their stress-handling abilities or a different framework by which they evaluate themselves. The results confirm that resilience, decisiveness, and motivational ability during crises are seen as critical managerial competencies. At the same time, they highlight the opportunity to further develop self-confidence and crisis management skills through leadership development programs and managerial coaching.

The cluster Career Path and Experience reflected the respondents' evaluation of work history, breadth of professional experience, and the ability to learn from practice. The assessed competencies included professional performance, project management skills, team leadership capability, customer insight, and continuous professional development. Employees perceive these characteristics as fundamental prerequisites for credible and effective leadership.

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Table 6. Career Path and Experience - descriptive

Competency	Mean (Employees)	SD (Employees)	Mean (Managers)	SD (Managers)
Had broad knowledge	3,476744	0,861479	3,305556	1,009086
Had experience across industries	3,02907	0,907585	3,138889	1,099423
Had experience in people management	3,976744	0,871602	3,333333	1,17108
Reflected on mistakes and learned from them	4,465116	0,752348	4,083333	0,806226
Managed complex projects	3,30814	0,893998	2,777778	1,333333
Achieved success in their field	3,325581	0,984581	3,194444	1,260826
Anticipated customer needs	3,796512	0,857979	3,638889	0,833333
Held a university degree	2,540698	1,330513	4,583333	1,130739

Source: the authors

Employees assigned the highest importance to the ability to reflect and learn from mistakes (Able to reflect on mistakes and learn from them) (4.47; SD = 0.75), followed by Had experience in leading people (3.98; SD = 0.87) and Able to articulate customer needs (3.80; SD = 0.86). Significantly lower importance was attributed to formal education — Graduated from university received the lowest rating within the entire cluster (2.54; SD = 1.33), indicating a shift in employee preferences towards practical experience over formal qualifications.

Managers' self-assessment was generally lower or comparable for most competencies, except for Graduated from university (4.58; SD = 1.13), where managers rated themselves significantly higher than the employees' expectations. A similar gap was observed for Had experience with managing complex projects (employees: 3.31; managers: 2.78). Slightly higher self-assessment was also noted in Had experience across different industries, although the difference was not substantial.

In conclusion, employees place greater emphasis on concrete leadership skills and practical applicability rather than on formal degrees or prestigious qualifications. The observed discrepancies point to a potential need for managers to balance the importance they assign to formal prerequisites or academic background with the practical and soft skills valued by their teams.

The cluster Use of Modern Technologies evaluated the degree of technological openness and the ability to use digital tools for more effective leadership and team management. Given the growing digitalisation of the corporate environment, the adoption of hybrid work models, and the pressure for automation, technological preparedness is increasingly viewed as a prerequisite for effective modern leadership.

Table 7. Use of Modern Technologies - descriptive

Competency	Mean (Employees)	SD (Employees)	Mean (Managers)	SD (Managers)
Worked with modern technologies and management tools	3,982558	0,868378	4,111111	0,708228
Understood trends in digitalisation and automation	3,598837	0,902627	3,638889	0,866941
Effectively used technologies to improve processes	3,959302	0,847132	3,861111	0,899294
Was open to innovations and new ways of working	4,040698	0,78254	4,138889	0,930523

Source: the authors

From the employees' perspective, the highest importance was attributed to Being open to innovations (4.26; SD = 0.73) and Able to use technologies to improve work processes (4.11; SD = 0.77). All other items within this cluster also exceeded the average value of 3.8, indicating that technological competencies are perceived as crucial across the full range of assessed dimensions. Managers traditionally rated themselves lower than employees. The highest self-assessment was recorded for I am open to innovations and new ways of working (3.78; SD = 0.88), and the lowest for I understand trends in digitalisation and automation (3.42; SD = 1.03). The difference between employees' expectations and managers' self-assessments ranged approximately from 0.4 to 0.6 points across the items, suggesting a mild but consistent perception gap.

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The results indicate that employees expect managers not only to possess technical skills but, more importantly, to have a strategic orientation toward digitalisation and the ability to actively integrate new tools into daily work. However, it is precisely at this level where managers often do not perceive their competencies as sufficiently strong, highlighting an opportunity for further professional development.

4.2 Synthesis of RQ1: Are there statistically significant differences between how managers assess their own leadership abilities and what their subordinates expect from them?

The results across all seven thematic areas confirmed the existence of a perception gap between employees' expectations and managers' self-assessments. In every area, employees consistently rated the importance of individual competencies higher than managers rated their own abilities. This systematic difference underlines the relevance of a deeper analysis of specific areas where the perception gap is most pronounced, which is further elaborated in Research Question RQ2.

4.3 Identification of the Perception Gap: Statistical Analysis of Differences (RQ2)

After confirming the existence of a perception gap (see RQ1), the research focused on a detailed identification of the areas where the mismatch between employees' expectations and managers' self-assessments was most significant. The aim of this phase was to determine in which competency clusters and specific competencies the differences were not only evident in terms of mean scores but also statistically significant.

An independent two-sample t-test was employed to test the statistical significance of differences between the groups. This test allows verification of whether the difference between the mean values in the employee and manager populations is due to chance.
Statistical significance was determined based on the p-value, where:

- $p < 0.05$ was interpreted as a statistically significant difference.
- $p \geq 0.05$ was interpreted as a statistically non-significant difference.

The results of the t-test provide a foundation for identifying the competencies that warrant increased attention in terms of leadership development. In cases where a statistically significant difference between the groups was found, the practical impact was subsequently analysed through the calculation of effect size (Cohen's d), which is discussed in detail in the context of RQ3.

Table 8. Statistical most and least significant managerial competencies, t-test

Competency	t-test value	p-value
Had a university degree	-9,54376524	1,94025E-13
Was resilient to stress and pressure	7,826552024	1,33245E-09
Made decisions effectively under high pressure	6,514655282	8,52095E-08
Remained calm and composed under stress	6,505371139	9,62005E-08
Made quick and effective decisions	6,290979597	1,51526E-07
Understood trends in digitalisation and automation	-0,25025331	0,803375017
Supported innovation and new approaches	-0,23037395	0,818677874
Managed teams in hybrid (physical and online) environments	-0,19524808	0,845946743
Maintained and built good relationships with colleagues	0,042043841	0,96661107
Was tactful and diplomatic	0,003877432	0,996920869

Source: the authors

A pronounced perception gap was recorded for the competency Resilient to stress and pressure, where employees attributed very high importance to this ability, while managers rated their own skills in this area significantly lower ($p < 0.001$). This difference highlights the critical need to develop psychological resilience as part of managerial training. Another significant difference emerged for the competency Able to make decisions under high pressure ($p < 0.001$). Employees placed high demands on quick and effective decision-making in crisis situations, while managers assessed their own decision-making abilities under pressure more

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critically. The competency Emotionally stable and able to regulate emotions ($p < 0.001$) also showed a large perception gap. Stability in challenging situations was highly valued by employees, whereas managers rated themselves lower in this area. A substantial difference was also recorded for the competency Experienced in crisis management ($p < 0.001$). While employees considered crisis management experience an important prerequisite, managers rated themselves more cautiously in this domain. A significant discrepancy was also identified in the competency Excellent memory ($p < 0.001$), where employees expected a high level of cognitive preparedness, but managers rated their ability to retain detailed information considerably lower.

Conversely, relative agreement between employee expectations and managers' self-assessments was observed in the competency Supported innovation and new approaches ($p = 0.197$). The results suggest a high degree of understanding between the two groups regarding openness to innovation. Similarly, for the competency Friendly and approachable ($p = 0.124$), the differences were not statistically significant. Social approachability and the building of a friendly working environment are perceived similarly by both managers and employees. The competency Able to establish and maintain good relationships with colleagues ($p = 0.332$) also did not exhibit significant differences. Expectations regarding team relationships were relatively aligned between employees and managers. Likewise, for Able to collaborate effectively with colleagues across departments ($p = 0.091$), no statistically significant difference was identified, suggesting that interdepartmental collaboration is perceived similarly by both groups. The last competency with minimal differences was Open to innovations and new trends ($p = 0.070$). The results show that, in terms of innovative approaches, managers and their subordinates are relatively synchronised in their perceptions.

4.4 Synthesis of RQ2: Which thematic areas show the greatest discrepancies between subordinate expectations and manager self-assessments?

As part of a deeper analysis of perception gaps, the evaluation was also conducted at the level of individual thematic clusters. This approach allows not only the identification of individual deviations in specific competencies but also reveals patterns across broader areas of managerial activities. Cluster-based analysis provides a more comprehensive view of which groups of skills present the greatest challenges for managers in meeting employee expectations, and where perceptions between the two groups show higher levels of alignment.

In the Psychological and Personality Factors cluster, the perception gap was the most pronounced. For most competencies, the difference between employee expectations and manager self-assessments was statistically significant. The largest deviations concerned stress management, quick decision-making, and emotional stability. The results indicate that psychological resilience, cognitive flexibility, and the ability to handle dynamic situations are crucial areas for managerial development.

The Values and Motivation area showed an overall smaller perception gap. Statistically significant differences appeared mainly in long-term vision and concern for sustainability, while most value-oriented competencies were perceived relatively similarly by both groups. This suggests that managers are aware of the importance of ethical and value-driven leadership, although there are still gaps in strategic orientation and broader social responsibility.

In the Social and Communication Skills cluster, differences between groups were predominantly small to moderate. Statistically significant gaps were found in the ability to inspire teams, perform public speaking, and project natural authority. However, everyday interpersonal communication showed a high degree of alignment, suggesting that managers generally meet their subordinates' expectations in basic social and communication skills.

The perception gap in the Culture and Organizational Context cluster was less pronounced but noticeable, particularly in competencies related to working in international environments and aligning organisational goals with individual employee needs. The findings suggest that the ability to effectively adapt to diverse organisational contexts represents an area with potential for targeted managerial development.

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The Crisis Management area emerged as one of the key areas with a significant perception gap. Employees placed strong expectations on the ability to make quick and calm decisions under pressure, whereas managers rated these competencies more cautiously. The results underscore the need for the development of crisis preparedness, emotional stability, and strategic communication skills in challenging situations.

Discrepancies in the Career Path and Experience cluster were, on average, lower. An exception was the competency related to the importance of higher education, where managers placed greater emphasis on formal education than employees did. Otherwise, there was relative agreement between the groups regarding leadership skills, learning ability, and the capacity for self-reflection.

In the Use of Modern Technologies cluster, a slight but consistent perception gap was identified. Managers tend to underestimate their abilities in digitalisation and the use of technology to improve work processes. The results suggest that technological competence remains an area with considerable potential for further development, especially in the context of the increasing importance of workplace digitalisation.

4.5 Practical significance of perception gaps: Evaluation using Cohen's d

After confirming the existence of a perception gap and identifying the areas with the largest discrepancies (see RQ1 and RQ2), the research further focused on assessing the practical significance of these differences. The aim was to determine whether the discrepancies between employee expectations and manager self-assessments are not only statistically significant but also reach a level of effect size that could have a real impact on working relationships, team dynamics, and leadership effectiveness. To evaluate practical significance, the method of calculating the effect size using Cohen's d was employed. This coefficient allows the interpretation of the size of the difference independently of the sample size and indicates the extent to which the difference is meaningful in real-world terms.

According to commonly used interpretive standards, the values of Cohen's d are classified as follows:

- small effect: $d \approx 0.2$
- medium effect: $d \approx 0.5$
- large effect: $d \geq 0.8$

Table 9. Practical relevance of managerial competencies - Cohen's d

Competency	Cohen_d
Was self-confident	0,81919
Had natural authority	0,876697
Had excellent communication skills	0,89876
Had the ability to persuade and argue effectively	0,916922
Quickly assessed crisis situations	1,035646
Had good judgment	1,058112
Had experience in crisis management	1,080597
Effectively resolved conflicts	1,149871
Motivated the team during crisis periods	1,164954
Negotiated and found compromises	1,181725
Was emotionally stable and regulated emotions	1,312692
Remained calm and rational in challenging situations	1,375441
Effectively managed crisis communication	1,473543
Made quick and effective decisions	1,477343
Made decisions effectively under high pressure	1,643387
Remained resilient and composed under stress	1,715995
Was resilient to stress and pressure	2,007112

Source: the authors

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This analysis made it possible to identify areas where the differences between employee expectations and manager self-assessments are not only statistically but also practically significant, meaning that these differences are likely to influence everyday work dynamics and leadership effectiveness. The results showed that, particularly in the areas of stress management, crisis decision-making, and communication, the gaps between the groups reached very high Cohen's d values, often exceeding the threshold for a large effect ($d \geq 0.8$).

The highest practical effect was recorded for the competence resistant to stress and pressure, where Cohen's d reached a value of 2.01. This result underscores the crucial importance of psychological resilience for employees' perception of the managerial role while simultaneously signalling that managers tend to underestimate this ability themselves. Similarly, high values were found for competence resistant to stress and not easily unsettled ($d = 1.72$), confirming that the ability to remain calm under pressure is a key expectation among employees.

Decision-making competencies under pressure represented another major area of practical discrepancy. The competence able to make decisions even under high pressure achieved a value of $d = 1.64$, and able to make quick and effective decisions reached $d = 1.48$. These results suggest that employees perceive the ability for fast, decisive action as a critical success factor for managers, whereas managers evaluate this ability more cautiously.

A significant effect was also noted for the competence able to manage crisis communication effectively ($d = 1.47$), reaffirming that effective communication during crises is fundamental to maintaining team trust. Similar trends were observed for remained calm and rational in demanding situations ($d = 1.38$) and emotionally stable and able to regulate emotions ($d = 1.31$), reflecting employees' expectations that managers should not only act rationally but also manage their emotions under pressure.

Other competencies with a high practical effect included crisis leadership skills such as able to motivate the team during a crisis period ($d = 1.16$), able to negotiate and find compromises ($d = 1.18$), and able to effectively resolve conflicts ($d = 1.15$). These abilities are crucial not only for managing crisis situations but also for day-to-day leadership in dynamic environments.

A significant practical difference was also observed for the competence experienced in crisis management ($d = 1.08$), confirming that employees regard crisis management experience as a critical part of a manager's qualification. Competences possessed good judgment ($d = 1.06$) and able to quickly assess a crisis situation ($d = 1.04$) further illustrate the expectation for high alertness and strategic decision-making ability.

Among the competences with a large practical effect, communication and presentation skills were also identified. Competences such as able to persuade and argue effectively ($d = 0.92$), possessed excellent communication skills ($d = 0.90$), and had natural authority ($d = 0.88$) indicate that employees expect managers to not only demonstrate decisiveness and resilience but also to communicate clearly, present persuasively, and naturally command respect.

4.6 Synthesis of RQ3: How significant are these differences in terms of practical impact?

The analysis of effect size using Cohen's d revealed that the perception gap with the greatest practical impact is concentrated primarily in the clusters of psychological and personality factors and crisis behaviour. These clusters showed the highest Cohen's d values, often well above 1.0, indicating a very strong practical effect of the differences on workplace relationships and leadership effectiveness. Employees place significant expectations on managers in terms of psychological resilience, the ability to make quick decisions under pressure, and emotional stability, whereas managers tend to assess these competencies more cautiously.

In the area of social and communication skills, the differences were less pronounced; however, some key competencies—such as the ability to communicate persuasively and naturally earn respect—showed practically

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significant effects. This indicates that there is room for targeted development in this area as well, especially concerning presentation and negotiation skills.

In the other clusters—values and motivation, culture and context, career path, and use of modern technologies—the practical effects were, on average, lower. The results suggest that while there are some expectations in these areas, the differences between employees and managers do not have as strong an impact on team and organisational functioning as they do in stress management, crisis leadership, and interpersonal communication. Overall, the analysis confirms that the targeted development of psychological resilience, crisis management skills, and communication competencies should be a key priority for future training and development programs aimed at enhancing managerial effectiveness and building greater trust in leadership.

5. Conclusions

The aim of this study was to analyse perception differences between how managers assess their own competencies and what competencies are expected of them by their subordinates. This gap is a key topic in management, as it can significantly affect trust, satisfaction, and team effectiveness. Accordingly, three research questions were systematically addressed, focusing on the existence of a perception gap, identifying areas with the greatest and most minor discrepancies, and assessing the practical impact of these differences.

The results showed that a systematic perception gap indeed exists across most competency areas (RQ1), with the greatest discrepancies found in psychological resilience, crisis management, and rapid decision-making, while the highest degree of alignment was found in social and communication skills (RQ2). The practical impact of these differences (assessed via Cohen's d) was highest in areas related to stress management, crisis decision-making, and emotional stability. These differences reached high effect size values ($d > 0.8$), confirming that they can significantly influence leadership effectiveness in practice (RQ3).

These findings confirm that managers' self-perception of their competencies is not always aligned with the expectations of their teams and highlight the importance of targeted development of specific managerial skills within the context of contemporary workplace demands.

The results of this research support the conclusion that the perception gap between employee expectations and manager self-assessments is a significant factor influencing leadership effectiveness, aligning with the findings of Fleenor et al. (2020), who emphasised that realistic self-awareness is a key predictor of successful leadership. The greatest discrepancies identified in stress management and decision-making under pressure correspond with the findings of Breevaart et al. (2022), who found psychological resilience to be a critical factor in the post-pandemic era of uncertainty.

The study also showed a smaller gap in social and communication skills, supporting Shore et al. (2018), who highlighted the importance of inclusive and empathetic leadership in diverse work environments. These results further reinforce the relevance of developing soft skills, particularly in the context of hybrid work, as emphasised by Kniffin et al. (2021).

Conversely, a slight but consistent gap was observed in technological adaptation, echoing the concerns raised by Molino et al. (2020), who noted that technological transformation imposes new demands on managers for which many are not yet fully prepared. The findings of this study thus confirm the need for systematic development of technological literacy as an integral part of modern leadership.

5.1 Research Limitations and Suggestions for Future Research

Although this research has provided valuable insights into the perceptual differences between employees and managers, it is important to acknowledge certain limitations that should be considered when interpreting the results and planning future studies.

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One of the main limitations is the use of subjective evaluations by managers. Self-assessment is naturally prone to biases, whether in the form of underestimation or overestimation of one's own abilities.

Another limitation is that the analysis was based predominantly on a quantitative approach, offering a broad but less in-depth perspective on the issue of perceptual discrepancies. Future research could enrich this perspective by incorporating qualitative inquiries.

A specific limitation also lies in the homogeneity of the studied sample. The organisational context, industry, corporate culture, and geographic location could have influenced how managerial competencies are perceived. Expanding the research to a broader range of organisations and cultural contexts could yield more robust and generalisable results.

Finally, it should be noted that this study primarily mapped perceptions at a single point in time. Given the dynamic nature of the work environment, it would be beneficial to conduct longitudinal studies to track how the perception gap evolves over time, for example, in relation to the implementation of development programs, crisis events, or technological changes.

As part of the follow-up research, a profile of the ideal manager will be developed based on employee preferences regarding age, nationality, leadership style, cultural characteristics, visual presentation, and other demographic and behavioural attributes. This profile will supplement and expand the current findings on managerial competencies by adding the dimension of employees' preferred personal and visual characteristics of managers. The results of this subsequent study will be published separately.

5.2 Interpretation of Results in a Broader Context and Practical Implications

The results of this research confirm the crucial role of alignment between employee expectations and manager self-assessment. Significant perceptual discrepancies were identified, particularly in the domains of psychological resilience, crisis management, and technological adaptation. These gaps suggest potential weaknesses that may impact not only leadership effectiveness but also employee engagement and team satisfaction. The ability of managers to realistically perceive their own strengths and limitations has emerged as a critical factor for success in today’s dynamic and turbulent environment.

Across all clusters, employees systematically rated the importance and presence of leadership competencies higher than managers rated themselves. This general trend suggests that managers tend to underestimate their own abilities, especially in areas that are emotionally and situationally demanding.

The greatest perceptual gaps were recorded in areas related to psychological resilience, such as stress resistance, decision-making under pressure, and emotional regulation. Managers evaluated themselves significantly lower than employees in these areas, even though these competencies were among the most highly valued by employees. These findings align with the current leadership demands in environments characterised by high volatility, uncertainty, complexity, and ambiguity. They confirm the need to focus leadership development efforts on building resilience and decision-making skills under pressure.

In contrast, smaller perceptual discrepancies were observed in social and communication skills. In this domain, managers rated themselves more similarly to employees, especially in everyday interpersonal competencies such as friendliness, collaboration, and relationship-building. However, some divergence remained in more complex tasks such as public speaking, conflict resolution, and influencing others. This highlights that while managers meet expectations in basic communication, they may still lack confidence in skills requiring authority and persuasion.

A mild but consistent gap appeared in technological adaptation. Managers slightly underestimated their competence in integrating digital tools and following innovation trends compared to employee assessments. While the gap was not as wide as in psychological areas, it reveals a latent risk in long-term leadership readiness.

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This is consistent with current literature pointing to the need for digital leadership in times of organisational transformation.

Some of the identified perceptual discrepancies may be explained by psychological mechanisms such as self-serving bias or imposter syndrome. Alternatively, they may reflect a lack of effective self-assessment tools or rapidly shifting employee expectations. These factors underscore the need for organisations to integrate structured feedback systems, self-awareness training, and regular calibration of expectations between leaders and teams.

From a practical standpoint, the results suggest that development programs should focus on:

- Psychological resilience – training in stress management, emotional regulation, and decision-making under pressure should become a standard part of leadership curricula across organisational levels.
- Crisis leadership – managers must be prepared for high-stakes, unexpected situations requiring calm, clarity, and confident communication. Simulation-based programs and crisis communication workshops are recommended.
- Technological adaptability – although not perceived as a major weakness by managers, the ability to strategically apply technology remains a competitive advantage that should be intentionally cultivated.
- Self-awareness and feedback integration – introducing 360-degree feedback, peer coaching, and leadership reflection tools can help managers align their self-perceptions with team expectations.

The insights of this study provide actionable guidance for shaping future leadership development in accordance with employee expectations and the evolving demands of today's labour market. By mapping where perception gaps are most pronounced, organisations can target training and resources where they are most needed—particularly in areas of resilience, crisis competence, and communication authority. Moreover, the study contributes a novel perspective by combining employee evaluations and manager self-assessments across a broad spectrum of competencies, offering a more comprehensive understanding of what constitutes effective leadership in contemporary workplaces.

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REGIONAL AND NATIONAL CSR VARIATIONS: ANALYZING CROSS-COUNTRY DIFFERENCES IN CSR ADOPTION AND EFFECTIVENESS IN CZECHIA, POLAND, AND SLOVAKIA*

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Abstract. Corporate Social Responsibility (CSR) plays a crucial role in navigating sustainable business practices and enhancing long-term competitiveness globally. Specific features of this phenomenon are reached in transitioning economies where national contexts and specific structures of organizations shape CSR strategies. This study examines them and examines the impact of CSR on business performance and sustainability across the Visegrad region (Czechia, Poland, and Slovakia). It is built based on stakeholder theory and analyses data from 375 companies using descriptive statistics, Principal Component Analysis (PCA), and k-means clustering. Our findings point to significant cross-country differences in CSR impact, where Slovakia shows the highest levels of integration across monitored CSR dimensions, especially in organizational culture, brand sustainability, and investor engagement. Factor analysis unveils a strong underlying construct driving CSR impacts using variables such as human capital empowerment and risk management. Outcomes show consistent importance across countries, but cluster analysis points to two business profiles in the region: companies with integrated CSR practices and those with emerging or fragmented approaches. Slovakia predominantly involves the more advanced type, while Poland and the Czech Republic show more variability. This paper contributes to CSR literature by providing empirical evidence on regional nuances in CSR strategies and their link to firm performance. It offers insights for policymakers usable to harmonize CSR frameworks in the region and for businesses to strengthen CSR-driven value creation. Also, the specifically tailored national interventions and stronger regional collaboration are recommended to close gaps and foster sustainable economic growth.

Keywords: corporate social responsibility (CSR); Visegrad region; business sustainability; cross-country analysis; cluster analysis

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1. Introduction

Corporate Social Responsibility (CSR) is nowadays understood as a serious driver of business sustainability, competitiveness, and societal value, especially in the current era defined by sensitive stakeholder expectations and environmental challenges. On the global level, companies increasingly view this concept as an essential component of their strategic frameworks, able to create synergetic effects from enhancing brand reputation, to

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fostering innovation, or mitigating risks (Arabska & Terziev, 2016). In Central Europe, particularly in the Visegrad region, the integration of CSR practices visibly varies due to nuances in their cultural norms, economic structures, and regulatory environments (Koleva et al., 2010).

Despite the growing body of research, just a partial understanding of its impacts on both the cross-country and organizational levels in this region remains, since existing studies often overlook the shades of interplay between national contexts and CSR integration, leaving gaps in knowledge (Colovic et al., 2019). Also, there is a deficiency in empirical evidence of business classification based on core CSR practices or to identify underlying latent factors that drive these practices, particularly in transitioning economies (Barnett et al., 2020; Dartey-Baah & Amoako, 2021). This study aims to address these gaps by examining CSR impacts on business performance and sustainability in the Visegrad countries by seeking to: (1) Identify cross-country differences in CSR impacts across Czechia, Poland, and Slovakia; (2) Explore the underlying latent factors driving CSR practices in the region; (3) Classify firms into clusters based on CSR integration levels and analyse how these clusters vary by national and firm-specific attributes. To achieve these, the study addresses the following set of research questions:

RQ1: What are the differences in CSR impacts across the three Visegrad countries?
RQ2: What are the underlying latent factors driving CSR impacts in the Visegrad region?
RQ3: How can businesses in the Visegrad region be categorized based on CSR integration levels?
RQ4: What are the defining characteristics of each CSR cluster?
RQ5: How do these clusters vary across countries and firm-specific attributes?

The study is built on the basis of stakeholder theory, which highlights that, in regard to long-term success, organizations must balance the interests of diverse stakeholders (Rodríguez-Gómez et al., 2020). It also reaches the frameworks on CSR's multidimensional impacts, incorporating aspects such as organizational culture, brand sustainability, innovation, and competitive advantage to explore CSR dynamics in these transitioning economies. Therefore, the achieved findings contribute to the academic discourse on CSR by showing empirical insights into its cross-country variability and business-level impacts on the specific example of the Visegrad region.

The results can guide policymakers by highlighting the need to design tailored CSR regulations that reflect national priorities and foster regional synergies as well. It is also providing actionable recommendations for businesses to enhance their CSR strategies, improve sustainability outcomes, and align with global standards.

2. Literature review

Corporate social responsibility (CSR) has become a natural tool for business self-regulation that balances economic, social, and environmental company initiatives, improving business performance, stakeholder trust, and public image on an international scale (Ryan et al., 2010; Tamvada, 2020; Wen & Deltas, 2022). As a concept, it implies taking responsibility for an entity's impact on society and the environment beyond the generation of profit (Masum et al., 2020). It covers a wide range of activities collectively aimed at improving the triple approach of social, environmental, and economic conditions while enhancing ethical obligations to positively contribute to the communities and environments in which they operate (Hamza & Jarboui, 2020; Khan et al, 2021; Waheed & Zhang, 2022). This effort includes not just adhering to legal standards but also voluntarily taking steps to boost the welfare of stakeholders such as employees, communities, and other entities in the company's environment (Tamvada, 2020; Nahar & Khurana, 2023).

The importance of social responsibility in business practice is multilayered and complex since it helps to build and maintain a positive reputation inside and outside the entity, which can lead to increased customer and employee loyalty and trust (Ullah et al., 2020; Islam et al., 2021); it can further drive employee engagement and satisfaction, encourage a more motivated and productive workforce (Bu et al., 2022); and, by addressing environmental and social issues, businesses can reduce various risks and identify new market opportunities which can ultimately lead to their sustainable growth (Lu et al., 2021; Le at al., 2024).

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Moreover, corporate social responsibility is nowadays increasingly seen as a critical factor in investor decisions, with many private investors and financial institutions prioritizing companies with strong responsibility and sustainability records (Chen et al., 2020; Des Jardine et al., 2024), which is a phenomenon well-documented in academic and industry literature. Therefore, it can be said that companies that are implementing effective CSR strategies tend to experience several benefits, including heightened financial performance, improved risk management, and greater operational efficiency (Cho & Lee, 2019; Devie et al., 2020; Franco et al., 2020; Kim et al., 2021).

Thus, implementation of responsible practices can lead to cost savings through efficiency economic, social, and environmental waste reduction, and sustainable management of all resources which can widely help to mitigate companies negative environmental and social impacts and contribute to well-being, which at the same time aligning corporate goals with broader societal and economic objectives (Niyommaneerat et al., 2023; Khan et al., 2021; Le at al., 2024). This alignment has a strong potential to lead to long-term business viability and resilience, as companies that prioritize sustainability are generally better equipped to address a turbulent business environment visible through regulatory change, market shifts, and stakeholder expectations (Gromis di Trana et al., 2022; Kandpal et al., 2024).

Despite the concept of corporate social responsibility being widely applied on a global scale, its implementation can slightly vary on a regional level, based on the common customs of selected nationalities rooted in their values and beliefs, which are mirrored in their business practices (Khumalo et al., 2025). Several authors agree that CSR is globally recognized in the same way (Goergen et al., 2019), but local customs can severely affect specific activities through which it is implemented based on the values of local communities (Perry, 2012). Therefore, companies must recognize these nuances and adjust their CSR strategies across regions and countries, since despite similar or the same regulatory systems in these areas, the specific CSR implementation is necessary. For example, in the European Union (EU), efforts for centrally regulated non-financial reporting initiatives are implemented (Kinderman, 2020; Halkos & Nomikos, 2021; Redondo Alamillos & de Mariz, 2022), but social and culturally specific in selected countries create a diverse environment not suitable for meaningful implementation of general strategies.

Historically, a specific group of countries sharing several similarities is the Visegrad region, where the transition from centrally planned to market-oriented economies has created a unique context for CSR development and implementation (Mammadova, 2022; Kozáková et al., 2023). Factually, CSR practices in these countries were limited, but recently, the growing recognition of their importance (Przytuła et al., 2019; Kozáková et al., 2024) is visible. This approach is driven by increased globalization connected with integration into the EU and harmonization with its regulations, while generally copying the trend of rising awareness of social and environmental issues, corporate governance, and community engagement (Hąbek, 2018; Skýpalová et al., 2024). Therefore, businesses in these countries are increasingly adopting CSR practices to enhance their competitiveness and reputation in both domestic and international markets. However, the level of CSR implementation and its impacts vary across the region, influenced by nuanced cultural, economic background, and specifics it its national regulations (Kozáková et al, 2023).

In efforts to fully recognise the significant role of CSR in building a company's performance and sustainability, the specific impacts should be identified (Halme, 2020; Bacinello et al., 2021; Zhang et al., 2023). These impacts can be visible in the form of changes in selected KPIs, but also masked in the form of positive changes in organizational culture. This 'invisible" phenomenon can significantly improve employees' quality of life, creating a specific feeling of the 'spirit of the organization' (Aranki et al., 2019). Between organizational culture and CSR is a strong bond, since responsible initiatives play a key role in shaping organizational culture (Espasandín-Bustelo, 2021), and businesses that prioritize CSR tend to foster a culture of ethical behaviour, transparency, and social responsibility too.

This philosophy can enhance employee morale, loyalty, and productivity, as people are more likely to be engaged and committed to organizations that reflect their values (Kucharska & Kowalczyk, 2019; Wan et al., 2020; Ullah et al., 2022). Thus, investing in social responsibility has a great potential to empower human capital, bonding employees with organization and help to enhance their skills, satisfaction, and engagement since it is

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well defined in scientific literature that companies that provide opportunities for professional development and community involvement can build a more skilled and motivated workforce (Al Kerdawy, 2019; Diaz-Carrion et al., 2020; Nazir et al., 2021). It is also important to mention that creating such an environment enhances a wider synergic effect visible through several positive impacts on the sustainability of businesses and their brands (Cowan & Guzman, 2020; Mahmood & Bashir, 2020; Khuong et al., 2021). By demonstrating some level of commitment to social and environmental issues, companies can build strong, positively perceived brands that resonate with consumers, which can be translated into increased customer loyalty and a competitive advantage on the market (Akbari et al., 2020; Gupta et al., 2020).

Implementation of corporate social responsibility can also drive innovation, although indirectly. By encouraging companies to develop new products, services, and processes that address social and environmental challenges, companies can be led to new business opportunities, cost savings, and improved market positioning (Zhou et al., 2020; Mendes et al., 2023; Le et al., 2024). Additionally, integrating CSR into business operations can improve risk management by identifying and mitigating potential social and environmental risks, which enables companies to be better equipped to avoid regulatory penalties, reputational damage, and operational disruptions (Karwowski & Raulinajtys-Grzybek, 2021; Lu et al., 2022).

Respecting this, CSR implementation and adopting sustainable practices usually lead to cost efficiencies and profitability enhancing through improved resource management (Abdallah & Al-Ghwayeen, 2020; Muhmad & Muhamad, 2021). On the other hand, CSR can contribute to profitability by revenue growth since its implementation is helping to open new markets by attracting socially conscious consumers, and differentiating products and services (Urip, 2010; Bhardwaj et al., 2018; Miethlich & Oldenburg, 2019). This effect is not exclusive to multinationals, since it is widely described in the case of small and medium-sized enterprises (Tiep Le et al., 2023) and emerging markets (Kumar & Srivastava, 2020).

Despite their size or market share, businesses that are perceived as responsible and ethical are more likely to attract and retain customers (Tanveer et al., 2021) and investors, since companies with robust CSR practices are often seen as lower-risk and higher-potential investments, leading to greater access to capital (Chatzitheodorou et al., 2019; Weston & Nnadi, 2023). Here, other positive effects of CSR initiatives cannot be forgotten since they promote transparency and accountability by encouraging companies to disclose their social and environmental impacts, which builds trust of stakeholders, including customers, employees, investors, and regulators (Lu et al., 2019; Caputo et al., 2021; Wong et al., 2021). Respecting this, all we can state is that CSR implementation can enhance a company's competitive position by differentiating it from competitors and building a strong reputation, which can lead to increased market share, customer loyalty, and long-term success.

3. Methodology

This study aims to analyse the impact of CSR implementation on business performance and sustainability in selected Visegrad countries (Czechia, Poland, and Slovakia) by describing cross-country differences and the underlying patterns of CSR adoption on regional and national levels. The data were collected using an online questionnaire survey designed to assess a wider range of CSR-related information. But, for this study, only the questions related to the impact of CSR practices on businesses were included. This part of the survey employed structured questions with Likert-scale responses (Batterton & Hale, 2017; Tanujaya et al., 2022) supporting the focus on dimensions connected with the impacts of implementation of responsible activities, which have been shown as influencers of consumer perceptions and brand loyalty (Muniz et al., 2019; Yuan, 2023).

The survey went through a pilot phase in November 2022, involving 10 companies per country, and continued with the full data collection between November 2022 and November 2023, utilizing diverse addressing methods to ensure broad representation across the region. Trained researchers assisted participants as needed, although most responses were submitted independently (Mack, 2005), promoting a more accurate representation of participant views, minimizing research bias, and maximizing response rates (Brick, 2017). The survey was promoted through various, the only prerequisite for participation in the study was that the company must be registered in the Commercial register in one of the monitored countries. In later stages, the stratified randomization (Aoyama, 1954) was used, and participants were targeted using direct e-mails, aiming to provide

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a balanced sample per country and company size. Throughout the process, ethical guidelines were followed to ensure the integrity and confidentiality of the data collection process. Participation was voluntary based on informed consent (Kreuter et al., 2020), finalized data were anonymized (Díaz et al., 2021), and research complied with the ethical standards for social sciences (Curty et al., 2016), applying principles of data responsible handling and minimizing potential biases (Cragin et al., 2010; Mannheimer et al., 2018).

For data analysing, the final sample of 375 business entities evenly distributed across Czechia, Poland, and Slovakia (125 per country) and across size categories (microenterprises (0–9 employees), small enterprises (10–49 employees), medium enterprises (50–249 employees), large enterprises (250+ employees), and extra-large enterprises (500+ employees)) where 25 per category in every country was included. The 500+ category was added to ensure representation, aligning EU general categorization of business and current requirements on CSR reporting. Approximately 65.3% of these companies were part of multinational corporations. They operated in diverse sectors, relatively evenly distributed between trade (30.1%), service (36.5%), and production (33.3%). The sample also featured a variety of legal forms: Joint stock companies (15.5%), Limited liability companies (66%), Limited partnerships (65.9%), Public companies (3.5%), and Sole proprietorships (5.6%). Turnover varied, with 21.3% reporting micro turnover (€0–€1M), 35.2% small turnover (€1M–€50M), 23% medium turnover (€50M–€500M), 12% large turnover (€500M–€10B), and 8.5% mega turnover (€10B+). The used sample is diverse, but we believe that it creates a robust basis for further examination.

For this study, a specific set of variables was selected to assess CSR adoption and effectiveness across Czechia, Poland, and Slovakia, using the primary grouping variable 'CH1 Country' and variables capturing CSR impacts in 10 key dimensions (CSR-IMP01 to CSR-IMP10):

- CSR-IMP01: CSR-driven organizational culture impact;
- CSR-IMP02: CSR and brand sustainability impact;
- CSR-IMP03: Innovation and social impact realization;
- CSR-IMP04: CSR-integrated risk management impact;
- CSR-IMP05: Cost-efficiency via CSR practices impact;
- CSR-IMP06: Revenue growth and CSR integration impact;
- CSR-IMP07: Human capital and CSR empowerment impact;
- CSR-IMP08: Investor engagement for CSR impact;
- CSR-IMP09: CSR transparency and accountability impact;
- CSR-IMP10: Competitive enhancement via CSR impact.

Each of these CSR impacts were measured using a Likert scale (1–5), ranging from ‘no impact’ (1) to ‘very strong impact’ (5), capturing the degree to which CSR practices influence specific business outcomes. Additional firm-level characteristics provide contextual depth, including:

- Multinational integration (CH2): Part of an MNC or local;
- Legal form (CH3): Company types like Joint Stock or Limited Liability;
- Establishment period (CH4): Ranging from pre-1990 to 2020 and later;
- Business status (CH5): Family or non-family businesses;
- Turnover range (CH6): From micro (€0–1M) to mega (€10B+);
- Operational sector (CH7): Trade, service, or production;
- Company size (CH8): Micro (0–9 employees) to Extra Large (500+ employees);
- CEO gender (CH9): Male or female.

This set of variables was designed to capture organizational diversity, CSR adoption levels, providing insights into CSR practices across different business contexts. To ensure robust analysis, data were pre-processed and tested (Mishra et al., 2019). For the examined set of 11 variables, Cronbach’s Alpha of 0.955 indicates very high internal consistency, suggesting they are measuring the same underlying construct and are highly reliable (Meeker et al., 2021). CSR-IMP items have ‘corrected item-total correlations’ ranging from 0.806 to 0.868, showing strong correlations with the overall scale, and their 'Cronbach’s Alpha if item deleted' values range from 0.948 to 0.951, indicating that removing any of them would not significantly increase the overall reliability. The non-parametric tests were used due to the data’s significant deviation from normality (Mishra et al., 2019), as indicated by the Shapiro-Wilk test ($p < 0.05$). The correlation analysis using Spearman’s rho and Kendall’s

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Tau B (Essam et al., 2022) revealed interrelationships among the ten CSR impact dimensions, suggesting that implementation of corporate social responsibility creates synergistic benefits, where improvements in one dimension often drive enhancements in others. Country-specific differences in CSR impacts were explored further through Kruskal-Wallis and post hoc analyses to identify localized strategies for the Visegrad region. The identified strong interrelationships among CSR dimensions, with high correlations (e.g., CSR-IMP09 and CSR-IMP08, Spearman's rho = 0.729, $p < 0.001$; CSR-IMP05 and CSR-IMP06, Spearman's rho = 0.778, $p < 0.001$), indicate suitability for factor analysis which could uncover latent factors that group related CSR impacts, providing deeper insights into their alignment with business objectives. Previously mentioned high internal consistency and significant item-total correlations further support the use of factor analysis.

The first part of the study aims to identify differences in CSR impacts across countries and explore the role of national and organizational factors in shaping these outcomes. In regard to this, the first research question was designed: *RQ1: What are the differences in CSR impacts across the three Visegrad countries?* Here, the Kruskal-Wallis test (Kruskal & Wallis, 1952) was used to identify significant differences between the three countries based on a general hypothesis:

- H_0: There is no statistically significant difference in the impact of CSR implementation (CSR-IMP01 - CSR-IMP10) on performance and sustainability among the Visegrad region (1. Czechia, 2. Poland, 3. Slovakia).
- H_a: There is a statistically significant difference in the impact of CSR implementation (CSR-IMP01 - CSR-IMP10) on performance and sustainability among the Visegrad region (1. Czechia, 2. Poland, 3. Slovakia).

For subsequent identification of specific differences between countries, post hoc pairwise comparisons (Armstrong, 2014). To provide details on the distributions of responses, crosstab analyses were performed. The second part of the study focuses on examining the interrelations and underlying factors driving CSR impacts in Czechia, Poland, and Slovakia, aiming to answer additional two research questions: *RQ2: What are the underlying latent factors driving CSR impacts in the Visegrad region? RQ3: How do these factors differ across Czechia, Poland, and Slovakia?* The methodology for this part of the study combines techniques to assess data reliability, sampling adequacy, and latent factor structures, aiming to provide an understanding of CSR dynamics across the region. Reliability of the scale was assessed using Cronbach's α (Wadkar et al., 2016) for computing the overall scale reliability for the Visegrad region (α=0.965) and individual countries (α ranging from 0.921 to 0.979), which confirmed that the dataset consistently measures CSR impacts across dimensions and contexts. High reliability scores validate the robustness of the scale and its suitability for further analysis (Çorum, 2023). To ensure the dataset's suitability for further factor analysis, Bartlett's Test of Sphericity was conducted (Tobias & Carlson, 1969) which results ($\chi 2\backslash chi\hat{}2\chi 2$ ranging from 800 to 3982, $p<0.001$) confirmed sufficient intercorrelations among CSR dimensions for Principal Component Analysis (PCA) (Greenacre et al., 2022) and sampling adequacy was evaluated using the Kaiser-Meyer-Olkin (KMO) test with overall values (0.954 for the Visegrad region, 0.940 for Czechia, 0.929 for Poland, 0.881 for Slovakia) indicated strong shared variance among variables, supporting the validity of PCA. Next, Principal Component Analysis (PCA) was performed using varimax rotation to uncover latent factors causing CSR impacts. The percentage of variance explained ranged from 59.4% (Slovakia) to 84.3% (Poland), with a unified factor emerging as a significant driver of CSR impacts across dimensions.

The third part of the analysis was designed to identify various groups of businesses based on their CSR integration on the level of region as well as individual countries providing insights into CSR adoption and strategic differences between businesses and aims to answer the following research questions: *RQ4: How can businesses in the Visegrad region be categorized based on their CSR integration levels?; RQ5: What are the defining characteristics of each CSR cluster?; RQ6: How do these clusters vary across countries and firm-specific attributes?* The analysis was realized using factor scores generated from the PCA, ensuring dimensionality reduction while retaining the core variance of CSR-related variables. Items representing firm characteristics (e.g., legal form, multinational integration, turnover, and operational sector) were included in the analysis to support interpretations and enrich cluster characterization. For clustering, a two-step process was employed involving 'initial cluster centres' calculated based on REGR factor scores to define groups representing specific CSR profiles; and 'iterative refinement' where clustering converged within 2–5 iterations, with the convergence criterion set to minimal movement in cluster centres ($\Delta<0.001$).

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The K-means clustering algorithm was selected due to its effectiveness in partitioning data into non-overlapping groups while maximizing intra-cluster similarity and inter-cluster differences. Cluster interpretation was supported by cross-tabulation analyses, which provided detailed descriptions of clusters based on firm attributes (such as size, turnover, multinational status, legal form, operational sector, and CEO gender), enriching the understanding of CSR integration levels and differences between clusters.

It should be noted that this study has certain limitations, mainly based on the self-reported measures obtained through an online questionnaire survey, which served as the basis for the data collection, which may have been disposed to inaccuracies and potential response bias. Additionally, because the study only looked at Czech, Polish, and Slovak businesses, its conclusions might not be applicable to other companies in the Visegrad region or the surrounding area because the legal, economic, and cultural contexts of these countries differ from those of other regions, which could limit the findings' generalizability.

4. Results

The study is designed to provide an analysis of the impact of CSR implementation on business performance and sustainability across the Visegrad region, employing a combination of descriptive and statistical analysis. Findings presented in the text below reveal cross-country differences, identify underlying factors driving CSR adoption, and classify businesses into distinct CSR integration clusters. It will be described that key CSR dimensions, such as organizational culture, brand sustainability, and risk management, exhibit both commonalities and variations across countries, offering insights for tailoring CSR strategies. Additionally, firm-specific attributes such as size, sector, and multinational integration will be identified as significant determinants of CSR practices and will provide context for understanding regional and national dynamics.

4.1 Cross-country differences in CSR impacts

The first part of this study describes cross-country differences in the impact of CSR practices on business performance and sustainability in the Czech Republic, Poland and Slovakia addressing the research question RQ1 (What are the differences in CSR impacts across the three Visegrad countries?) and tests the associated hypotheses of no statistically significant difference in the impact of CSR implementation (CSR-IMP01–CSR-IMP10) on performance and sustainability among the Visegrad. Non-parametric statistical techniques, including the Kruskal-Wallis test and post hoc pairwise comparisons with Bonferroni correction, are employed to evaluate these hypotheses, ensuring robust identification of variations across the ten CSR dimensions with the aim to provide insights for tailoring CSR strategies for national and regional contexts.

Analysing the variable (CSR-IMP01), ***CSR-driven organizational culture,*** the significant differences were identified across the Visegrad countries ($p < 0.001$) and Slovakia exhibits the strongest impact, outperforming the Czechia ($p = 0.002$) and Poland ($p = 0.004$), while no significant difference was observed between the Czechia and Poland ($p = 1.000$). Crosstab analysis reveals that 50.4% of Slovak businesses report a ‘Strong impact,’ with no responses indicating ‘Negligible impact,’ signifying advanced CSR integration in the country. Conversely, 28% of Polish businesses report ‘No impact,’ reflecting weak CSR alignment with organizational culture, while Czechia falls in between, with responses concentrated in the ‘Average impact’ (39.2%) and ‘Strong impact’ (21.6%) categories, suggesting moderate CSR influence. Poland’s low impact indicates barriers such as limited CSR awareness and prioritization, suggesting the need for strategic efforts to address information gaps and enhance potential benefits from stronger CSR implementation. Czechia’s moderate performance reflects opportunities for targeted initiatives and for example, public-private collaborations to enhance CSR integration and localized CSR strategies. These should be beneficial for business in other countries too, since Slovaks should maintain and expand their CSR-driven cultural practices as a competitive advantage, Poland’s would benefit from awareness campaigns and resource allocation to foster CSR alignment with organizational culture, and Czech Republic can strengthen its position through collaborations and targeted interventions.

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In case of variable (CSR-IMP02) ***CSR and brand sustainability*** the analysis identifies significant differences across the three countries ($p < 0.001$) where Slovakia demonstrates the strongest impact, significantly outperforming the Czechia ($p = 0.000$) and Poland ($p = 0.000$), while no significant difference is observed between the Czechia and Poland ($p = 1.000$). Crosstab analysis reveals that Slovakia leads with 52% of businesses reporting a 'Strong impact' and 29.6% even stated 'Very strong impact,' with no responses in 'Negligible impact,' indicating robust CSR integration into brand-building strategies. Czechia shows a moderate CSR impact on brand sustainability, with most responses in 'Strong impact' (36.8%) and 'Average impact' (24.8%), and relatively fewer in 'Very strong impact' (13.6%). In contrast, Poland exhibits a polarized distribution, with a substantial 30.4% reporting 'No impact,' indicating weak CSR alignment, yet 24% indicating a 'Very strong impact,' reflecting significant variability. These findings suggest that Slovakia should capitalize on its strong CSR-brand alignment to further enhance consumer trust and brand equity, and Poland requires quite opposite efforts to bridge knowledge and resource gaps, focusing on raising awareness and improving the strategic implementation of CSR in branding. Czechia can strengthen its position by linking CSR to brand-building strategies and fostering collaborations to enhance CSR as a driver of brand sustainability.

Next, variable (CSR-IMP03) ***CSR-driven innovation and social impact realization*** reveal significant differences across countries ($p < 0.001$), too. Here, Slovakia demonstrates the strongest impact again, outperforming both the Czechia ($p = 0.001$) and Poland ($p = 0.000$), while no significant difference was observed between the Czechia and Poland ($p = 1.000$). In this indicator, Slovakia leads with 39.2% of businesses reporting a 'Strong impact' and 22.4% indicating a 'Very strong impact,' with no responses in 'Negligible impact,' which indicates robust integration of CSR into innovation and social impact strategies. On the other hand, Czechia again demonstrates moderate impacts, with the majority in 'Average impact' (37.6%), followed by smaller shares in 'Strong impact' (20.8%) and 'Very strong impact' (13.6%) and Poland shows even more dispersed pattern, with the highest proportion of responses in 'No impact' (29.6%), but notable shares in 'Strong impact' (24%) and 'Very strong impact' (14.4%) too. Slovakia's better performance reflects effective alignment between CSR and innovation, indicating a favourable business environment and investments in socially responsible research and development. In contrast, Poland's lower scores highlight challenges such as insufficient alignment of CSR with innovation frameworks or resource limitations, while Czechia occupies a middle ground, showing moderate progress and potential for further growth. This suggests that businesses in Slovakia should continue leveraging CSR to foster innovation and social impact. In Poland, targeted efforts are welcomed to align CSR with innovation strategies, supported by awareness campaigns, capacity-building initiatives, and stakeholder collaboration. Czechia can enhance its position by fostering partnerships between businesses, innovation hubs, and policymakers to better integrate CSR into innovation frameworks.

Analysis of the fourth variable (CSR-IMP04) ***CSR-integrated risk management*** enclosed significant differences in across countries ($p < 0.001$), highlighting varying levels of integration and effectiveness. Slovakia leads with the highest proportion of responses in the 'Strong impact' (46.4%) and 'Very strong impact' (8%) categories, with no responses in 'Negligible impact,' suggesting well-established CSR-driven risk management. In contrast, Poland has the largest share of 'No impact' responses (29.6%), reflecting foundational gaps in adopting CSR for risk management, likely due to limited awareness or resource constraints and Czechia demonstrates a more balanced distribution, with most responses in 'Average impact' (36.8%) and smaller shares in 'Strong impact' (24.8%) and 'Very strong impact' (6.4%), indicating moderate progress but growth opportunities. Here again, Slovakia should continue leveraging CSR-driven risk management as a competitive advantage to address market uncertainties and enhance resilience, and Polish businesses need to prioritize these initiatives and implement training programs and incentives to integrate CSR into their risk management strategies effectively. Meanwhile, Czech companies can further push, enhance these activities and align CSR practices with risk reduction goals.

Similarly, the analysis of (CSR-IMP05) ***Cost-efficiency via CSR practices*** reveals significant differences across countries ($p < 0.001$), underscoring distinct levels of CSR adoption for operational efficiency. Slovakia leads with the highest proportion of responses in the 'Strong impact' (40%) and 'Very strong impact' (14.4%) categories, and no responses in 'Negligible impact,' highlighting its effective use of CSR to drive cost-efficiency. Czechia exhibits a balanced distribution, with most responses in the 'Average impact' (32.8%) category and smaller shares in 'Strong impact' (22.4%) and 'Very strong impact' (8.8%), indicating moderate

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but consistent integration and Poland demonstrates a more dispersed pattern, with a significant share of responses in the 'No impact' category (29.6%) and fewer responses in higher impact categories, reflecting weaker alignment between CSR and cost-efficiency. In this case, Slovakia's success may stem from a strategic focus on resource optimization and sustainable practices, providing a model for others in the region. Poland's lower impact highlights the need for initiatives to raise awareness of CSR's potential, and Czechia, occupying a middle ground again, shows space for improvement.

The deep dive into the problem of (CSR-IMP06) ***Revenue growth and CSR integration*** shows differences again ($p < 0.001$), pointing to diverse levels of success in aligning CSR with financial outcomes. In this variable Slovakia demonstrates the strongest impact, with the highest proportion of responses in the 'Strong impact' (51.2%) and 'Very strong impact' (21.6%) categories, and no responses in 'Negligible impact' indicating a well-established link between CSR practices and financial performance, potentially driven by strategic alignment and stakeholder engagement. Czechia shows a more balanced distribution, with most responses in the 'Average impact' category (36%), followed by 'Strong impact' (24%) and a smaller share in 'Very strong impact' (10.4%), reflecting moderate but consistent integration of CSR into revenue growth strategies. Poland, in contrast, exhibits a weaker impact, with a significant share of responses in the 'No impact' category (30.4%) and 'Negligible impact' (16%), which indicates challenges and the need for localized CSR strategies to optimize revenue growth across the region. Especially, Poland should prioritize building awareness and offering guidance to businesses for strategic CSR implementation. Also, a tailored approach could be beneficial for the whole region to help maximize the financial benefits of CSR integration.

In case of (CSR-IMP07), ***Human capital and CSR empowerment*** outcomes reveal significant differences too ($p < 0.001$), reflecting varied integration of CSR into workforce development strategies. Slovakia exhibits the strongest performance again, with 47.2% of respondents reporting a 'Strong impact' and 13.6% indicating a 'Very strong impact,' and no responses in the 'Negligible' category, indicating advanced integration of CSR initiatives into employee empowerment and workforce development in the country. Czechia demonstrates moderate impacts again, with most responses in the 'Average impact' (33.6%) and 'Strong impact' (29.6%) categories, and a smaller proportion reporting 'Very strong impact' (8%). In contrast, Poland shows a dispersed pattern, with 28% of responses in the 'No impact' category and fewer in higher-impact categories, emphasizing the importance of tailored CSR strategies to enhance human capital empowerment across the Visegrad region. Businesses in Slovakia should just continue leveraging CSR as a strategic tool to strengthen workforce capabilities and retain talent. But in Poland, they should acknowledge its potential for workforce development, which can help optimize the benefits of these activities and competitive advantage across the region.

The problem of (CSR-IMP08) ***Investor engagement for CSR impact*** brings similar outcomes, significant differences across countries ($p < 0.001$), indicating variations in how CSR practices align with investor priorities and attract financial support. In case of this engagement, Slovakia demonstrates the strongest performance, with 46.4% of responses in the 'Strong impact' category and 20.8% in the 'Very strong impact' category, and no responses in the 'Negligible impact.' This highlights Slovakia's advanced use of CSR as a strategy to attract and retain investors, in which Czechia shows a balanced distribution, with most responses in 'Average impact' (30.4%) and 'Strong impact' (25.6%), and a smaller share in 'Very strong impact' (12%). In contrast, Poland has 29.6% of responses in the 'No impact' category and relatively fewer responses in higher-impact categories, indicating weaker integration. These findings further emphasize the need for localized CSR strategies where businesses in Slovakia should continue in applied approach, In Poland they should focus on raising awareness among investors about the strategic and financial benefits of CSR, supported by improved reporting frameworks and targeted outreach and in Czechia they can enhance its position by developing structured frameworks that explicitly link CSR initiatives to investor priorities.

The analysis of (CSR-IMP09) impact of ***CSR transparency and accountability*** identifies significant differences across the Visegrad countries ($p < 0.001$), reflecting varied levels of integration and emphasis where Slovakia demonstrates the strongest performance, with 46.4% of responses in the 'Strong impact' category and 13.6% in 'Very strong impact,' and no responses in 'Negligible impact' pointing to well-established culture of accountability and transparency likely driven by stakeholder expectations since regulations are similar among EU. Despite, Czechia shows a more balanced distribution, with most responses in 'Average impact' (31.2%)

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and 'Strong impact' (30.4%), but a smaller share (8.8%) in 'Very strong impact,' indicating moderate but less advanced CSR practices and Poland, however, has 28% of responses in the 'No impact' category and relatively few in higher-impact categories, suggesting weaker alignment. This further underlines the importance of tailoring CSR approaches since, in the changing framework of non-financial reporting, all companies in the EU must build trust and improve their frameworks to formalize their activities throughout the reports required by regulations. Therefore, companies in the region, and especially in Poland, must invest in capacity-building programs and address the gaps in their approaches.

Finally, the summarizing variable of (CSR-IMP10) ***Competitive enhancement via CSR*** pinpoint significant differences in the impact of CSR on competitive enhancement across the Visegrad countries ($p < 0.001$) positioning Slovakia as a leader as 46.4% of responses fall into the 'Strong impact' category and 13.6% into 'Very strong impact,' with no responses in 'Negligible impact' highlighting success in using CSR to gain a competitive edge, potentially driven by advanced integration of sustainability practices and alignment with stakeholder priorities. Here again, Czechia demonstrates a balanced but less pronounced performance, with most responses distributed between 'Average impact' (31.2%) and 'Strong impact' (30.4%), and only 8.8% reporting 'Very strong impact.' And again, Poland shows weaker alignment, with 28% of responses in the 'No impact' category and fewer in higher-impact categories, signalling a limited integration of CSR in competitive strategies. These findings suggest that tailored strategies are essential to optimize the competitive benefits of CSR in regions where the Slovak approach can serve as a regional benchmark. Aligning CSR more closely with business objectives could help to unlock significant potential for competitive gains in less advanced countries, such as Poland.

The cross-country analysis confirms differences in CSR impacts among Visegrad, with all ten dimensions showing p-values below 0.001, thereby rejecting the null hypothesis (H_0) in favor of the alternative (H_a). Slovakia emerges as a leader, with the strongest impacts across all dimensions, highlighting advanced CSR integration. Poland, by contrast, demonstrates weaker impacts in key areas, pointing to foundational challenges like limited awareness and strategic alignment. Czechia generally occupies a moderate position, reflecting steady but uneven progress across dimensions. These results highlight the necessity of localized CSR strategies that respond to specific national contexts but leverage regional synergies at the same time. Knowing and addressing existing disparities, businesses in the Visegrad region can optimize the performance and sustainability benefits of CSR and foster both national and regional growth.

4.2 Factor analysis

The second part of this study investigates the latent factors driving CSR impacts across the Visegrad region answering the research questions RQ2 (What are the underlying latent factors driving CSR impacts in the Visegrad region?) and RQ3 (How do these factors differ across Czechia, Poland, and Slovakia?), using PCA and reliability testing to examine the structural relationships among CSR dimensions. These methods assess the internal consistency of CSR variables and identify shared patterns in CSR impacts across the three countries, aiming to explore the interrelations among CSR dimensions and uncover latent structures that drive CSR impacts to provide insights for tailoring CSR strategies on both regional and national levels.

The reliability statistics for the CSR impact variables (CSR-IMP01 to CSR-IMP10) demonstrate excellent internal consistency across the Visegrad region ($\alpha = 0.965$) and within individual countries: Czechia ($\alpha = 0.960$), Poland ($\alpha = 0.979$), and Slovakia ($\alpha = 0.921$). Principal Component Analysis (PCA) here reveals that a single component accounts for a substantial percentage of the variance in CSR impacts across the region (76.4%) and within all individual countries separately: Czechia (73.9%), Poland (84.3%), and Slovakia (59.4%). The existence of a single component in every tested case suggests that CSR impacts are primarily driven by a unified underlying factor, though Slovakia's lower percentage indicates greater variability and less cohesive CSR integration. High component loadings across the Visegrad region reinforce the consistency of CSR impacts, with standout dimensions including CSR and brand sustainability impact (CSR-IMP02: 0.895) and Human capital empowerment (CSR-IMP07: 0.897).

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Here, analysis exhibits the existence of the strongest component loadings and lowest uniqueness values in Poland, with Competitive enhancement (CSR-IMP10: 0.939) and Risk management (CSR-IMP04: 0.934) emerging as key CSR drivers. Czechia demonstrates uniformly high loadings across all dimensions (CSR-IMP01 to CSR-IMP10: 0.811–0.899), reflecting a balanced approach to CSR integration. Slovakia, however, shows lower loadings for financial dimensions such as cost-efficiency (CSR-IMP05: 0.777) and revenue growth (CSR-IMP06: 0.759), alongside higher uniqueness values, indicating fragmented or evolving CSR practices. Dimensions such as organizational culture (CSR-IMP01: 0.858), brand sustainability (CSR-IMP02: 0.895), and risk management (CSR-IMP04: 0.891) consistently show high loadings across regions, underscoring their centrality to effective CSR strategies.

The existence of a unified CSR framework across the Visegrad region supports our previous recommendation to boost opportunities for regional collaboration and knowledge-sharing. In contrast with previous analysis, here can Poland's strong integration of CSR into competitive (CSR-IMP10: 0.939) and transparency strategies (CSR-IMP09: 0.916) can serve as a model for other countries, while Slovakia's lower cohesion highlights the need for tailored efforts to strengthen CSR's financial and strategic alignment. Prioritizing high-impact dimensions like organizational culture (CSR-IMP01: 0.858) and brand sustainability (CSR-IMP02: 0.895) could enhance CSR effectiveness across regions which further underscores the importance of harmonizing CSR strategies to amplify both regional and national benefits (Table 1).

Table 1. Principal Component Analysis- Component Loadings and Component Statistics

	Visegrad region		Czechia		Poland		Slovakia	
% of Variance	**76.4**		73.9		84.3		59.4	
	Component 1	Uniqueness	Component 1	Uniqueness	Component 1	Uniqueness	Component 1	Uniqueness
CSR-IMP01 CSR-driven organizational culture impact	0.858	0.264	0.847	0.283	0.900	0.190	0.856	0.267
CSR-IMP02 CSR and brand sustainability impact	0.895	0.199	0.852	0.273	0.915	0.162	0.819	0.329
CSR-IMP03 Innovation and social impact realization	0.865	0.252	0.869	0.244	0.906	0.180	0.800	0.360
CSR-IMP04 CSR-integrated risk management impact	0.891	0.205	0.858	0.263	0.934	0.128	0.789	0.378
CSR-IMP05 Cost-efficiency via CSR practices impact	0.845	0.286	0.811	0.341	0.908	0.176	0.777	0.396
CSR-IMP06 Revenue growth and CSR integration impact	0.870	0.243	0.850	0.278	0.905	0.180	0.759	0.423
CSR-IMP07 Human capital and CSR empowerment impact	0.897	0.195	0.892	0.205	0.928	0.138	0.742	0.449
CSR-IMP08 Investor engagement for CSR impact	0.850	0.278	0.823	0.322	0.928	0.138	0.737	0.458
CSR-IMP09 CSR transparency and accountability impact	0.877	0.230	0.892	0.204	0.916	0.161	0.722	0.479
CSR-IMP10 Competitive enhancement via CSR impact	0.892	0.204	0.899	0.191	0.939	0.118	0.690	0.524
Note. 'varimax' rotation was used								

Source: own elaboration

The results of the factor analysis on the country and regional level reveal a unified structure underlying CSR impact across the Visegrad region, where a single latent factor explains a significant proportion of the variance in CSR impacts with consistently high component loadings across key dimensions such as brand sustainability, organizational culture, and risk management. These outcomes suggest that CSR impacts are largely driven by shared patterns of adoption and integration across the region, although notable differences still exist among countries.

On the national level, it is demonstrated by strong CSR alignment in competitive enhancement and transparency in Poland, where advanced integration of these practices can be expected. In contrast, Slovakia, while exhibiting high loadings in several dimensions, shows variability in financial aspects such as cost-efficiency and revenue growth, reflecting evolving CSR practices. Czechia presents balanced but moderate integration of CSR impacts, highlighting potential for further improvement and development.

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4.3 Cluster analysis

The third part of this study complement previous part and examines the categorization of businesses based on their levels of CSR integration, addressing the research questions RQ4 (How can businesses in the Visegrad region be categorized based on CSR integration levels?), RQ5 (What are the defining characteristics of each CSR cluster?) and RQ6 (How do these clusters vary across countries and firm-specific attributes?). As a tool, the Principal Component Analysis (PCA) is used to derive factor scores that represent the core variance of CSR-related variables. Using these scores, the K-means clustering algorithm identifies distinct CSR profiles among the Visegrad region and businesses in Czechia, Poland, and Slovakia separately. This analysis highlights variations in CSR integration levels and explores how firm attributes (such as size, sector, and multinational status) influence cluster characteristics, which enable us to provide insights for enhancing CSR adoption and tailoring strategies to the unique contexts of each cluster and country.

The cluster analysis applied on the level of the Visegrad in general, identifies two distinct groups based on the REGR factor score, representing two diverse CSR profiles in the region:

- **CE Cluster 1 'Integrated CSR practices':** Centered at 1.65789, this cluster represents the majority of businesses with well-integrated CSR strategies across dimensions like brand sustainability, organizational culture, and competitive enhancement. This group includes 289 businesses (77.1%), primarily from Slovakia (117 cases, 40.5%), with lower representation from Czechia (91 cases, 31.5%) and Poland (81 cases, 28%). Cluster 1 businesses are larger, with strong representation of multinational corporations (40.1%) acting under the legal form of Limited Liability Company (66.4%), and higher turnover categories, such as medium (23.2%) and large turnover (13.5%). Sectors are balanced across trade (31.1%), service (33.9%), and production (35%), reflecting widespread CSR adoption. These businesses typically exhibit well-integrated CSR practices across dimensions.
- **CE Cluster 2 'Emerging CSR practices':** Centered at -1.98217, this cluster representing a smaller group of 86 businesses (22.9%), with less integrated or more fragmented CSR approaches typically from Poland (44 cases, 51.2%) and Czechia (34 cases, 39.5%), with minimal representation from Slovakia (8 cases, 9.3%). These firms are predominantly local (83.7%), smaller enterprises, such as microenterprises (33.7%), and lower turnover categories, including micro turnover (26.7%). Sectors are skewed toward service (45.3%) and trade (26.7%) since family businesses (26.7%) and Sole Proprietorships (13.9%) are more prominent, indicating resource constraints in adopting CSR.

The clustering process in this case converged in four iterations, with minimal movement in cluster centers, indicating well-defined and stable groupings. The ANOVA results ($F = 1079.107$, $p < 0.001$) confirm significant differences between clusters, though these results are descriptive due to the method's optimization of differences. The first cluster reflects strong CSR integration across dimensions and can serve as a model for CSR best practices in the Visegrad region, while the second cluster highlights businesses with emerging or fragmented CSR requiring tailored strategies, such as education and financial support, to enhance CSR implementation.

The specific country analysis in Czechia identifies two distinct CSR clusters, which again reflect variations in CSR integration and practices:

- **CZ Cluster 1 'Emerging CSR practices':** Initial centre at -2.03940, converging to a final center of -1.29146, with 36 cases (28.8% of the total) represents in Czechia businesses with limited or developing CSR practices realized mostly by local companies (77.8%), concentrated in the service (50%), using Limited Liability Companies (69.4%) legal form. They tend to have smaller turnover (44.4% in the €1M–€50M range) and include microenterprises (25%) and small enterprises (22.2%) that are typically non-family businesses (77.8%), with male leadership (91.7%) and relatively young, since they were established mostly in 1991–2000 (36.1%) and 2011–2020 (33.3%). This group represents Czech businesses facing resource constraints and structural challenges in adopting robust CSR practices.

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- **CZ Cluster 2 'Integrated CSR practices':** Initial centre at 1.93843, converging to a final center of 0.52239, with 89 cases (71.2% of the total) this cluster can be characterized by advanced CSR integration and broad alignment with strategic goals. While most of these businesses are still local (67.4%), there is a higher proportion of multinational corporations (32.6%) compared to Cluster 1. These companies are typically larger (with medium (22.5%) and extra-large enterprises (23.6%)), operating predominantly in services (40.4%) as Limited Liability Companies (66.3%) and their turnover is spread across categories, with 47.2% in the €1M–€50M range and 11.2% in € 10 B+. Established between 1991–2000 (39.3%) and 2011–2020 (28.1%), these businesses reflect a mix of older and newer firms, with leadership that includes a small but notable proportion of female CEOs (11.2%).

Based on these results, efforts in Czechia should focus on enhancing CSR adoption in Cluster 1, where policymakers can provide financial incentives, training programs, and awareness campaigns to address their gaps. Cluster 2 businesses, with advanced CSR integration and multinational connections, can serve as role models and mentors to smaller firms, fostering knowledge-sharing and collaboration.

The analysis of the situation in Poland similarly identifies two distinct CSR clusters:

- **PL Cluster 1 'Emerging CSR practices'**: This cluster includes 44 businesses (35.2%), centred at -1.21016, representing firms with limited or developing CSR practices. Most of these are local companies (88.6%), predominantly formalized as Limited Liability Companies (59.1%) operating in service (45.5%) sectors. They tend to be smaller firms, with 66% categorized as micro or small enterprises, and financially constrained, with 70.4% reporting micro (€0–€1M) or small (€1M–€50M) turnover. Many are younger businesses, established after 2000 (61.4%), and a significant portion are family-owned (34.1%) with predominantly male (81.8%) leadership. It can be said that these businesses face resource and structural challenges, requiring support to formalize CSR practices.

- **PL Cluster 2 'Integrated CSR practices'**: Cluster 2 in Poland includes 81 businesses (64.8%), centred at 0.65737, representing firms with advanced CSR strategies, driving best practices across industries. A larger proportion of these entities are multinational corporations (37%), which reflects access to global CSR frameworks. The cluster features Limited Liability Companies (60.5%), with high representation across service (40.7%), typically larger entities (53.1%) categorized as large or extra-large, and financially robust, with 50.6% reporting medium (€50M–€500M) or higher turnover. They include a mix of older and newer firms, mostly established between 1991 and 2010 (64.2%). Leadership is predominantly male (81.5%) but with a higher proportion of female CEOs (18.5%) compared to Cluster 1, demonstrating advanced CSR integration across dimensions and sectors.

Cluster analysis in Poland suggests that the first type of businesses require tailored interventions, such as financial incentives, CSR education, and capacity-building, to overcome resource and structural barriers to CSR adoption. Special attention in Poland should focus on supporting smaller, local firms, particularly in the service. Cluster 2 businesses, with their advanced CSR practices, can serve as role models, sharing best practices and mentoring Cluster 1 firms to enhance their overall sustainability outcomes, while leveraging Cluster 2's strengths will solidify Poland's leadership in CSR integration.

For Slovakia, conducted cluster analysis confirmed the existence of two similar clusters as in the rest of the region:

- **SK Cluster 1 'Integrated CSR practices'**: Cluster 1 includes 117 businesses (93.6%), representing the majority of Slovak firms with well-integrated CSR practices. Nearly half of these are multinational corporations (48.7%), demonstrating a balance of global and local CSR drivers. These businesses are predominantly Limited Liability Companies (70.1%), with a strong representation of production (41.9%). Companies vary widely in size and turnover, ranging from microenterprises (17.9%) to extra-large enterprises (21.4%), reflecting broad CSR adoption. Most were established between 1991–2000 (44.4%) and 2001–2010 (31.6%), with leadership predominantly male (86.3%). This cluster's dominance reflects Slovakia's mature and advanced CSR landscape, positioning it as a regional leader.
- **SK Cluster 2 'Emerging CSR practices'**: Cluster 2 in Slovakia consists of only 8 businesses (6.4%), representing a small minority with limited or fragmented CSR practices. The majority are local

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companies (87.5%) with Limited Liability Companies (75%) legal form, operating in production (50%). These businesses are primarily smaller, with microenterprises (50%) dominating and most reporting micro turnover (€0–€1M, 62.5%). Many are family-owned (62.5%) and established after 2001 (87.5%), suggesting relatively young businesses with resource constraints. Leadership is predominantly male (75%), but female representation is notable. This cluster reflects the challenges faced by small, locally focused businesses in integrating CSR practices.

The dominance of Cluster 1 underscores Slovakia's strong CSR integration, offering opportunities to position its businesses as regional CSR benchmarks. These firms can mentor smaller, less developed businesses in Cluster 2, fostering collaboration and knowledge sharing. Targeted interventions for Cluster 2, such as financial incentives, CSR education, and exposure to global frameworks, are strongly recommended since they would be essential to overcome resource and structural barriers (Figure 1). By bridging the gap between clusters, Slovakia can ensure a cohesive CSR landscape and reinforce its position as a sustainability leader in the Visegrad region.

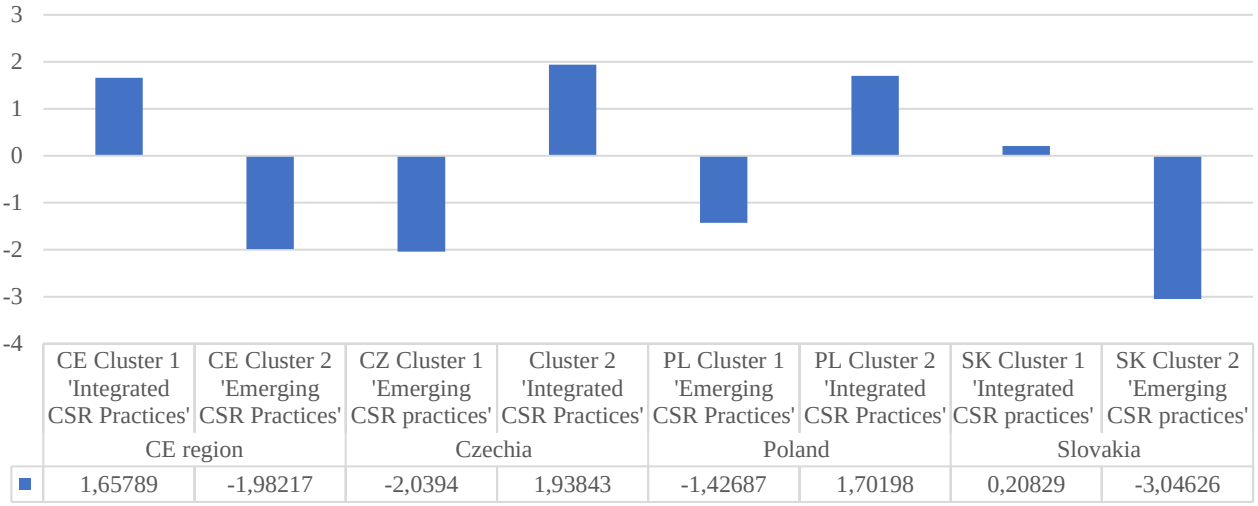


Figure 1. Initial cluster centres for the Visegrad region, Czechia, Poland, and Slovakia
Source: own elaboration

Conducted cluster analysis identified two primary groups of businesses across the Visegrad region and within each country: businesses with integrated CSR practices and businesses with emerging or fragmented CSR practices. This consistent structure indicates that, despite regional diversity, similar CSR approaches can be observed throughout the region. However, it must be highlighted that the representation of these groups varies by country, reflecting differences in local conditions, resources, and priorities. Among regions, Slovakia stands out with a dominant share of businesses in the integrated CSR cluster, showcasing advanced CSR adoption supported by stakeholder engagement. In contrast, Czechia and Poland have a higher proportion of businesses in the emerging CSR cluster when compared with Slovakia, often characterized by resource limitations, a local focus, and less strategic integration of CSR.

Despite the highest number of 'integrated' types of business being visible in every country separately, as well as generally in the region. These advanced businesses in each country provide a valuable foundation for mentoring and sharing best practices with units in the emerging cluster. Targeted interventions such as financial incentives, educational programs, and public-private partnerships can bridge the gap between the clusters, helping less developed businesses to improve their CSR implementation. Simultaneously, capitalizing on the strengths of businesses with advanced CSR practices has the potential to boost competitiveness and sustainability at both national and regional levels.

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5. Discussion

This study describes the impacts of CSR implementation in the Visegrad region while describing cross-country differences and typical clusters of companies using a similar approach. Our outcomes confirmed that Slovakia consistently shows higher impacts across all measured CSR performance metrics compared to Czechia and Poland, which is to some extent in line with the previous literature, confirming that the concept of corporate social responsibility in Slovakia has evolved significantly over the past decades. But, regarding this, it must be mentioned that the significant role in promoting CSR practices within the country is played by foreign companies or local subsidiaries of foreign multinationals entering the Slovak market after 1991 (Przytuła et al., 2019; Dubravská et al., 2021).

Kádeková et al. (2020) add that the commitment to CSR in Slovakia is evident through various activities such as support for local communities, environmental protection, employee welfare, and ethical business practices. But Falkner (2010) argues with the statement that Slovakia's institutional performance in enforcing EU social standards has major shortcomings, like the Czech Republic, Hungary, and Slovenia. Wójcik-Czerniawska and Grzymała (2023), on the other hand, highlight that Czechia, although identified as a country with a moderate approach in our research, has a higher innovation index and more statutory support for economic development at the regional and local governments when compared to Slovakia and Poland.

At the same time, our outcomes partially support previous research of Gavurová et al (2022), who stated that CSR strategies are most used in Hungary, Poland, and Slovakia, with the least use in the Czech Republic. But, the superior position of Poland identified by this study, we cannot confirm at all. Despite our outcomes presenting Slovakia as a regional leader, we must admit that CSR initiatives here can still be more effectively integrated into organizational culture, which can lead to a better overall impact of CSR on performance and sustainability, creating a synergic effect. Similar results were achieved by Govindan (2022), who aimed to implement CSR 40.0 practices with the outcome that ownership policy and rights enhance better integration of digitization with a company's conventional CSR, correlating with improved performance and sustainability, which, to a certain extent, supports the synergic effect too. Here, Kádeková et al. (2022) bring up that almost 90 % of food enterprises in Slovakia actively apply the concept of CSR in everyday life, with recycling being the most frequently used activity in environmental protection, which supports our outcomes too.

We believe that some form of establishment of a unified CSR framework across the Visegrad region can significantly enhance regional collaboration and policy harmonization since creating of unified CSR framework can help to CSR business practices, enhance regional sustainability goals, and help to foster a competitive advantage for firms, especially those operating in multiple countries within the region. This alignment is very important as it has the potential to help businesses boost their CSR initiatives, reduce operational complexities, and enhance their reputation across borders (Carroll & Shabana, 2010; Lii et al., 2011).

Furthermore, a unified approach can lead to shared best practices and resources, eventually promoting a more sustainable business environment in the region that benefits both businesses and local communities, as it was previously described for other geographic regions (Abdullah & Aziz, 2013). The implications for business, regardless they are multinational corporations or local companies, can be very favourable since they can benefit from strategies which enhance their market positioning using principles positively accepted by stakeholders in the region. This not only aids in compliance with varying national regulations aimed to stakeholders on the government and policymaking level but also strengthens their brand image as socially responsible entities positively accepted by other groups of stakeholders. By adopting this regional perspective on implementing CSR, businesses can also mitigate risks positively associated with disparate regulatory environments and foster greater investor confidence and consumer loyalty (Singh et al., 2017).

The identification of two clusters across the Visegrad region, as well as inside monitored countries, highlights the varying degrees of CSR maturity within the region while indicating similarities in fundamental approaches to CSR. The 'Integrated CSR practices' cluster reflects a more advanced understanding and implementation of CSR, characterized by strategic alignment with business objectives and stakeholder engagement. Conversely, the 'Emerging CSR practices' cluster represents an initial stage of CSR adoption, where businesses are beginning

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to recognize the importance of social responsibility but often lack comprehensive frameworks and strategies (Hąbek, 2019). This duality and outcomes of the first part of our study suggest that while the Visegrad countries face common challenges and opportunities in CSR, tailored strategies may be necessary to address the specific needs and contexts of each nation. Slovakia's strong representation in the 'Integrated CSR cluster' positions it as a potential regional leader in CSR practices. In our opinion, this prominence does not have a single reason, but it may stem from a combination of factors, including active civil society engagement and a growing awareness among businesses of the benefits of CSR (Skýpalová et al., 2023). As a leader, Slovakia can serve as a model for Czechia and Poland and help companies in these neighboured countries to enhance their approaches. Inspiring can be mainly demonstrated by how integrated CSR practices can enhance corporate reputation, stakeholder trust, and ultimately, financial performance.

Lessons from Slovakia's success could include the importance of aligning CSR initiatives with national development goals and opening collaboration between the public and private sectors to create a conducive environment for CSR growth (Dau et al., 2021). On the other hand, it should be noted that businesses in the 'Emerging CSR cluster', particularly in Poland and the Czech Republic, face significant structural and resource constraints that hinder their ability to adopt widespread CSR practices. These challenges may include limited financial resources, lack of expertise, and insufficient regulatory frameworks that do not incentivize CSR adoption (Zhang et al., 2019).

To bridge the gap between the 'Integrated' and 'Emerging' CSR clusters, specific measures could be implemented, such as providing financial incentives for CSR initiatives, improving access to training and resources for businesses, and promoting awareness campaigns that highlight the benefits of CSR (Nandy et al., 2022). Additionally, networking and creating partnerships between established firms and those in the 'Emerging group' could facilitate knowledge transfer and capacity building. These tailoring CSR strategies not only enhance their effectiveness but also align corporate initiatives with local expectations and norms, thereby fostering stronger community relations and enhancing corporate reputation (Lii & Lee, 2011).

Conclusions

This study discovered the impact of CSR practices on business performance and sustainability in the Visegrad region, addressing the topics of cross-country differences, latent factors driving CSR impacts, and clusters of businesses based on their CSR integration. The statistical analysis unveils significant cross-country variations in CSR impacts, with Slovakia leading in CSR integration across all ten dimensions, while Poland faced foundational challenges such as limited awareness and strategic alignment. Czechia exhibited moderate but uneven progress. Ongoing factor analysis identified a consistent CSR framework based on the monitored dimensions, like brand sustainability and human capital empowerment. Subsequent cluster analysis revealed two specific CSR profiles in the Visegrad region and in selected countries separately.

Analysis on both levels identifies two specific and relatively similar groups, which can be named as 'Integrated' and 'Emerging' CSR practices, while these are surprisingly consistent across the region. Despite, same name in selected countries, they slightly differ in their representation, where, for example, Slovakia shows the strongest presence of 'integrated' business units. These findings contribute to the theoretical understanding of CSR by demonstrating its multidimensional impact across diverse businesses and filling the gap in the understanding of this problem in the specific context of the Visegrad region.

Practically, this study emphasizes the importance of localized strategies to address country-specific challenges while showing space for tactics aiming to regional synergies. In the process of CSR enhancement in the region, Slovak businesses can serve as benchmarks for CSR excellence, offering valuable insights for improving CSR integration in Czechia and Poland. Based on these results, policymakers should prioritize interventions to bridge disparities in CSR adoption across regions, focusing on financial incentives, training programs, and awareness campaigns for businesses in emerging CSR clusters.

Regional collaboration can be very helpful in the process, especially when facilitating knowledge-sharing and standardization of CSR practices. For business entities in the Visegrad region, especially those in the 'Emerging'

group, we recommend targeting identified high-impact areas such as brand sustainability and organizational culture, which have the potential to enhance performance and promote trust of their stakeholders.

Here, it should be clearly stated that this study has some limitations. Because it relies exclusively on data self-reported by participants of the study, we should acknowledge the existence of potential biases based on the underrepresentation of participants who are not interested or informed about the topic of corporate social responsibility. Moreover, our focus on Czechia, Poland, and Slovakia, although it creates a logical basis for this study, limits the generalizability of achieved findings to other regions or countries. Therefore, our outcomes must be interpreted with caution, and future studies are recommended to address these limitations by incorporating broader geographical scopes. Future research could also explore CSR impacts at the industry level, on the cross-regional stage, or investigate external factors influencing CSR adoption (e.g., economic crises). The examination of the long-term effects of CSR on organizational resilience and stakeholder engagement would also be a beneficial and interesting idea for future studies, especially in the Visegrad region.

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STRESS EXPRESSION AT WORK AND TECHNIQUES TO MANAGE IT: GENDER AND AGE ASPECTS

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Abstract. The article systematically presents the issues of stress at work in the context of scientific literature; the factors that cause stress at work are analysed, and techniques for managing stress are provided. Research objective: after examining the factors that cause stress at work to provide techniques for managing stress. Analytical descriptive, quantitative and statistical research methods were applied. When using a quantitative research strategy and considering respondents' assessment (n=303), the stress situation at work was identified, the reasons causing stress at work were determined, and techniques for managing stress at work were provided. After analysing the stress situation at work, it was found that more than three-thirds of the study participants experienced stress at work often or very often. In contrast, only a few participants experienced it rarely or very rarely. Whereas a comparative data analysis from a gender perspective showed that stress expression at work is more common in women than men, after providing a comparative study in groups of participants of different age groups, it was found that more stress at work experienced a larger portion of the study participants under 25 years of age and from 26 to 45 years of age compared to those aged 46 and over. The research results showed that the factors impacting stress at work are these: the lack of training on stress reduction in the organisation, heavy workload, too high demands at work which do not match the knowledge and skills of employees, the lack of time to complete tasks, as well as underestimation of a person's efforts and encouragement for high results, employees are not provided with professional development and career opportunities. According to the research results, it is evident that managing stress at work should be implemented comprehensively by covering the aspect of work organisation planning, ensuring workload and professional development opportunities, improving a motivation system, creating a favourable psychological climate, recognising employees' efforts and training how to cope with stress. On the other hand, while implementing the stress management system at work, it is appropriate to consider gender and age. The research results provided insights into the reasons causing stress at work and the possibilities for its management. The obtained results will have lasting value in scientific discussion, since guidelines for stress reduction at work with particular attention to gender and age peculiarities are provided.

Keywords: stress at work; the reasons causing stress at work; stress management; employees; gender; age

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1. Introduction

Changes occurring in the workplace, accelerating pace of life, improving technologies, a rapidly developing service sector, work organisation peculiarities, the increasing workload, task completion speed and the increasing requirements for work performance in a dynamic and constantly changing labour market inevitably affect the health of employees, their life and the quality of work. In this context, stress at work and its management become urgent issues and encourage to consider the signs of stress at work, its sources, dynamics and assessment, as well as techniques preventing stress (Dutta & Mishra, 2024; Gunasekara et al., 2024). It should be noted that the analysis of stress at work and its determining factors is not a new phenomenon, and it is widely discussed. Work quality is perceived as an integral part of the quality of life (Cueva-Pila, Suazo, &

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Ortiz, 2023), and attention to studying stress management at work increases (Bushi, 2022; Schwarz, Feldmann & Schmitz, 2022; Lobo et al., 2023).

The relevance of managing stress at work is presented in scientific literature by showing its negative consequences experienced by individuals and organisations. Scientists point out that stress can cause physical and psychosomatic disorders (Leszczynska, 2023). Researchers point out that stress is a factor causing economic and social losses and admit that the inability to identify and manage the effects of stress can be costly to the organisation. Scientists admit that stress at work can reduce employee engagement in work activities and impact employee turnover, what has a negative impact on productivity indicators (Lee, 2018; Imran & Ayub, 2017; Koszela, 2020; Lutfiani Putri Windia, Singh & Rashid, 2021). These facts show that managing stress at work is an integral part of organisation's human resource management, and is causally related to ensuring the physical and mental well-being of employees and operational efficiency, as well as work productivity and the quality of results.

The following questions define the research problem: What are the factors causing stress at work? How does an assessment of stress at work differ in different age and gender groups? What are ways to manage stress at work?

Taking into account the need to implement stress management at work based on the insights of scientific literature, *the research objective is* to examine the factors causing stress at work and to determine its management directions.

Research tasks:

1. To justify theoretically the causes of stress at work and techniques to manage it.
2. To investigate and compare the differences of stress among women and men and different age groups.
3. To identify ways of stress management at work.

The issues of stress management at work are being discussed in various aspects. However, there is a lack of research investigating relationship between of employee age and gender and stress experienced at work. Therefore, it is unclear what causes stress at work to employees of different ages and what impact the expression of stress at work in women and men. In this context, it is necessary to investigate the factors causing stress at work, considering gender and age differences and suggest measures for stress reduction. The research is important since it allowed us to propose ways of managing stress at work taking into account particular work environment characteristics. In future, the study could be extended by more representative or cross-border samples and incorporating the elements of the qualitative method into the survey (e.g., open questions, group discussion (focus group), etc.); regression modelling and factor analysis could provide more insights and supplement quantitative conclusions.

2. Causes of stress at work and its management opportunities: theoretical aspect

To ensure the organisation's competitive advantage, functioning, and development, particular attention has to be paid to human resources; therefore, the issues of managing stress at work in today's labour market are of major importance. The scientific literature describes stress as a mismatch between a person's needs and coping capabilities when faced with unusually demanding requirements and a lack of autonomy (Zeuge et al., 2023).

Stress is associated with protective reactions occurring in the human body as a response to certain stimuli (stressors) and irritants or adverse factors and stressful situations (Rebok et al., 2019), which an individual assesses as aggravating or exceeding his existing resources and opportunities and causing danger to his well-being (Cueva-Pila, Suazo & Ortiz, 2023). Whereas, when stress is experienced in the work environment, the research of this sphere is oriented to the identification of stressors and defining the signs of stressor assessment when relating it to a professional aspect, for example, job specifics of general teachers (Sperati et al., 2024), health professionals (Haemmig, 2024), lawyers (Pierson et al., 2017; Valickas & Vanagaitė, 2019).

When analysing stress effects at work, it was noted that stress impacts an employee, the quality of his work, and work productivity (Kim et al., 2017). On the one hand, experienced stress can positively impact a person, and

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the reasons for it could be positive for an organisation and a person. Stress, related to positive consequences, is called eustress, which is described as a positive voltage promoting efficiency and having a positive impact on the physical and mental functioning of the body, which corresponds to the excitement caused by new challenges. Even though stress is a normal reaction to many circumstances, it can also have negative consequences. In contrast, long-lasting stress, which is called distress, is related to negative experiences and impaired cognitive function, which can cause negative consequences to a person and his work results (Vyas & Luk, 2011; Cottini et al., 2022), as well as turnover indicators (Lutfiani Putri Windia, Singh & Rashid, 2021). Usually, negative consequences of stress are related to physical disorders and health problems (Charkhabi et al., 2024). Leszczynska (2023) analysed the negative consequences of stress on a person's health and distinguished the cognitive, physiological, and behavioural manifestations of stress. However, some scientists found out that stress at work can not only cause negative consequences to a person's physical and psychological health, but it could be one of the reasons for employee absenteeism and turnover, increased accidents, poor work performance and work quality. The research carried out by Main, Glozier and Wright (2005) showed that work results of employees who experienced stress at work decreased by seven times compared to those who did not experience stress at work. The latter opinion was supported by some scientists who admit that stress at work is related to decreased operational efficiency and a lack of work productivity. Valickas and Vanagaitė (2019) state that stress at work can cause decreased concentration, hasty irrational decisions and poor performance results. The physical and psychological health of employees impact their work productivity. Some scientists note that stress at work decreases employee motivation and desire to go to work (Goldstein et al., 2017). Stress at work negatively affects job satisfaction. Moreover, constant stress at work suppresses the person's need for self-development and improvement (Vyas & Luk, 2011) or even causes burnout (Žiedelis, 2019). A social aspect states that constant stress at work can impact more frequent conflicts at the workplace, harm relationships with colleagues or even affect relationships with family members. Constant stress at work can influence employee behaviour and mutual relations. Therefore, stress at work not only causes physical and psychological disorders but can also affect employee turnover and absenteeism, decreased work efficiency and quality, and negative consequences, which can cause significant costs to the organisation.

After estimating the negative consequences of stress experienced by employees and the organisation, it is necessary to determine the factors causing stress at work and find ways to reduce stress. Scientists who analysed usually were focused on the factors occurring within the organisation (Didbalytė, Mikaliūkštienė & Fatkulina, 2022). Some scientists point out the relationship between stress at work, high requirements and demands placed on employees, and strained relationships among employees (Cueva-Pila, Suazo & Ortiz, 2023). According to Leszczynska (2023), too heavy or too low workload, complicated work that does not match the employees' competencies, monotonous activities, contradictory or unclear requirements, as well as unfavourable or harmful working conditions and physically demanding work could be one of the reasons causing stress at work. Moreover, the researcher notices that stress at work can be caused by a low salary, poor career opportunities, job instability or a temporary employment contract, inappropriate leadership methods, a lack of social support, scarce opportunities to participate in decision-making processes, cases of discrimination and unfavourable microclimate. At the same time, Cottini et al. (2022) found that increased responsibility, improper distribution of duties, poor relationships with colleagues and the boss, unclear work goals and the lack of support and assistance from the manager are the main reasons causing stress at work. A limited (short) deadline for work, the abundance of tasks, inappropriate environment, the lack of necessary tools and equipment to perform work and the lack of instructions for completing tasks could be the reasons causing stress at work.

On the other hand, stress at work could be increased by excessive commitments related to the profession, the shortage of resources for implementing requirements and limited career opportunities. In contrast, job instability and the lack of job guarantees are linked to increased anxiety (Haider, Fatima & de Pablos-Heredero, 2020). In the meantime, other scientists notify that non-recognition of an employee as a specialist and underestimation of his efforts, limited opportunities to participate in decision-making processes, as well as the uncertainty of the employee's role and functions and contradictory requirements not only reduce the employee's motivation (Koszela, 2020) and his involvement into activities but also increase stress at work, while Cottini et al. (2022) distinguish the aspect of the nature of work and state that stress at work could be caused by boring activities, long-lasting unchanging nature of work and monotonous activities with little tension. Thus, according to scientists, the application of limited motivational techniques, the lack of balance between the efforts made and

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the reward for work, respect and recognition of employees, an inflexible work schedule, heavy workload and other aspects occurring within the organisation could be one of the reasons causing stress at work. However, it should be noted that the reasons for stress at work and the reactions evoked depend on the individual characteristics of a person, situational awareness, and the ability to solve problems (Roohafza et al., 2016). In contrast, a person's reaction to a stressful situation and the ability to cope with it depends on the strategies for stress reduction used in that situation and how specific stressors are assessed by an individual based on his personal experience.

Bearing in mind that in modern organisations, stress is a common phenomenon that hurts employees' physical and mental health, searching for stress management techniques is becoming a subject of significant importance to analysts and researchers. Based on the theory of stress at work management, scientists propose to cope with stress in three ways and discern individual (covering the aspects of didactics, promoting a healthy lifestyle and training on stress management), individual and organisational (covering time management, the development of communication skills and the balance between work and personal life, increasing employee resistance to specific stressors) and organisational (covering changes in the current situation, eliminating the source of the problem, improving the work content and the working environment, career management and leadership development). The latter opinion is supported by many researchers who point out the activities that help employees cope with stress at work (Roohafza et al., 2016). Based on this theory, it is evident that an organisation should participate in the process of stress at work management. The scientists who analysed the aspects of stress at work management notify that it is important to identify the conditions that cause stress (Khanna et al., 2019). The latter opinion is supported by Arsalan, Majid, Butt and Anwar (2019), who admit that to reduce stress at work, it is necessary to find out the specific nature of stress and the sources that cause it, as well as the reasons of stressful tension and foresee a potential crisis when there is no reaction to stress signals for a long time. At the same time, other scientists state that providing employees with access to professional advice is necessary. Alvi, Kayani & Mir (2020) point out the aspect of didactics at the organisational level. The importance of implementation of training provides the conclusion that social support, ensuring employee satisfaction, stress management training and the reaction to stressful situations, the implementation of wellness programmes and relaxation techniques applied at work, and the assistance of professional psychologist could be one of the factors that contribute to job satisfaction and one of the techniques for managing stress at work. Some researchers emphasise the importance of an employer in managing stress at work and focus on applying appropriate measures for stress reduction (Imran & Ayub, 2017; Xie et al., 2024; Iredahl et al., 2025).

Other researchers' insights related to managing stress at work are also significant. Alvi, Kayani and Mir (2020), Haider, Fatima and de Pablos-Heredero (2020) relate a good mood and rarely experienced stress at work to the conditions enabling employees to have professional development and career opportunities, while other scientists (Weideman & Hofmeyr, 2020; Lutfiani Putri Windia, Singh & Rashid, 2021) state that a flexible work schedule in terms of time and place, the opportunities to plan employees' activities, consistent work and time planning involve employees into work activities and reduce stress at work. Some other researchers stress a social aspect and highlight the importance of communication with colleagues and the management based on reliability and openness. Goldstein, Pulakos, Semedo and Passmore (2017) admit that relationships based on help and support are the main factors affecting employees' mood at work. Published works present detailed characteristics of work in an organisation, when stress at work is understood as a phenomenon that is inseparable from job dissatisfaction. Scientists state that high work requirements (Fletcher, Carter & Lyubovnikova, 2018), a heavy workload and the lack of support for task completion (de la Torre-Ruiz, Vidal-Salazar & Cordón-Pozo, 2019), the lack of employee recognition (Čuček & Kač, 2020) and other processes within an organisation could increase work dissatisfaction, and could be one of the factors evoking stress at work. At the same time, Toniolo-Barrios and ten Brummelhuis (2023) notify that properly planned workload and mindfulness could cause job satisfaction and reduce stress. According to (Krywalski-Santiago, 2020), ensuring the sense of certainty of employees in terms of their roles at work is related to greater job satisfaction and leads to less stress at work.

In summary, it could be stated that to reduce stress at work, it is necessary to find out stress specificity, the reasons and factors causing stress at work and to foresee its management techniques considering the specifics of work organisation and the aspects of human resource management, didactics and professional development, as well as motivation strategies and ensuring favourable microclimate.

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3. Research methodology

Samples of research participants and organisation of the study. The research array consisted of 303 respondents (persons working in Lithuanian organisations), 204 of which (67.3%) were women and 99 (32.7%) were men. When assessing respondents according to age, it is seen that most respondents were from 26 years of age to 45 years of age (n = 115; 38%) and an older age group from 46 years of age and over (n = 112; 37%), while a smaller part of participants (n =76; 25%) were up to 25 years of age. Research sample convenient. The method of the questionnaire was applied - an online survey using an electronic system. Based on the quality control principle, an internal audit of the research was performed (completeness of the questionnaire, consistency and duration of the survey execution), whereas the questionnaires which were filled out incompletely or carelessly (e.g., all the columns of the questionnaire had the same numbers marked, etc.) were not included into the further database analysis. The research participants were introduced to the research objective and carried out anonymously; while the obtained results were processed and provided for generalisation, data confidentiality was ensured. The principles of voluntariness and self-determination for participation in the survey were observed during the research performance. Respondents were free to decide whether to participate in the survey or not; therefore, filling out the questionnaire was treated as consent to participate in the survey.

Research methodology. Analytical descriptive. Systematic analysis of scientific literature and research on the topic under consideration is based on comparative and generalisation methods. *Quantitative method*. When analysing the phenomena of stress at work, quantitative data collection and analysis were applied, which enabled the disclosure of the situation covering stress at work and identifying the factors causing it. The questionnaire consisted of questions aimed at collecting demographic and social data about respondents and finding out the attitude of the respondents to the situation of stress at work; based on theoretical insights and criteria distinguished in scientific literature, the questionnaire covers 20 statements for identifying the reasons causing stress at work, was created which was aimed at defining techniques for managing stress at work. Such factors as flexible work schedule in terms of time and place enabling a person to work independently and make decisions (Haider, Fatima & de Pablos-Heredero, 2020) that represent organisational trust in employees (Weideman & Hofmeyr, 2020; Lutfiani Putri Windia, Singh & Rashid, 2021; Demircioglu, 2021) are considered as the factors positively affecting the employee's mood and causing zero stress at work; based on this discovery statements included into the questionnaire enabled to assess the aspects of a flexible attitude to work organisation and to create favourable working conditions. Creation of favourable working conditions and providing with all necessary tools for work are distinguished as the factors ensuring employees' good mood and causing zero stress at work (Imran & Ayub, 2017); the research covers such spheres as peculiarities of work organisation (workload, assignment of tasks, work content, introduction of employees to the specifics of work and its main functions, establishing working conditions, ensuring necessary tools for work, etc.). On the other hand, a favourable psychological microclimate at work, good social relations with colleagues and the manager (Roohafza et al., 2016; Goldstein et al., 2017), as well as ensuring the efficiency of internal communication (Krywalski-Santiago, 2020), are related to employees' satisfaction and zero stress at work; based on this the assessment of microclimate at work and maintaining communication with the manager and colleagues were highlighted as the object of analysis. Moreover, employees' satisfaction and zero stress at work are related to the recognition of employees as specialists and acknowledging their efforts (Čuček & Kač, 2020), as well as establishing opportunities for professional and career development (Alvi, Kayani & Mir, 2020; Haider, Fatima & de Pablos-Heredero, 2020) and applying motivation methods with regard to employee needs (Fletcher, Carter & Lyubovnikova, 2018; Koszela, 2020) the research covers the assessment of the spheres of personal and professional development creation and a motivation system. It is considered that identification of the highlighted factors could be assessed as one of the techniques of managing stress at work, which would enable the reduction of stress at work. The questionnaire consists of 20 statements; possible answers were assessed using the Likert scale, where the highest score (5) means the strongest support of the statement (completely agree), while one score - the strongest disagreement (completely disagree). The results were obtained after summing up the answers of the statements - numerical values. The validity and reliability of the questionnaire were determined by calculating the meanings of *Cronbach's alpha*, which enabled us to determine whether all statements reflected the test quantity and allowed us to specify the number of questions required. The results of statistical data analysis show that the internal degree of compatibility of the questionnaire statements (n=20) about the factors causing stress at work is relatively high (Cronbach's alpha = 0.8357) and varies from 0.8191

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to 0.8421. Based on the fact that internal compatibility should be from 0 to 1, and the value of Cronbach's alpha coefficient - 0.60, the research is considered proper, which shows that the questionnaire is highly reliable. The value of Cronbach's alpha shows that variables included in the questionnaire are oriented toward analysing the factors causing stress at work. *Methods of statistical data analysis.* The obtained data was processed using statistical data analysis. The quantitative research instrument consisted of ordinal and nominal scales; therefore, absolute and percentage frequencies and scale averages were calculated. The average (M) and its standard deviation (SD) were used to describe the values of the Likert scale. In contrast, Student's t-test was used to compare the averages of variables of the Likert scale in two independent samples. To compare the averages of more than two groups under normal distribution, the analysis of variance - (ANOVA) was used. When the significance level was less than 0.05, the difference in characteristics is considered statistically significant. Statistical data analysis was performed using the software data package SPSS, which has 17 versions, and the MS Excel 2016 computer program.

4. Reasons causing stress at work and the opportunities to manage it: analysis of empirical research results

The increasing workload, the intensive pace of task completion and the increasing requirements are the factors causing stress at work. Therefore, managing stress at work is becoming more relevant and is raising new discussions for scientists trying to find out possible ways to manage the causes of stress at work. The survey was performed to find possible ways to manage stress at work. The frequency of stress at work experienced by employees over the past six months was identified. The research results in the general sample showed (see Table 1), that over the past six months, almost three-thirds (87.4%) of respondents experienced stress at work very often (39.6%) or often (47.8%) and according to the assessment results of only a small part of respondents experienced stress seldom (8.1%) or very seldom (4.5%). The research results revealed that over the past six months, none of the research participants experienced stress at work. Thus, the research results highlighted the stress problem at work and its management's relevance.

The research indicators obtained after data analysis demonstrated the need to reduce stress at work in groups of respondents of different ages and genders. The comparative data analysis showed (see Table 1) that men participating in the study more seldom experienced stress at work than women. The research results showed that almost half (48.3%) of women who participated in the study very often (22.1%) or often (26.2%) experienced stress at work over the past six months. Based on the research results it is evident that more than a third (39.1%) of men participating in the study experienced stress at work very often (17.5%) or often (21.6%) over the past six months. The results show that a larger part of men participating in the study seldom (5.3%) or very seldom (2.6%) experienced stress at work over the past six months. In contrast, only a small part of women experienced stress at work seldom (2.8%) or very seldom (1.9%).

A comparative analysis in groups of the research participants groups of different ages showed (see Table 1) that a bigger part of respondents up to 25 years of age (35.1%) and from 26 to 45 years of age (29.7%) experienced stress at work very often (up to 25 years of age (16.9%), from 26 to 45 years of age (13.6%)) or often (up to 25 years of age (18.2%), from 26 to 45 years of age (16.1%)) and only less than a quarter (22.6%) of the research participants from 46 years of age and older very often (9.1%) or often (13.5%) experienced stress at work over the past six months, while a bigger part of respondents of this age (5.6%) experienced stress at work seldom (3.8%) or very seldom (1.8%) up to 25 years of age (3%) and from 26 to 45 years of age (4%). The tendencies revealed during the research performance foster the identification of the reasons for stress at work and the implementation of the system for managing stress at work with regard to the aspects of gender and age.

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Table 1. The assessment of stress at work experienced in groups of men and women of different ages over the past six months presented in the general sample (%)

	Very often	Often	Seldom	Very seldom	Never experienced stress at work
General sample	39.6	47.8	8.1	4.5	0
Men's group	17.5	21.6	5.3	2.6	0
Women's group	22.1	26.2	2.8	1.9	0
Under 25 age group	16.9	18.2	1.9	1.1	0
From 26 to 45 age group	13.6	16.1	2.4	1.6	0
From 46 and over age group	9.1	13.5	3.8	1.8	0

Creating favourable working conditions, ensuring career and professional development opportunities, establishing favourable microcats, employee recognition and assessment, and involving and motivating activities fostering job satisfaction and employees' satisfaction are the factors which reduce stress at work. On the other hand, requirements that are too high do not match the employees' competencies, the lack of time for task completion, and the heavy and excessive workload increase stress at work. Therefore, to find effective techniques for managing stress at work, the focus was laid on the factors reducing stress, such as reviewing the peculiarities of work organisation, creating a favourable microclimate, establishing opportunities for professional development and career, etc.

When analysing the data in the general sample, the highest averages of estimates show (see Figure 1) that the most important factors causing stress at work are these: too high requirements that are not in compliance with employees' knowledge and skills when the tasks provided to employees are too complicated due to the lack of competences (M=4.61) and when there is too little time to complete tasks (M=4.45). On the other hand, according to the results of the research participants, underestimation of work results and the lack of encouragement for high results of employees (M=4.51), as well as scarce opportunities for self-realisation and revealing one's own personal abilities and skills (M=4.49) are the factors causing stress at work. Moreover, after analysing the factors causing stress at work, the obtained highest average of estimates shows the need for training on how to cope with stress at work; according to the assessment of the research participants, in an organisation, employees lack training on coping with stress at work. (M=4.66). However, the obtained lowest average estimates (see Figure 1) show that an organisation does not provide employees with proper working conditions (not a comfortable workplace, poor lighting and ventilation of premises, noise, temperature, etc.) (M=3.45) the lack of necessary work tools (M=3.47) and also the shortage of clarity when the employee's responsibilities and functions are vaguely defined (M=3.39); they are not the only factors causing stress at work. Harassment with unpleasant words and actions (M=3.4) and the manifestation of conflicts and tense relations among colleagues (M=3.53) are the factors that cause the least stress at work.

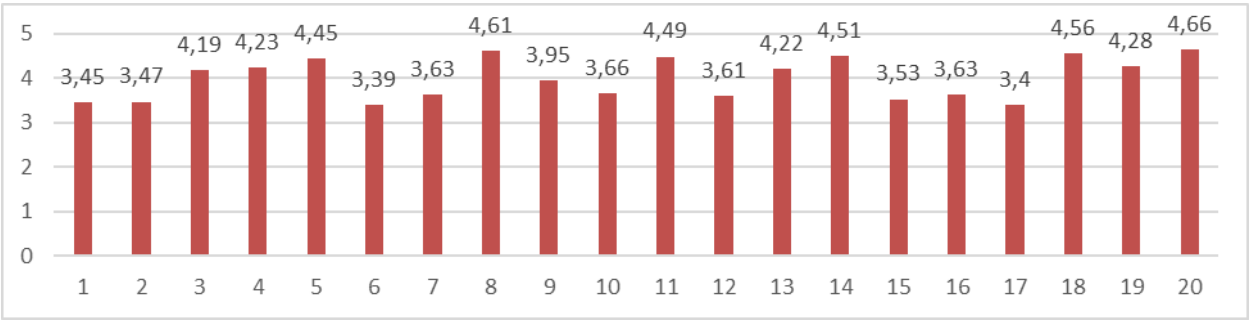


Figure 1. The assessment of the subjective attitude towards stress at work (n=303; average value (M), Max=5)

Note:

1. My working conditions are unsuitable for the job (uncomfortable workplace, poor lighting and ventilation of premises, noise, temperature, etc.)
2. The lack of necessary tools and equipment to do the job
3. Flexible working conditions are not provided (inflexible work schedule, etc.)
4. I have an excessive workload; I work much and very intensely
11. Organisation does not provide me with the opportunities for self-realisation, revealing my abilities and skills to do what I do best
12. I cannot develop myself professionally, acquire new knowledge and skills, or improve my qualification
13. The lack of professional career opportunities
14. My work results are not acknowledged; I am not encouraged to achieve good work results

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5. Too little time for task completion; deadlines for work completion are unreasonable
6. It is not clear what is expected from me; the lack of defined duties and functions
7. Tasks are not clearly defined, and there is a lack of precise instructions for task completion (I have not been introduced to how to perform the tasks, and there is no discussion on how to achieve goals)
8. Requirements placed on me exceed my knowledge and skills / too complicated tasks, and I have no competencies to complete them
9. I am not informed about the processes and changes taking place in the organisation
10. Tiring work routine
15. There is friction and conflicts between me and my colleagues, prevailing strained relationships
16. I am on bad terms with the manager; I can not openly and freely express my attitude, opinion and beliefs on the issues of ongoing activities, make suggestions, communicate freely
17. I am being harassed with unpleasant words and actions
18. The salary does not match the results of my work
19. The organisation does not care how I feel at work
20. The organisation does not provide training on how to manage stress

A comparative analysis of the factors causing stress at work in groups of men and women showed statistically significant differences in five categories consisting of twenty answers (see Table 2). After calculating t-test results, it was found statistically significantly higher ($p<0.05$) averages of estimates in the group of women, which shows that women believe that there is a lack of information about processes and changes occurring within the organisation that ensures the quality (M=4.03, SD=1,06) and provides employees with the opportunities for professional development, acquiring new knowledge and skills (M=3.74, SD=0.75), which cause stress at work, compared to the men group the average estimates of which are significantly lower (respectively: (M=3.77, SD=0.92) and (M=3.33, SD=0.89)). Women who participated in the research assessed ($p<0.05$) conflicts and strained relationships with colleagues (M=3.83, SD=0.83) with significantly higher average estimates. At the same time, they considered harassment with words and actions (M=3.53, SD=1,17) as one of the reasons causing stress at work compared to men who participated in the survey (respectively: (M=2.92, SD=0.89) and (M=3.13, SD=1.33)). After calculating the t-test, it was found that statistically higher average estimates (t=2.511, p=0,013) of women show (M=4.74, SD=0,61) that they relate the lack of training on managing stress at work to the factor causing stress compared to the men participating in the survey (M=4.48, SD=0.92). When assessing other reasons causing stress at work, statistically significant differences in terms of gender were not detected (see Table 2), which suggests that the latter factors causing stress at work are assessed similarly by men and women.

Table 2. A subjective assessment of men participating in the survey (n=99) and women (n=204) with regard to the factors causing stress at work (average value (M), standard deviation (SD) and the significance level of differences; Max=5)

	Women's group		Men's group		t	p
	M	SD	M	SD		
My working conditions are unsuitable for the job (uncomfortable workplace, poor lighting and ventilation of premises, noise, temperature, etc.)	3.42	0.89	3.51	0.76	-0.851	0.395
The lack of necessary tools and equipment to do the job	3.46	0.78	3.48	0.88	-0.241	0.809
Flexible working conditions are not provided (inflexible work schedule, etc.)	4.18	0.78	4.20	0.86	-0.21	0.834
I have an excessive workload; I work much and very intensely	4.25	0.86	4.21	0.77	0.322	0.748
Too little time for task completion, deadlines for work completion are unreasonable	4.50	0.85	4.36	0.87	1.256	0.21
It is not clear what is expected from me; the lack of defined duties and functions	3.41	0.72	3.35	0.75	0.652	0.515
Tasks are not clearly defined; there is a lack of precise instructions for task completion (I have not been introduced to how to perform the tasks, and there is no discussion on how to achieve goals)	3.61	0.94	3.68	0.79	-0.667	0.505
Requirements placed on me exceed my knowledge and skills / too complicated tasks, and I have no competencies to complete them	4.63	0.69	4.58	0.72	0.66	0.51
I am not informed about the processes and changes taking place in the organisation	4.03	1.06	3.77	0.92	2.137	**0.033**
Tiring work routine	3.63	1.04	3.73	0.93	-0.77	0.442
The organisation does not provide me with the opportunities for self-realisation, revealing my abilities and skills to do what I do best	4.49	0.67	4.47	0.77	0.179	0.858
I can not develop myself professionally, acquire new knowledge and skills, or improve my qualification	3.74	0.75	3.33	0.89	3.911	**0.001**
The lack of professional career opportunities	4.24	0.98	4.19	0.82	0.451	0.652

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My work results are not acknowledged, and I am not encouraged to achieve good work results	4.52	0.9	4.48	0.77	0.376	0.707
There is friction and conflicts between me and my colleagues, prevailing strained relationships	3.83	0.83	2.92	0.89	8.776	**0.001**
I am on bad terms with the manager; I cannot openly and freely express my attitude, opinion and beliefs on the issues of ongoing activities, make suggestions, communicate freely	3.71	1.56	3.45	1.53	1.348	0.179
I am being harassed with unpleasant words and actions	3.53	1.17	3.13	1.33	2.691	**0.008**
The salary does not match the results of my work	4.62	0.87	4.44	0.82	1.659	0.098
The organisation does not care how I feel at work	4.31	1.01	4.21	0.91	0.807	0.42
The organisation does not provide training on how to manage stress	4.74	0.61	4.48	0.92	2.511	**0.013**

Bearing in mind that scientific literature usually emphasises the aspect of age differences, it would be reasonable to investigate how assessing the factors causing stress at work impacts the age of respondents. When discussing the factors causing stress at work with regard to age, the data was analysed using analysis of variance (ANOVA). Comparative data analysis showed that the average stress estimates at work assessment are statistically significantly related to the age of respondents even in fourteen out of twenty answers (see Table 3-8). Stjudent's t-test was applied to find out the differences in the assessment of respondents of different age groups, whereas statistically significant differences in average estimates were discussed in the data analysis.

Analysis of variance (ANOVA) showed that the assessment of all factors causing stress at work is statistically significantly related to the age of respondents (see Table 3). After completing calculations, it became evident that the lack of favourable working conditions (e.g., inflexible work schedule, etc.) ($F=9.468$, $p=0.001$), a heavy workload when the employee must work hard ($F=47.596$, $p=0.001$), the lack of time for task completion or unreasonable deadlines for work completion ($F=3.703$, $p=0.026$) and unsuitable working conditions (uncomfortable place to work, lighting, poor ventilation of premises, noise, temperature, etc.) ($F=4.527$, $p=0.012$) and the lack of necessary tools and equipment for working ($F=17.182$, $p=0.001$) are considered as the factors causing stress at work and are assessed differently in different age groups. According to the research results, it could be stated that the lack of favourable working conditions and an inflexible work schedule are the factors causing stress at work in the group of respondents under 25 years of age ($M=4.49$, $SD=0.6$), compared to those from 26 to 45 years of age ($M=4.19$, $SD=0.79$), while in the group of respondents from 46 years of age and over ($M=3.98$, $SD=0.87$) significantly lower average estimates ($p<0.05$) were found out. After calculating t-test, statistically significant differences in the assessment in groups from 26 to 45 years of age and from 46 and over were not detected ($t=1.894$, $p=0.06$), which shows that the lack of favourable working conditions, which is one of the factors causing stress at work was assessed similarly in this age group. After performing Stjudent's t-test the assessment results in groups of respondents under 25 years of age and from 26 to 45 years of age are significantly higher ($p<0.05$); a heavy workload, when a person works hard and intensely (respectively: ($M=4.63$, $SD=0.51$) and ($M=4.49$, $SD=0.71$)) is considered as the factor causing stress at work and was assessed by respondents from 46 years of age and over ($M=3.71$, $SD=0.87$), while the assessment of this phenomenon of respondents under 25 years of age and from 26 to 45 years of age was almost of the same level and did not differ significantly ($t=1.64$, $p=0.103$). Moreover, the assessment with regard to the shortage of time for task completion, when the deadline for work completion is unreasonable, was assessed by significantly higher average estimates ($t=2.86$, $p=0.005$) of respondents under 25 years of age ($M=4.64$, $SD=0.69$), compared to those from 46 years of age and older ($M=4.3$, $SD=0.95$). However, no statistically significant differences in assessing the factors causing stress at work of respondents under 25 years of age and from 26 to 45 years of age ($t=1.575$, $p=0.117$) and from 26 to 45 years of age and from 46 years of age and older ($t=1.397$, $p=0.164$) were obtained, which shows that the lack of time for task completion and unreasonable deadlines for work completion causing stress at work were assessed similarly. Whereas, in the group of respondents from 46 years of age and older, the average estimates of factors causing stress at work were significantly higher ($p<0.05$), which shows that stress is caused by unfavourable working conditions (uncomfortable workplace, poor lighting and ventilation of premises, noise, temperature, etc.) ($M=3.63$, $SD=0.81$) and the lack of tools and equipment for task performance ($M=3.78$, $SD=0.76$), compared to those under 25 years of age (respectively: ($M=3.32$, $SD=0.79$) and ($M=3.12$, $SD=0.83$)), and from 26 to 45 years of age (respectively: ($M=3.35$, $SD=0.9$) ir ($M=3.4$, $SD=0.75$)) research participants. However, after calculating t-test statistical analysis showed that the assessment of unfavourable working conditions (uncomfortable workplace, poor lighting and ventilation of premise, noise,

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temperature, etc.) in participants under 25 years of age and from 26 to 45 years of age was of the same level and did not differ significantly (t=-0.253, p=0.8).

Table 3. The subjective attitude towards the factors causing stress at work assessed in groups of respondents of different ages (average value (M), standard deviation (SD) and significance level of differences; Max=5)

	Under 25 years of age (n=76)	From 26 to 45 years of age (n=115)	From 46 years of age and over (n=112)	F	p
My working conditions are unsuitable for the job (uncomfortable workplace, poor lighting and ventilation of premises, noise, temperature, etc.)	3.32 (0.79)	3.35 (0.9)	3.63 (0.81)	4.527	**0.012**
The lack of necessary tools and equipment to do the job	3.12 (0.83)	3.4 (0.75)	3.78 (0.76)	17.182	**0.001**
Flexible working conditions are not provided (inflexible work schedule, etc.)	4.49 (0.6)	4.19 (0.79)	3.98 (0.87)	9.468	**0.001**
I have an excessive workload; I work much and very intensely	4.63 (0.51)	4.49 (0.71)	3.71 (0.87)	47.596	**0.001**
Too little time for task completion, deadlines for work completion are unreasonable	4.64 (0.69)	4.47 (0.84)	4.3 (0.95)	3.703	**0.026**

When analysing the techniques for managing stress at work, the scientific literature focuses on the importance of internal communication quality assurance, covering the provision of information on the roles performed, functions and duties and clearly defined tasks and instructions for their completion, etc. According to the data of analysis of variance, it is evident (see Table 4) that the research participants under 25 years of age believe that the lack of clarity of task performance, when there are no clearly defined roles and duties (M=3.71, SD=0.69), as well as the lack of defined tasks and objectives when employees are not provided with the tools necessary for their task performance (M=4.41, SD=0.55), were the factors causing stress at work compared to those from 26 to 45 years of age (respectively: (M=3.3, SD=0.66) ir (M=3.34, SD=0.7)), and respondents form 46 years of age and over (respectively: (M=3.28, SD=0.76) and (M=3.4, SD=0.95)), in the groups of which statistically lower average estimates were found out; these variables are statistically related to the respondent's age (respectively: (F=10.265, p=0.001) and (F=51.566, p=0.001)). When assessing these variables,, attention was paid to the fact that after calculating t-test and performing a comparative analysis in groups of respondents from 26 to 45 years of age and over, statistically significant average variables were not detected (respectively, (t=0.199, p=0.842) and (t=-0.563, p=0.574)), which shows that the factors causing stress at work are assessed similarly by participants of these age groups.

Table 4. The assessment of the subjective attitude towards the factors causing stress at work in the level of internal communication, the quality assurance in groups of different ages of the research participants (average value (M), standard deviation (SD) and the level of significance of differences; Max=5)

	Under 25 years of age (n=76)	From 26 to 45 years of age (n=115)	From 46 years of age and over (n=112)	F	p
It is not clear what is expected from me; the lack of defined duties and functions	3.71 (0.69)	3.30 (0.66)	3.28 (0.76)	10.265	**0.001**
Tasks are not clearly defined; there is a lack of precise instructions for task completion (I have not been introduced to how to perform the tasks, and there is no discussion on how to achieve goals)	4.41 (0.55)	3.34 (0.7)	3.4 (0.95)	51.566	**0.001**

According to scientists, employee recognition and the acknowledgement of their efforts, adequate financial compensation corresponding to work results, introduction of employees to processes and changes occurring in the organisation, the ability to be part of the organisation and distribution of tasks with regard to the abilities and competencies of employees could be the factors reducing stress at work and evoking positive emotions. Whereas, when employees feel unimportant and disrespected, and their efforts are not acknowledged, when there is no balance between the work performed, efforts made, and the reward received, this could cause stress. When analysing the research data in the level of personal recognition analysis of variance showed (see Table 5), that respondents under 25 years of age experience stress when they feel the lack of information about the processes and changes occurring in the organisation (M=4.45, SD=0.64) compared to those from 26 to 45 years of age (M=3.86, SD=0.97) and from 46 years of age and over (M=3.7, SD=1.17); the average estimates in these

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groups are statistically significant (respectively: (t=5.025, p=0.001) and (t=5.66, p=0.001)) lower average estimates; this variable is statistically significantly related to the age of respondents (F=13.909, p=0.001). However, in assessing this variable, the focus is laid on the fact that after a comparative analysis in the groups of respondents from 26 to 45 years of age and from 46 years of age and over, a statistically significant difference was not found (t=1.153, p=0.25), it shows that the assessment of factors causing stress at work is rated at a similar level. After applying analysis of variance (ANOVA), it was found that underestimation of work results and the lack of encouragement for work results are the factors causing stress at work; it is statistically significant and related to the age of respondents (F=4.16 p=0.017). Thus, the research participants under 25 years of age and from 26 to 45 years of age underestimation of work results and the lack of encouragement for good work results (respectively under 25 years of age (M=4.66, SD=0.74) and from 26 to 45 years of age (M=4.59, SD=0.74)) assessed as the factors causing stress at work by statistically higher averages of estimates (respectively (t=2.554, p=0.011) and (t=2.21, p=0.028)) compared to those respondents of 46 years of age and over (M=4.33 SD=1.02). Whereas a comparative data analysis showed that underestimation of work results and the lack of encouragement for good work as the factors causing stress at work were assessed by the research participants under 25 years of age and from 26 years of age to 45 years of age and over and their assessment did not differ statistically significantly (t=0.61, p=0.542). Moreover, a comparative analysis in terms of age showed that according to the assessment of the younger research participants (under 25 years of age) the requirements for employees do not match their knowledge and skills. At the same time, the tasks provided are too complex and need more competencies to perform them (M=4.78, SD=0.56) and they are considered as the factors causing stress at work; they assessed the factors with significantly higher average estimates ($p<0.05$) compared to the participants from 26 to 45 years of age and over (M=4.58, SD=0.71) (M=4.54, SD=0.76) (respectively (t=2.102, p=0.037) and (t=2.508, p=0.013)).

Table 5. A subjective assessment of the attitude towards the factors causing stress at work with regard to a person's recognition and acknowledgement in groups of participants of different ages (average value (M), standard deviation (SD) and a significance level of differences; Max=5)

	Under 25 years of age (n=76)	From 26 to 45 years of age (n=115)	From 46 years of age and over (n=112)	F	p
I am not informed about the processes and changes taking place in the organisation	4.45 (0.64)	3.86 (0.97)	3.7 (1.17)	13.909	**0.001**
My work results are not acknowledged, and I am not encouraged to achieve good work results	4.66 (0.74)	4.59 (0.74)	4.33 (1.02)	4.16	**0.017**
The salary does not match the results of my work	4.66 (0.72)	4.57 (0.86)	4.49 (0.93)	0.864	0.423
Requirements placed on me exceed my knowledge and skills / too complicated tasks, and I have no competencies to complete them	4.78 (0.56)	4.58 (0.71)	4.54 (0.76)	2.898	0.057

Based on the insights of researchers, work content matching employees' expectations and needs, as well as the opportunities for their professional development and career promotion, evoke a higher degree of satisfaction, which could lead to experiencing less stress at work. Comparative data analysis showed that the attitude when assessing the factors causing stress is related to the established opportunities for professional development and is statistically significantly associated with respondents' age in three out of four categories of answers (see Table 6). According to the research results, it is evident that tiring work routine, monotonous and boring work (M=4.25, SD=0.57), as well as limited opportunities for professional development in the organisation, acquiring new knowledge and skills for improving one's qualification (M=4.17, SD=0.72) are the factors causing stress for younger employees (under 25 years of age) compared to those from 26 to 45 years of age (respectively: (M=3.71, SD=1.04) and (M=3.34, SD=0.77)) and from 46 years of age and over (respectively: (M=3.21, SD=0.99) and (M=3.5, SD=0.76)) research participants who assessed the factors causing stress at work by statistically significantly lower average estimates, (respectively: under 25 years of age and from 26 to 45 years of age (t=5.025, p=0.001) and (t=7.495, p=0.001); under 25 years of age and from 46 years of age and over (t=9.08, p=0.001) and (t=6.074, p=0.001)); these variables are statistically significantly related to the age of respondents (respectively: (F=28.655, p=0.001) and (F=29.651, p=0.001)), after calculating t-test the revealed statistically insignificant differences in averages (t=-1.583, p=0.115) show that participants from 26 to 45 years of age (M=3.34, SD=0.77) and from 46 years of age and over (M=3.5, SD=0.76) considered that the lack of opportunities for professional development and acquiring new knowledge and skills are the factors causing

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stress at work and they rated them similarly. Analysis of variance (ANOVA) showed that the lack of self-realisation and revealing one's abilities and skills cause stress at work and is statistically significantly related to the age of participants (F=43.84 p=0.001). Therefore, the research participants under 25 years of age (M=4.82, SD=0.45) and from 26 to 45 years of age (M=4.69, SD=0.58) assessed the lack of the opportunities for self-realisation and revealing one's one personal abilities and skills causing stress at work with significantly higher average estimates (respectively, under 25 years of age and from 46 years of age and over (t=8.705, p=0.001); in the groups from 26 to 45 years of age and from 46 years of age (t=7.142, p=0.001)) average estimates compared to participants from 46 years of age and over (M=4.05, SD=0.75). A comparative analysis showed that the lack of opportunities for self-realisation and revealing one's abilities and skills cause stress at work for participants under 25 years of age and from 26 to 45 years of age and did not differ statistically significantly (t=1.712, p=0.088). The lack of opportunities for professional development is considered as the factor causing stress at work, and it is not statistically significantly related to the age of participants (F=1.886, p=0.153) and this suggests that the research participants of different ages believe that limited opportunities for professional development are equal to stress at work. After calculating the t-test, a significant difference in variables (t=1.995, p=0.05) shows that for the research participants under 25 years of age, the lack of opportunities for professional development (M=4.36, SD=0.8) is considered the factor causing stress at work. In contrast, older participants 46 years of age and over-assessed it in lower average estimates (M=4.1, SD=0.98).

Table 6. The assessment of a subjective attitude towards the factors causing stress in the level of professional development in groups of participants of different ages (average value (M), standard deviation (SD) and the significance level of differences; Max=5)

	Under 25 years of age (n=76)	From 26 to 45 years of age (n=115)	From 46 years of age and over (n=112)	F	p
Tiring work routine	4.25 (0.57)	3.71 (1.04)	3.21 (0.99)	28.655	**0.001**
The organisation does not provide me with the opportunities for self-realisation, revealing my abilities and skills to do what I do best	4.82 (0.45)	4.69 (0.58)	4.05 (0.75)	43.84	**0.001**
I cannot develop myself professionally, acquire new knowledge and skills, or improve my qualification	4.17 (0.72)	3.34 (0.77)	3.5 (0.76)	29.651	**0.001**
The lack of professional career opportunities	4.36 (0.8)	4.26 (0.96)	4.1 (0.98)	1.886	0.153

When analysing the reasons for stress at work and searching for techniques for managing stress, attention is usually paid to a social aspect when relating it to a favourable microclimate in the organisation, ensuring relationships with colleagues and the manager based on team unity and good relationships among employees and ensuring support of employees, which could reduce stress at work. After calculating t-test and performing statistical data analysis, significantly higher average estimates ($p<0.05$) were found in the assessment of participants under 25 years of age and from 26 to 45 years of age, which shows that strained relationships and conflicts with colleagues (respectively: (M=3.88, SD=0.82) and (M=3.67, SD=0.93)) and harassment with unpleasant words and actions (respectively: (M=3.66, SD=1.18) and (M=3.48, SD=1.28)) are the factors causing stress at work, whereas in the group of older participants (from 46 years of age and over) the average estimates were significantly lower, which suggests that older participants less attribute these factors to the ones that cause stress at work (respectively: (M=3.16, SD=0.94) and (M=3.15, SD=1.19)); these variables are statistically significantly related to (see Table 7) the age of the research participants (respectively: (F=16.371, p=0.001) and (F=4.236, p=0.015)). However, after calculating t-test, comparative data analysis showed that prevailing strained relationships and conflicts with colleagues (t=1.658, p=0.099) as well as verbal and physical harassment (t=0.978, p=0.329) are the factors causing stress at work, both for participants under 25 years of age and from 26 to 45 years of age and are assessed with similar average estimates and did not differ statistically significantly. On the other hand, statistical data analysis showed that respondents under 25 years of age conflict with the manager when an employee can't express his attitude, opinion and beliefs on the topics of his activities, provide proposals and communicate freely (M=3.96, SD=1.52) are the factors causing stress at work, whereas for participants from 46 years of age and over these factors were assessed by lower average estimates (M=3.42, SD=1.56); and statistically significant average of estimates was obtained (t=2.355, p=0.02). Whereas in the groups of respondents under 25 years of age and from 26 to 45 years of age (t=1.552, p=0.122), from 26 to 45 years of age and from 46 years of age and over (t=0.971, p=0.36) this variable as the factor causing stress at work was assessed similarly.

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Table 7. The assessment of a subjective attitude towards the factors causing stress in the level of microclimate in the groups of participants of different ages (average value (M), standard deviation (SD) and a significance level of differences; Max=5)

	Under 25 years of age (n=76)	From 26 to 45 years of age (n=115)	From 46 years of age and over (n=112)	F	p
There is friction and conflicts between me and my colleagues, prevailing strained relationships	3.88 (0.82)	3.67 (0.93)	3.16 (0.94)	16.371	**0.001**
I am on bad terms with the manager; I cannot openly and freely express my attitude, opinion and beliefs on the issues of ongoing activities, make suggestions, communicate freely	3.96 (1.52)	3.61 (1.54)	3.42 (1.56)	2.79	0.063
I am being harassed with unpleasant words and actions	3.66 (1.18)	3.48 (1.28)	3.15 (1.19)	4.236	**0.015**

Caring for employees' satisfaction when providing not only mandatory social guarantees but also additional support and employee training by providing not only professional but also general competencies are the factors affecting the satisfaction of employees, which should reduce stress at work. After performing statistical data analysis, the obtained higher average of estimates in groups of participants under 25 years of age (M=4.42, SD=0.88) show that for younger employees, the lack of job satisfaction causes stress, compared to the assessment of participants from 26 to 45 years of age (M=4.31, SD=0.98) and from 46 years of age and over (M=4.14, SD=1.03). Moreover, participants from 26 to 45 years of age assessed the lack of training on how to manage stress at work as the factor causing stress and evaluated it with higher average estimates (M=4.7, SD=0.7) compared to participants under 25 years of age (M=4.66, SD=0.72) and from 46 years of age and over (M=4.62, SD=0.77) and they less relate it to the experienced stress. However, after applying analysis of variance (ANOVA) (see Table 8), it became clear that the assessment of factors causing stress in groups of respondents of different ages according to the latter variables was similar and slightly differed regardless of age (respectively: (F=197, p=0.141) and (F=033, p=0.717)).

Table 8. The assessment of a subjective attitude towards the factors causing stress at work in the level of ensuing job satisfaction of employees in groups of respondents of different ages (average value (M), standard deviation (SD) and a significance level of differences; Max=5)

	Under 25 years of age (n=76)	From 26 to 45 years of age (n=115)	From 46 years of age and over (n=112)	F	p
The organisation does not care how I feel at work	4.42 (0.88)	4.31 (0.98)	4.14 (1.03)	1.97	0.141
The organisation does not provide training on how to manage stress	4.66 (0.72)	4.7 (0.7)	4.62 (0.77)	0.33	0.717

After summarising the research results, it is evident that the assessment of the factors evoking stress at work is statistically significantly related to the age of respondents. As seen from the data analysis, the research participants under 25 years of age relate the factors causing stress at work to a heavy workload and the lack of time for task completion, inflexible working conditions and limited opportunities for professional development and self-realisation, as well as tiring work routine and monotonous and boring work compared to those respondents over 46 years of age and older. The research participants under 25 years of age assessed strained relationships and conflicts among colleagues and verbal and psychological harassment with higher average estimates and considered them as the factors causing stress at work compared to those respondents from 46 years of age and over. On the other hand, respondents under 25 years of age were assessed with higher average estimates of the lack of balance between the provided requirements and the competencies of employees, defined duties and functions and precise instructions for completing tasks, information about the processes and changes occurring within the organisation and underestimation of employees' efforts and incentives for the achieved results and considered them as the factors causing stress at work compared to those respondents from 26 to 45 years of age and from 46 years of age and over who considered those factors as causing less stress at work. However, respondents from 46 years of age and over-assessed the lack of tools and equipment to perform work and unsuitable working conditions (uncomfortable workplace, poor lighting and ventilation of premises, noise, temperature, etc.) as the factors causing stress at work compared to those respondents under 25 years of age and from 26 to 45 years of age.

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Opportunities for managing stress at work. After analysing the scientific literature, it is evident that the stress problem at work is relevant and is of increasing concern. The latter fact is confirmed by the results of this research, which show that most of the research participants often or very often experience stress at work. To ensure employees' physical and mental health and avoid negative economic (financial) and social consequences in the organisation, it is necessary to look for techniques and methods for managing stress at work and implement them when taking into account the processes occurring within the organisation. After defining the reasons causing stress at work, it could be stated that it is a complex phenomenon covering the aspects of work organisation, providing employees with working conditions, applying the motivation system, considering micro-climate within the organisation, ensuring the quality of internal communication, providing the opportunities for professional and personal development and conducting training on the topics related to managing stress at work. On the basis of the problems found out in the course of the research performance, the following categories were distinguished: 1) the features of work organisation are related to providing favourable working conditions adapted to the task performed, providing employees with tools and equipment to perform work, a flexible schedule, evenly distributed workload, distribution of activities with regard to individual abilities and the acquired competences, etc.; 2) the development of active internal communication which would ensure the clarity of information for performing tasks, defining the exact time for completing tasks, defining the duties and functions of employees, etc.; 3) providing the opportunities for professional development, self-realisation and professional career, etc.; 4) employee recognition and appreciation covering the implementation of the system related to employees' appreciation for their efforts and results using a motivation strategy, involving employees into decision-making processes related to their activities, ensuring the opportunities to plan and coordinate work processes together, determining the salary that corresponds to their work performed , etc.; 5) improving micro climate within the organisation which covers such aspects as respectful and open communication with the manager, providing assistance in case of difficulties, eliminating verbal and psychological harassment, etc.; 6) ensuring employees' satisfaction in the work environment and educational aspect related to the implementation of training on stress management, providing consultations of psychologists who could give advice on stress at work management during work (within the organisation), recognising and nurturing stress at work managing techniques, responding to stressful situations and searching for solutions. It should be noted that the distinguished components of the organisational level would contribute to ensuring employees' physical and mental health. Moreover, it would also guarantee the achievement of the organisation's goals and their implementation, as well as operational efficiency, work productivity and competitive advantage in labour market conditions. On the other hand, after performing calculations in the groups of women and men of different ages participating in the research, it is evident that when implementing the system for reducing stress at work and forecasting the techniques for managing stress at work, an important aspect becomes the need to consider the gender aspect and the characteristics of employees of different ages. For example, encouraging active involvement in the processes and changes occurring within the organisation, ensuring opportunities for professional development, acquiring new knowledge and skills and improving one's qualifications for gaining valuable experience could be one of the ways to reduce stress at work experienced by women. On the other hand, after assessing that ensuring a favourable microclimate at work and good social relationships with colleagues are some of the classical factors affecting employees' satisfaction, it is necessary to provide employees (especially women) with the opportunity to feel themselves part of the organisation and create and establish relationships based on respect and recognition when eliminating verbal and physical harassment. Moreover, implementing techniques for managing stress that employees (especially women) experience at work, providing employees with knowledge, and orienting and transforming employees' (especially women's) attitudes towards managing and coping with it is becoming relevant. According to the findings of a comparative data analysis with regard to the age of participants, it is likely that an evenly distributed workload, providing enough time for task completion and adequately distributed duties and responsibilities with regard to the employees' abilities and competencies, improving the opportunities for professional development and career and motivating employees for the achieved results could be the factors reducing stress at work in the group of younger respondents (under 25 years of age). On the other hand, a person usually associates his work with self-realisation in professional activities. Therefore, recognising a person and acknowledging his work results, ensuring opportunities for professional development and revealing one's abilities and skills could be one of the ways to reduce stress at work (especially for respondents under 45 years of age). Moreover, in the process of managing stress at work, it is important to ensure internal communication to reduce the feeling of uncertainty of employees (especially employees under 25 years of age) due to their roles in the organisation, provide them

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with information about their functions and duties while clearly defining tasks and providing them with precise instructions on how to complete them.

Conclusions

1. Theoretical analysis of scientific literature revealed that the complex nature of stress phenomenon is determined by the processes occurring within the organisation, improper work organisation and planning, a heavy workload, high demands raised, strained relationships and limited opportunities for professional development and the autonomy to act independently and make decisions, the lack of recognition and acknowledgement of a person and the lack of a motivation system. Therefore, stress management at work should be implemented comprehensively while covering the specifics of work organisation, ensuring the opportunities for professional development and self-realisation, ensuring a favourable micro-climate within the organisation and internal communication, as well as acknowledging employees' efforts and considering the aspects of didactics.

2. The research defined the current situation of stress experienced at work and the factors causing it:
2.1. Almost three-thirds of the research participants admit that over the past six months, they experienced stress at work very often (39.6%) or often (47.8), while only a small part of the research participants over the past six months experienced stress at work seldom (8.1%) or very seldom (4.5%). A comparative analysis with regard to gender showed that the expression of stress at work experienced to a fantastic extent is more common in women participating in the research (48.3%) than men (39.1%). In contrast, a comparative data analysis in the groups of respondents of different ages showed that over the past six months, the research participants under 25 years of age (35.1%) and from 26 to 45 years of age (29.7%) very often or often experienced stress at work compared to those participants from 46 years of age and over (22.6%).
2.2.The highest average scores provided in the study in a general sample show that there is a lack of training on managing stress at work, a heavy workload, too high requirements that do not match the knowledge, skills and competencies of employees to perform tasks, unreasonable deadlines for completing tasks, the salary does not match the results obtained, underestimation of a person's efforts, the lack of encouragement for work results and the lack of the opportunities for professional development, career and self-realisation could be the factors causing stress at work which are related to the processes occurring within the organisation.
2.3. The results showed that the assessment of the factors causing stress at work with regard to gender differs. A comparative analysis showed that women participating in the research admitted that the lack of information about the processes and changes occurring within the organisation, limited opportunities for professional development, acquiring new knowledge and skills and improving one's qualification, existing conflicts and strained relationships among colleagues, harassment with unpleasant words and actions and the lack of training on stress management are the reasons causing stress at work and assessed them with statistically significantly higher average estimates compared to men participating in the research.
2.4. The results of analysis of variance (ANOVA) showed that the assessment of the factors causing stress at work is statistically significantly related to the age of respondents even in fourteen cases out of twenty:

- Respondents under 25 years of age and from 26 to 45 years of age considered that the lack of flexible work conditions, a heavy workload and the lack of time for completing tasks when unreasonable time for completing tasks is set are the factors causing stress at work and assessed them with statistically significantly higher average estimates compared to those participants from 46 years of age and over who believed that unsuitable working conditions and the lack of tools and equipment to do work cause stress at work.
- Younger research participants (under 25 years of age) considered that the lack of clarity on the duties and functions of employees, clearly defined tasks and instructions for performing tasks, as well as raising too high demands which do not match the knowledge, skills and competences of employees are the factors causing stress at work and assessed them with significantly higher average estimates compared to older research participants.
- Respondents under 25 years of age believe that the lack of information about the processes and changes occurring within the organisation, underestimation of efforts of employees, the lack of encouragement for the achieved results, prevailing work routine and monotonous work, limited opportunities for professional development and acquiring new knowledge and skills and the lack of opportunities for

self-realisation and revealing one's skills and abilities are the factors causing stress at work compared to those respondents from 46 years of age and over.

- The research participants under 25 years of age consider that the prevailing strained relationships and conflicts with colleagues and harassment with unpleasant words and actions are the factors causing stress at work compared to those respondents from 46 years of age and over who believe that the latter factors are less stressful.

3. The situation of stress experienced at work at the organisational level requires a complex decision-making process covering work organisation, ensuring the opportunities for effective internal communication and personal and professional development and self-realisation in the work environment, providing career opportunities, improving a motivation system, creating favourable psychological micro-climate, recognition of employees, acknowledging the efforts of employees and ensuring employees' satisfaction in the work environment and considering the aspects of didactics. On the other hand, when implementing the system to reduce stress experienced by employees at work, it would be reasonable to consider the aspects of gender and age.

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LINKING ENTREPRENEURIAL ATTRIBUTES TO ENTREPRENEURIAL PERFORMANCE: AN EMPIRICAL STUDY OF YOUNG ENTREPRENEURS*

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Abstract. Young entrepreneurs play a major role of entrepreneurship, but their average successful rate is only about 2%, showing very low entrepreneurial performance. The entrepreneurial attribute of young entrepreneurs, which greatly influences entrepreneurial performance, includes many aspects and may interact complicatedly with each other, posing great challenges to the cultivation of entrepreneurial talents. In this paper, the constitution of entrepreneurial attribute was systematically summarized as entrepreneurial personality, entrepreneurial competence and entrepreneurial knowledge. The relationship between entrepreneurial performance and these three parts was then empirically studied. It was found that the influence of entrepreneurial knowledge was the most significant and entrepreneurial competence took the second place. Moreover, the direct impact of entrepreneurial personality on entrepreneurial performance was not significant, which was completely mediated by entrepreneurial knowledge and entrepreneurial competence. These three variables of entrepreneurial personality, entrepreneurial competence, and entrepreneurial knowledge explained 60.1% variation of entrepreneurial performance, which indicated that the empirical results verified the theoretical model well. These findings not only make a breakthrough in the theoretical research of entrepreneurial attribute, but also have practical applications on cultivation and education strategy of young entrepreneurs.

Key words: young entrepreneurs; entrepreneurial attribute; entrepreneurial performance; statistical analysis; personality

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1. Introduction

Young entrepreneurs, with the age ranging from 18 to 35 (the State Council, 2017), become the backbone of innovation and entrepreneurship. They are energetic and smart, and often use existed information, resources, opportunities or technologies to start businesses on an appropriate platform or carrier. However, although the proportion of young entrepreneurs in China has reached to 6.3% in recent years, the average rate of their

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successful entrepreneurship is only 2% (Wang et al., 2021), which might be attributed to their limitation of entrepreneurial attribute.

Entrepreneurial attribute is a key factor that affects the success of entrepreneurship. Entrepreneurial attribute includes not only the basic personality that is accumulated and internalized on individual growth by social achievements, but also the potential ability that need to be developed in the future. The formation of entrepreneurial attribute is more easily affected by acquired factors instead of congenital factors, so learning experience and social practice play important roles on its development. Therefore, it is both urgent and feasible to clarify the constitution and inherent interrelationships of entrepreneurial attribute, as well as to investigate its relationship with entrepreneurial performance. This can not only promote the development of entrepreneurial theory, but also improve the successful rate and performance of entrepreneurship, which will cultivate a large number of entrepreneurial talents, expand employment and promote economy.

2. Literature review and hypotheses

2.1 Entrepreneurial attribute

Entrepreneurial attribute refers to the individual characteristics of entrepreneurs that were reflected during entrepreneurial activities such as setting up new jobs, expanding new businesses and commences. Many researchers tried to understand it by identifying the traits and characteristics of entrepreneurs, which have been reported by a lot of literatures.

Shahin et al. (2021) and Liu et al. (2025) studied young entrepreneurs at different stages of the learning journey and evaluated the awareness of entrepreneurship, relevant knowledge, entrepreneurial self-efficacy (ESE), and entrepreneurial intentions. They were influenced by the experience, training, education, family background and other demographic variables of entrepreneurs. Ho et al. (2024) reviewed a lot of the literature and identified seven adolescent attributes that were linked to entrepreneurial attribute, including innovativeness, opportunity recognition, risk-taking propensity, proactiveness, foresighted thinking, ethical and sustainable thinking, and interpersonal communication. Kong (2018) explored the abilities and characteristics of college-student entrepreneurs. He established the theory model and evaluation indicators of entrepreneurial attribute, which included consciousness, ability, thinking, spirit, professional knowledge, and personality characteristics. Bird (2019) proposed that entrepreneurial attribute were underlying characteristics such as specific knowledge, motives, traits, self-images, social roles and skills that resulted in venture birth, survival and growth. Zhang et al. (2021) found that the key factors of entrepreneurial attribute included spirit, consciousness and ability. Entrepreneurial consciousness included entrepreneurial need, motivation and passion. Entrepreneurial competence included 16 indicators, such as opportunity recognition, innovation ability and market development etc. Li et al. (2022) set up a composite evaluation system to quantify the influence of entrepreneurial education on college students' entrepreneurial attribute. They thought that this education could train entrepreneurial skills and management/marketing abilities, and improve intrinsic quality and knowledge literacy.

According to the literature above, it can be found that entrepreneurial attribute shows the typical characteristics of multi-dimensional structure, which includes the following three aspects of personality, competence, and knowledge.

Entrepreneurial personality. Entrepreneurial personality represents the psychological characteristics of young entrepreneurs that are relatively stable, such as personality characteristics, morality, consciousness, etc. Among of them, personality characteristics play a moderating role to the entrepreneur behaviour. Morality is the reflection of entrepreneur spirit. Consciousness includes demand, motivation, ideals and beliefs, among which the demand and motivation are the internal driving force and precondition of entrepreneurship.

Entrepreneurial competence. Entrepreneurial competence refers to various abilities that appear during entrepreneurship, mainly including abilities of innovation and change, identify and grasp opportunity, risk assessment, operate and manage enterprise. Thereof, innovation ability is the core competence of entrepreneurial attribute.

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Entrepreneurial knowledge. Entrepreneurial knowledge, the primary necessity during entrepreneurship, includes theoretical knowledge and practical experience such as business management, law, market operation, and policy. It is the basic constituent of entrepreneurial attribute.

2.2 Entrepreneurial performance

Entrepreneurial performance is mostly used to evaluate the operation and management performance of start-up enterprises at the organizational level. In early studies, entrepreneurial performance was often generalized to survival indicators and growth indicators. Survival indicators represent the guarantee and possibility of the enterprises' existence, which are regarded as basic conditions for the success of entrepreneurship. Growth indicators represent the operation and development of enterprises, which are main indicators to measure entrepreneurial performance. However, it is often difficult to compare financial indicators or data between different types of enterprises, so some subjective indicators were added to characterize entrepreneurial performance in later literatures (Vij et al., 2016; Gao et al., 2024). On this basis, a lot of researchers reported how to measure or evaluate entrepreneurial performance. Wach et al. (2020) thought that the conceptualisation of entrepreneurial success should account for various, holistic, and integrated elements, especially in the context of comparative entrepreneurship. Gerschewski et al. (2025) suggested that the concepts of entrepreneurial success was consisted of multiple dimensions that combine together to define the direction of entrepreneurs when developing their businesses. They found that entrepreneurs revealed success configurations in terms of sustainability, profit, growth, or some combination of these, along with a purpose defined at the individual, business, and societal levels, or any combination of these. Wach et al. (2016) proposed the criteria of entrepreneurial success ranging from minimal success (survival) to maximal success (growth) and considered it as four types of main indicators, namely, growth indicators, firm stability indicators, position in the market, and firm survival capture. Rahman et al. (2015) measured entrepreneurs' business success by 9 indicators. Among of them, sales, profits, overall growth, debt level and satisfactory on financial condition belonged to financial performance, and the number of jobs, customer trust and confidence, contribution to the community development, and satisfied customers belonged to non-financial performance.

2.3 Hypotheses

As for the relationship between entrepreneurial attribute and entrepreneurial performance, most researchers investigated from one aspect of entrepreneurial attribute, namely, entrepreneurial personality or entrepreneurial competence or entrepreneurial knowledge. There was nearly no literature that covered all the aspects of entrepreneurial attributes to show its whole influence on entrepreneurial performance. This is precisely the start of our research that makes three hypotheses as follows.

2.3.1 Relationship between entrepreneurial personality, entrepreneurial competence, and entrepreneurial performance

Staniewski et al. (2016) assessed the relationships between the personality of entrepreneurs and economic success of SME in Poland. According to 294 samples, they found that personality disposition was relevant to the maintenance of liquidity, the competitiveness of companies, the developing chances of companies, and the innovativeness of companies. Self-efficacy also affects entrepreneurial performance. On the one hand, self-efficacy determined the choice of individuals and the persistence to achieve goals, so as to impact the motivation and behavior of entrepreneurs. On the other hand, entrepreneurs with high self-efficacy believed that they had more business knowledge and professional skills, and managed enterprises more effectively, all of which could promote entrepreneurial performance (Chadha et al., 2025). Wang et al. (2024) examined the influence of digital capabilities in sculpting entrepreneurial orientation and enhancing metaverse entrepreneurial performance. The empirical findings showed that the positive impact of digital capabilities on entrepreneurial orientation and metaverse entrepreneurial performance, with entrepreneurial orientation mediating this relationship. Neneh (2019) examined the effect of personality traits on the orientation from recognizing opportunity to practicing business. He found that alertness greatly influenced entrepreneurial intention, and then affected innovation behavior and successful entrepreneurship. Thus, we believe that personality traits of entrepreneurs, such as self-efficacy, consciousness of risk, sense of innovation, and risk-taking play important roles during the successful entrepreneurship. Therefore, we propose the following hypothesis:

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Hypothesis 1: Entrepreneurial personality is positively related to entrepreneurial performance.

Laouiti et al. (2022) used fsQCA to shed new light in the relationships between the Big Five personality traits and students' entrepreneurship. By capturing the interdependencies of openness, conscientiousness, extraversion, agreeableness, and emotional stability, they found that the combination of emotional stability and high openness to experience was core for entrepreneurship among the students. Obschonka et al. (2017) found that an entrepreneurial Big Five personality was associated with early entrepreneurial competence and could predict entrepreneurial social capital. Personality characteristics, such as self-esteem, innovation consciousness, and proactivity motivation, influenced entrepreneurial competence greatly.

Rahman et al. (2015) explored the influence of support from large private organizations on entrepreneurship at the base of economic pyramid. They found that entrepreneurial competencies contribute to business success and play a mediate role between the technical/training supports and business success. Xia et al. (2020) investigated the relationship among entrepreneurial perseverance, entrepreneurial competence and entrepreneurial performance. It was found that entrepreneurial competence had a positive mediate effect between entrepreneurial perseverance and entrepreneurial performance. Furthermore, the stronger the entrepreneur's competence was, the stronger the mediate effect was. Thus, two key issues have risen from the above literatures. Firstly, entrepreneurial competence was greatly influenced by the personality traits of entrepreneurs such as conscientiousness, leadership, self-esteem, innovation and consciousness. Secondly, some entrepreneurial competence mediated the relationship between entrepreneurial personality and entrepreneurial performance. Therefore, we propose the following hypothesis:

Hypothesis 2: Entrepreneurial competence mediates the relationship between entrepreneurial personality and entrepreneurial performance.

2.3.2 Relationship between entrepreneurial personality, entrepreneurial knowledge, and entrepreneurial performance

Sadiq et al. (2025) adopted a dimensional view of the knowledge-management model to investigate the effect of entrepreneurial knowledge on sustainable entrepreneurship. The results revealed that knowledge creation and transfer had a significant and positive relationship with sustainable entrepreneurship. Moreover, information acceptance of entrepreneurs significantly moderated the relationship between knowledge creation, knowledge transfer and storage, and sustainable entrepreneurship. Degeest et al. (2018) examined the relationship between the general mental ability (GMA) of entrepreneurs and the multiple indicators of entrepreneurial performance with meta-analysis. They found that the effect of GMA on entrepreneurial performance was partially mediated through entrepreneurial knowledge and skill. Dai et al. (2019) studied the influence of personality traits of top management team members (TMT) on the performance of venture. They draw the conclusion that knowledge integration played a partial mediate effect on the relationship between TMT's extraversion, agreeableness, conscientiousness, openness to experience and the performance of the venture. Farooq et al. (2018) explored the effect of entrepreneurial orientation on business performance. The result showed that knowledge management mediated the relationship between entrepreneurial orientation and business performance.
Thus, the knowledge and experience of entrepreneurs, as well as knowledge management and knowledge fusion, would mediate the relationship between personality traits and business performance. Therefore, we propose the following hypothesis:

Hypothesis 3: Entrepreneurial knowledge mediates the relationship between entrepreneurial personality and entrepreneurial performance.

The proposed model was shown in Figure 1 below.

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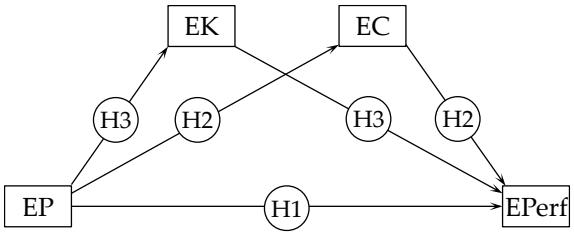


Figure 1. The proposed model

3. Data and methodology

3.1. Sample and data collection

In order to test the above hypotheses, we collected data from young entrepreneurs under the age of 35 in Mainland China. With the help of business accelerators, government agents and MBA students, the questionnaire was sent to respondents in year 2024. We guaranteed that all the responses would be kept confidential and anonymous, and only used for research purpose. Research findings would be used to guide policy-making and entrepreneurs' education, which would be beneficial for their entrepreneurship in the future. On the base of the above commitment and encouragement, we received 312 responses, and the number of valid questionnaires was 222. Among the valid questionnaires, the percentage of male respondents is 53.3% and the percentage of female respondents is 46.7%. In fact, the actual number of male respondents is much larger, but too many invalid responses lower their percentage. As for the age of respondents, the questionnaire covers people in the range of 18 to 35, which meets the demand of this research. For the educational background, the proportion of undergraduates is as high as 58% and the proportion of masters and doctors is only 6%. As far as the entrepreneurial motivation is concerned, entrepreneurship is a type of spiritual pursuit to get a better life instead of avoiding the pressure on employment. Before starting a business, the top three original occupations of respondents are college students, urban workers, and farmers and off-farm workers.

In this survey, 52% enterprises supply less than 10 jobs and 36% enterprises have the start-up capital of less than ¥100000 ($15000), which indicates that most of the enterprises started by young entrepreneurs are small and micro enterprises. The samples are widely distributed from the view of employee numbers, start-up capital and working area, which meets the demand of research.

3.2 Measure

According to the popular back-translation procedure (Brislin, 1980), the scales were translated from English to Chinese, and then to English by two independent bilingual individuals to ensure equivalency of meaning.

Entrepreneurial personality (EP). Entrepreneurial personality was measured with 10-items scale based on Laouiti et al. (2022) and Chadha et al. (2025). Participants make a choice among a five-point response scale ranging from 1 (strongly disagree) to 5 (strongly agree). Sample items were "I have strong perseverance to face all kinds of difficulties and setbacks" and "I have a strong desire to start a business". Cronbach's alpha in this study was 0.960.

Entrepreneurial competence (EC). Entrepreneurial competence was measured with 10-item scale based on Zhang et al. (2022) and Rahman et al. (2015). Participants make a choice among a 5-point scale to show whether they agreed with statements as "I have strong ability to explore new things and situations" and "I have strong ability to learn with various tools". Cronbach's alpha in this study was 0.970.

Entrepreneurial knowledge (EK). Entrepreneurial knowledge was measured with 4-item scale developed by Sadiq et al. (2025). Sample items include "I have a deep understanding of entrepreneurship policy" and "I have rich knowledge of business management". Cronbach's alpha in this study was 0.922.

Entrepreneurial performance (EPerf). Entrepreneurial performance was measured with 6-item scale developed by Wach et al. (2020) and Wang et al. (2024). Sample items include "the market share of your

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company is growing rapidly" and "the number of employees in your company is growing rapidly". Cronbach's alpha in this study was 0.941.

3.3 Data Analyses

Both entrepreneurial personality and entrepreneurial competence were not measured by one mature scale, so exploratory factor analysis was conducted with SPSS 22.0 by the 72 valid questionnaires firstly. LISREL8.70 was then used for confirmatory factor analysis by the 150 valid questionnaires. Correlation analysis was done with SPSS 22.0. SPSS PROCESS macro was utilized to test hypotheses of indirect effects, in which Model 6 was chosen to examine the model with two mediate variables. As for the data, we put entrepreneurial personality into X, entrepreneurial knowledge into M1, entrepreneurial competence into M2, and entrepreneurial performance into Y. Some control variables including gender, age, education, and scale of organization, were inputted as covariates.

4. Results

4.1 Reliability and Validity Tests

According to the results of exploratory factor analysis (See the Electronic Supplementary Material 1 for more information), the reliability of entrepreneurial knowledge was improved after the item "I am familiar with the knowledge about industry and product" was deleted, so this item was deleted. After that, the items of all variables were proved to meet the expectation by the reliability test, Kaiser–Meyer–Olkin test and factor loading analysis.

The reliability in this study was evaluated by Cronbach's alpha, which was 0.960, 0.970, 0.922, and 0.941 for entrepreneurial personality, entrepreneurial competence, entrepreneurial knowledge, and entrepreneurial knowledge, respectively (Table 1). All these values of Cronbach's alpha were higher than the threshold value of 0.7 (Nunnally et al., 1994), indicating that the measurement of all constructs was reliable.

The validity of the measurement was tested as follows. Firstly, all the indicators were measured on the base of previous literatures, which supported the content validity. Secondly, a series of confirmative factor analysis (CFA) were run to test the convergent validity with LISREL8.70. The results of factor loading, CR, and AVE were shown in Table 1. The factor loading, composite reliability, and convergence validity of all indicators largely exceeded 0.5, 0.7, and 0.5, respectively. These results proved the convergent validity of the measurement. Finally, the square root value of AVE of each construct was larger than its correlation coefficients to other constructs, so the discriminant validity was proved (Fornell et al., 1981).

The results of confirmatory fitting analysis for the single factor model of all indicators did not fit well (χ^2/df = 10.882, RMSEA = 0.258, SRMR = 0.12, NFI = 0.88, NNFI = 0.89, CFI = 0.90), indicating that there was no significant common method bias in the measurement.

Table 1. Reliability and validity of the construct

Constructs	Cronbach's α	Factor loading	Composite reliability (CR)	Convergence validity (AVE)	Discriminant validity			
					EP	EK	EC	EPerf
EP	0.960	0.77-0.89	0.9601	0.7067	(0.841)			
EK	0.970	0.85-0.93	0.9253	0.8052	0.431	(0.897)		
EC	0.922	0.79-0.92	0.970	0.7646	0.695	0.722	(0.874)	
EPerf	0.941	0.79-0.92	0.9412	0.728	0.446	0.743	0.678	(0.853)

Notes: n = 150; EP = entrepreneurial personality; EK = entrepreneurial knowledge; EC = entrepreneurial competence; EPerf = entrepreneurial performance. The values in round brackets are the square root of the AVE. Other values in the columns of Discriminant validity are correlations.

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4.2 Descriptive statistics analysis

Table 2 shows the mean value, the standard deviation, and the correlation of all variables. As shown in Table 2, entrepreneurial personality was positively related to entrepreneurial performance ($r = 0.446$, $p < 0.001$), entrepreneurial competence was positively related to entrepreneurial performance ($r = 0.678$, $p < 0.001$), entrepreneurial knowledge was positively related to entrepreneurial performance ($r = 0.743$, $p < 0.001$), entrepreneurial personality was positively related to entrepreneurial knowledge ($r = 0.431$, $p < 0.001$) , entrepreneurial knowledge was positively related to entrepreneurial competence ($r = 0.722$, $p < 0.001$), and entrepreneurial personality was positively related to entrepreneurial competence ($r = 0.695$, $p < 0.001$). These results were fully consistent with the tendency of our supposition, which gave primary evidence for all the hypotheses. It was noteworthy that there was also a significant correlation between scale of organization and entrepreneurial performance ($r = 0.327$, $p < 0.001$).

Table 2. Mean value, standard deviation, and correlation of descriptive statistics analysis

Variables	Gender	Age	Education	Scale of organization	EP	EC	EK	EPerf
Gender	1							
Age	-0.407**	1						
Education	0.100	-0.448***	1					
Scale of organization	-0.078	0.003	0.151	1				
EP	-0.149	0.045	-0.003	0.289***	1			
EC	-0.116	-0.084	0.219**	0.364***	0.695***	1		
EK	-0.023	-0.107	0.194*	0.315***	0.431***	0.722***	1	
EPerf	-0.031	-0.033	0.132	0.327***	0.446***	0.678***	0.743***	1
Mean	1.47	26.9	2.51	2.15	4.011	3.79	3.37	3.35
Standard deviation	0.501	5.61	0.873	1.496	0.882	0.816	0.857	0.758

Notes: n=150; *p < 0.05; **p < 0.01; ***p < 0.001. EP = entrepreneurial personality; EK = entrepreneurial knowledge; EC = entrepreneurial competence; EPerf = entrepreneurial performance.

4.3 Hypothesis Testing

The results of hypothesis testing are summarized in Table 3. The relationship between entrepreneurial personality and entrepreneurial performance was significant ($\beta=0.338$, $p < 0.01$), so Hypothesis 1 was verified. According to a bootstrapped 95% confidence interval of [0.130, 0.584], the total effect of entrepreneurial personality to entrepreneurial performance in this model was significant ($\beta =0.338$, $p <0.01$). However, after entrepreneurial knowledge and entrepreneurial competence were added as mediate variables, the direct effect of entrepreneurial personality to entrepreneurial performance became insignificant and the total indirect effect of entrepreneurial personality on entrepreneurial performance was significant ($\beta = 0.332$, $p < 0.001$). Thus, the indirect effect of entrepreneurial personality on entrepreneurial performance through entrepreneurial knowledge was positive (0.172), and Hypothesis 3 was verified. Moreover, the indirect effect of entrepreneurial personality on entrepreneurial performance through entrepreneurial competence was checked to be positive (0.115) by the same method, so Hypothesis 2 was proved. Unexpectedly, we found that these two mediators were not completely juxtaposed, but showed positive indirect effect of entrepreneurial personality on entrepreneurial performance through entrepreneurial knowledge and entrepreneurial competence in serial (0.045). In addition, these three variables of entrepreneurial personality, entrepreneurial knowledge, and entrepreneurial competence explained the 60.1% variation of entrepreneurial performance ($R^2=0.601$), which indicated that the empirical results verified the theoretical model well.

Table 3. The results of PROCESS macro for mediate analysis

Regression analysis	Coeff	SE	*t*	*p*	LLCI	ULCI	R^2	F
Dependent variable = EPerf[a] Predictor variables							0.253	5.797***
EP	0.338	0.117	2.898	0.004	0.108	0.569		
Dependent variable = EK[a] Predictor variables							0.256	6.746***
EP	0.372	0.112	3.323	0.001	0.151	0.593		
Dependent variable =EC[a] Predictor variables							0.723	52.373***
EP	0.431	0.092	4.674	0.000	0.2494	0.614		

EK	0.455	0.062	7.394	0.000	0.334	0.577		
Dependent variable =EPerf[a]							0.601	22.608***
Predictor variables								
EP	0.006	0.091	0.069	0.945	-0.174	0.187		
EC	0.266	0.115	2.318	0.022	0.039	0.492		
EK	0.464	0.075	6.227	0.000	0.317	0.611		
Total effect of EP on EPerf	Effect	SE	*t*	*p*	LLCI	ULCI		
	0.338	0.117	2.898	0.004	0.108	0.569		
Direct effect of EP on EPerf	Effect	SE	*t*	*p*	LLCI	ULCI		
	0.006	0.091	0.069	0.945	-0.174	0.187		
Total indirect effect of EP on EPerf	Effect	Boot[b] SE	Boot[b] LLCI		Boot[b] ULCI			
	0.332	0.081	0.182		0.500			
Indirect effect of EP on EPerf through EK	Effect	Boot[b] SE	Boot[b] LLCI		Boot[b] ULCI			
	0.172	0.050	0.084		0.284			
Indirect effect of EP on EPerf through EC	Effect	Boot[b] SE	Boot[b] LLCI		Boot[b] ULCI			
	0.115	0.054	0.016		0.238			
Indirect effect of EP on EPerf through EK and EC in serial	Effect	Boot[b] SE	Boot[b] LLCI		Boot[b] ULCI			
	0.045	0.022	0.010		0.101			

Notes: n = 150; EP = entrepreneurial personality; EK = entrepreneurial knowledge; EC = entrepreneurial competence; EPerf = entrepreneurial performance. Control variables = gender, age, education, and scale of organization; LLCI = lower limit of 95% confidence interval; ULCI = upper limit of 95% confidence interval. [a]Direct effect; [b] 5000 bootstrap samples used. ***p < 0.001.

The validated model was shown in Figure 2 below.

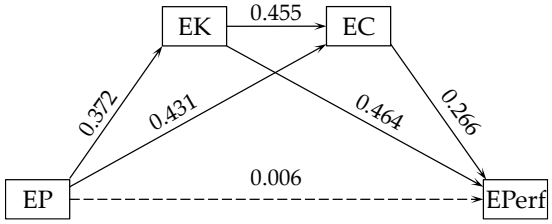


Figure 2. The validated model

5. Discussion

On the base of literatures and interview surveys, the components of entrepreneurial attribute were obtained and a model that entrepreneurial attribute impacted entrepreneurial performance was supposed. SPSS22.0, LISREL8.70 and SPSS PROCESS macro were then used for statistical analysis, so that the relationship between entrepreneurial attribute and entrepreneurial performance was explored to obtain the final model.

5.1 Theoretical Implications

The influence of entrepreneurial attribute on entrepreneurial performance has been comprehensively studied. This was very different from the previous literatures that only a few aspects of entrepreneurial attribute were chosen to find their relationship with entrepreneurial performance. Thus, the theoretical implications of this paper can be summarized as the following three points.

(1) The constitution of entrepreneurial attribute of young entrepreneurs was established. Entrepreneurial attribute was composed of three variables, namely, entrepreneurial personality, entrepreneurial competence and entrepreneurial knowledge. Entrepreneurial personality represented the psychological characteristics of individuals during the entrepreneurial process, which was composed of 10 indicators. Entrepreneurial competence was various abilities that entrepreneurs should have, which was composed of 10 indicators. Entrepreneurial knowledge referred to the knowledge system that entrepreneurs should have, including 3 indicators. The items of entrepreneurial personality and entrepreneurial competence were in accordance with the original design. By contrast, the items of entrepreneurial knowledge were changed from 4 to 3 by deleting

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the item "I am familiar with the knowledge about industry and product", since the respondent's score in this item was much higher than that in other items, namely, the internal consistency was poor. Therefore, it would fail the test of Cronbach's alpha if this item was retained. This item represented theoretical knowledge of entrepreneurship and it was relatively abundant, so it would be important to strengthen the practical knowledge of young entrepreneurs.

(2) The relationship between entrepreneurial personality, entrepreneurial competence, entrepreneurial knowledge and entrepreneurial performance was investigated by empirical testing. The results showed that entrepreneurial attribute certainly impact entrepreneurial performance. The direct impact was not significant and the indirect impact was significant. More importantly, the indirect impact was implemented through three paths by two mediate variables - entrepreneurial knowledge and entrepreneurial competence. Firstly, entrepreneurial personality affected entrepreneurial performance through entrepreneurial knowledge. Secondly, entrepreneurial personality affected entrepreneurial performance through entrepreneurial competence. Thirdly, entrepreneurial personality affected entrepreneurial performance by the serial relationship from entrepreneurial knowledge to entrepreneurial competence. The final results showed that three variables of entrepreneurial personality, entrepreneurial competence, and entrepreneurial knowledge explained the 60.1% variation of entrepreneurial performance (R^2=0.601), which indicated that the empirical results verified the theoretical model well.

(3) The approach that improves entrepreneurial performance through entrepreneurial attribute was developed. It was found that the influence of entrepreneurial knowledge was the most significant (β = 0.464), and entrepreneurial competence toke the second place (β = 0.266). Moreover, the influence of entrepreneurial personality on entrepreneurial performance was completely mediated by entrepreneurial knowledge and entrepreneurial competence. Therefore, in order to improve entrepreneurial performance, the first thing is to improve entrepreneurial knowledge, followed by entrepreneurial competence, and some attentions should be partly paid to entrepreneurial personality. This would give theoretical guidance for entrepreneurial management.

5.2 Practical Implications

(1) Entrepreneurial training is the most effective way to improve entrepreneurial attribute, which mainly lead to the improvement of entrepreneurial knowledge and entrepreneurial competence. Firstly, various training programs, including general courses for fresh entrepreneurs and special training for different entrepreneurs, should be established according to their social experience, educational background and entrepreneurial field. Secondly, flexible training way should be provided including theoretical courses, entrepreneurship lectures and online learning, so that entrepreneurial training can cover the whole cultivation process of young entrepreneurs. Finally, the practical training should be strengthened as well, such as mature entrepreneurial projects and multidimensional practical exercises.

(2) The standardization, specialization and elaboration of start-up accelerators need to be enhanced, which could improve the entrepreneurial competence of young entrepreneurs. The start-up accelerator is a type of service organization for entrepreneurship that reduces their cost and improves success rate. Start-up accelerators build a platform for the communication of young entrepreneurs, and provide case sharing, practical guidance, project diagnosis, technology transfer, product exhibition, and financing guidance. In order to achieve these goals, diverse accelerators need to be built depending on various government platforms, and the management, evaluation, and development of these accelerators should be strengthened.

(3) Entrepreneurs must develop their special entrepreneurial personality to improve entrepreneurial performance. Firstly, young entrepreneurs should overcome their own shortcomings according to the industrial requirement for entrepreneurial attribute. Secondly, young entrepreneurs should complete their career planning, improve their understanding of entrepreneurship, and correct some wrong attitude or behaviour of doing business. Finally, some entrepreneurial personality and entrepreneurial competence, such as perseverance, self-efficacy, and entrepreneurial alertness, might be improved by mental training.

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Limitations and expectations

The limitation of this study is reflected in the following aspects.

(1) The scope of sampling is not large enough. The survey target in this study involves many industries and enterprises with different scale, but convenient sampling was employed instead of random sampling. Thus, most of the samples come from Jinan, Qingdao and Dongying, which might limit the application of research findings. Therefore, the scope of investigation should be expanded and the method of random sampling should be adopted to improve this research in the future.

(2) The measurement of variables was subjective. Although the data had passed the reliability and validity test, it comes from the subjective judgment of the respondents, which leads to some limitation on inspecting causal relationship. More objective measurement should be considered in the future, such as typical case tracking over a long period of time.

(3) The model of the relationship between entrepreneurial attribute and entrepreneurial performance can be further explored. On one hand, are there other mediators or moderators to enhance their correlation? On the other hand, the weighting of different indicators in the constitution of entrepreneurial attribute can be introduced to evaluate their relationship. In the future, this model would be enhanced through more theoretical research and practical investigation, so that it might better guide the practice of young entrepreneurs.

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Ethics, Consent to Participate, and Consent to Publish declarations
Approval was obtained from the ethics committee. The procedures used in this study adhere to the tenets of the Declaration of Helsinki. Freely-given and informed consent to participate in the study was obtained from participants. All responses of participants are kept confidential and anonymous, and no potentially identifiable images or data are collected. All participants agreed to publish the collected data.

Data availability declaration. The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author Contribution declaration
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ENVIRONMENTAL TRAINING AND GREEN EMPLOYEE BEHAVIOR*

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Abstract. The present study explores the relationship between organizational environmental identity and employees' green behavior in the workplace. The current study contributes to the field by examining this relationship, which has not been extensively researched. Consequently, the domain of environmental components in employee education has emerged as a particularly significant issue. The primary objective of this study is to explore proactive environmental aspects and their impact on employee engagement. The present study employed correspondence analysis, and the ensuing results were interpreted through the implementation of a chi-square test, wherein the chi-square value was juxtaposed with the critical value. In this test, degrees of freedom (df) play a pivotal role, as they are employed to ascertain the critical value of the chi-square distribution. This critical value serves as a benchmark against which the calculated Chi-square value from the test is evaluated. The critical values are contingent on the degrees of freedom and the designated significance level. In this study, a significant level of 0.05 was employed. Notably, there is no statistically significant difference between initial or regular green learning and employee engagement. Furthermore, our findings indicate a substantial discrepancy between the size of the organization and the impact of both initial and regular employee environmental training. The integration of environmental practices into the daily routines of employees has been identified as a key factor in reducing the environmental impacts of organizations. The present study contributes to the extant literature on human capital and environmental management.

Keywords: learning; education; training; employee engagement; behavior

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Additional disciplines: sociology; ecology and environment

1. Introduction

The purpose of business is not just to make a profit. Global warming and environmental issues have become critical for the whole world. Therefore, businesses must adopt and adhere to green growth strategies. Their future survival depends on sustainability, which is considered as one of the fundamental responsibilities of business (Ahmed et al., 2023). Nowadays, companies accept responsibility for the negative impact of their

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business activities on the environment, so they try to change how they do business to mitigate the damage. However, it is always a question of whether companies adopt social responsibility measures with the motive to act proactively for image reasons or just to comply with the regulations imposed by law (Stojanović et al., 2016; Ranaweera, 2022). External stakeholders insist that companies should apply environmental standards in their operations. Enterprises are expected to take responsibility for current activities and not compromise the needs of future generations. Porter and Linde (1995) suggest that, in a broader sense, environmental CSR activities can stimulate innovation, reduce costs, conserve resources, and thus create competitive advantage and loyal consumers. In this way, social responsibility benefits society and the organizations themselves, primarily in the form of their long-term sustainability in the marketplace. In today's highly competitive market, an organization's added value may be precisely what it seeks to be different in some positive way to maintain its position.

2. Theoretical background

Social responsibility can also be defined in terms of ethical obligations that enterprises must fulfill towards their employees, customers, and the general community (Šupeková & Krchová, 2021). In this regard, it is imperative to acknowledge the significance of customers as a pivotal component of society. It is equally crucial to recognize the expectation among customers that organizations prioritize climate and environmental concerns in a manner that is on par with the significance of their business practices (Mahajan, 2024). Some studies explain the positive relationship between employee education through environmental training and green human resource management practices (Bazrkar & Moshiripour, 2021). Other studies confirm that green learning is an important tool to improve employees' awareness and commitment to environmental issues, which could lead to innovative and pro-environmental behaviors in organizations. (Carbalo-Penela et al., 2023; Noor et al., 2023; Mensah et al., 2023 Yang & Li, 2023).

Research has examined the influence of green human resource management (green HRM) on employee ecological behavior (EEB). This research draws on Ability-Motivation-Opportunity theory. The findings indicate that green HRM exerts a positive influence on green culture and green satisfaction. Moreover, the findings reveal a positive relationship between green satisfaction and EEB, with green satisfaction fully mediating the association between green HRM and EEB (Noor Faezah et al., 2024a). Another study offers guidelines to decision makers for enhancing employee ecological behavior (EEB) and environmental commitment in the workplace. (Noor Faezah et al., 2024b). A subsequent study offers significant implications for practitioners, educational policymakers, and leaders to promote Green Transition Mechanism (GTM) and employee engagement for sustainable environmental performance. The promotion of green skill development, the engagement of employees with green initiatives, and the promotion of employees with green skills have the potential to assist organizations, particularly higher education institutions (HEIs), in enhancing their sustainable environmental performance and attaining a competitive advantage. The findings of several researchers suggest the following: Firstly, the quality of employees is positively associated with the reporting of corporate environmental sustainability. Secondly, companies with more educated employees are more likely to provide environmental and sustainable information with high standards and quality. Thirdly, companies with more educated employees are more likely to release environmental and sustainable information in solo reports as a reflection of the corporate attention on and initiative in environmental sustainability (Umair et al., 2024).

Furthermore, researchers found that higher education-level employees have a stronger impact on corporate environmental sustainability (Cabagnols et al., 2022; Fang & Li, 2024). Additionally, evidence suggests a significant and positive relationship between environmental self-identity and employee green workplace behavior (Xing & Mohamed Zainal, 2024). The findings of several studies indicate that enhancing employee engagement and organizational commitment can be achieved through increased investment in green supply chain management (GSCM) practice drivers of social and operating performance. These include environmental education, green marketing, and green warehousing and distribution. A review of the extant literature reveals a positive correlation between GHRM practices and pro-environment promotion behavior among university employees, particularly when supported by GHRM training and education programs (Ciptomulyono et al., 2024).

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The authors have set out to address this research gap by investigating the relationship between green employee training, a component of green human resource management practices, and the level of employee engagement.

3. Research objective and methodology

Training is one of the human resources activities that has the potential to influence the pro-environmental behavior of employees. The present study employs a quantitative research methodology, with the objective of investigating proactive environmental aspects and their impact on employee engagement. Guided by the primary objective of the research, the following research question was formulated: What is the relationship between the application of environmental aspects in employee training and employee engagement? To that end, we have formulated two research hypotheses:

H1: There is a statistically significant relationship between green employee learning and the level of employee engagement.

H2: There is a statistically significant relationship between the application of environmental aspects in employee training and the size of the organization.

In accordance with Jaskova's (2021) assertion, the empirical data was collected from the respondents during the phase of acquiring the empirical material. The questionnaire was disseminated electronically, employing Google Forms as the digital platform. The designated timeframe for data collection was one month, commencing on 1.3.2024 and concluding on 31.3.2024. The research population comprised 150 respondents from various organizations within the Trenčín Region, with 31% belonging to medium-sized organizations and 69% to large organizations. This approach aligns with the perspective outlined by Adams and Zutshi (2004). The hypotheses were tested using Statistica.cz, a statistical program, which enabled the analysis of contingency tables and correspondence analysis. This methodology allowed for the examination of the relationships between categories of the tables. The results of the correspondence analysis can be interpreted with a chi-square test. The result of the test is expressed using the chi-squared value, which is then compared with the critical value from the chi-squared distribution. It is imperative to note that the degrees of freedom (df) play a pivotal role in the interpretation of the results obtained from the chi-squared test. These degrees of freedom are instrumental in determining the critical value of the chi-squared distribution, which serves as the benchmark against which the calculated chi-squared value from the test is assessed. The critical values, which are presented in tables for the chi-square distribution, are contingent on the degrees of freedom and the designated significance level, most commonly 0.05 or 0.01. In this study, a significant level of 0.05 was employed.

4. Results

As illustrated in Table 1, the questionnaire delved into the investigation of two primary factors. Firstly, the inquiry focused on whether newly recruited employees had undergone initial training that placed a particular emphasis on environmental issues. Secondly, it examined the extent to which this training had influenced their job engagement and, conversely, whether their level of engagement at work had any bearing on the company's environmental impact. Additionally, the survey sought to shed light on the relationship between the size of the organization and the incorporation of environmental considerations in the training it provided.

Table 1. Results of statistical investigation

Factor	p-value	Hypothesis Acceptance/rejection
Green learning and employee engagement	0,2282	H1 ×
Environmental aspects in training and the size of the organization	0,0058	H2 ✓

Source: calculations by the authors

Note: H1: There is a statistically significant relationship between green employee learning and the level of employee engagement (denied).
H2: There is a statistically significant relationship between the application of environmental aspects in employee training and the size of the organization (verified).

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The results of the correspondence analysis indicate that the $\chi 2$ test value is 10.5561 at degrees of freedom df=8 with a significance level of p<0.2282, which is below the established α=5%. This finding suggests that there is no statistically significant relationship between initial green learning and employee engagement. A similar outcome was observed in a subsequent correspondence analysis, which yielded a $\chi 2$ test value of 11.6050 at degrees of freedom df=8 and a significance level of p<0.1698, again falling below the established α=5%. This finding suggests that there is no statistically significant relationship between regular green learning activities and employee engagement.

Tables 2 and 3 demonstrate that the survey inquired about the potential impact of organization size on the provision of both initial and regular green learning activities.

Table 2. Initial environmental training vs. organization size

Organization	Organizing the initial training on the environment	Initial training on the environment - respondent unable to comment	The initial training on the environment has never been organized	Total
Medium-sized organization	10,67 %	2,67%	17,33%	30,67%
Large organization	34 %	14,67%	20,67%	69,33%
Total	44,67%	17,33%	38%	100%

Source: calculations by the authors (questionnaire survey 03/2024)

The correspondence analysis yielded a $\chi 2$ test value of 10.2965 at degrees of freedom df=2, with a significance level of p<0.0058, which is above the selected α=5%. This finding indicates a statistically significant relationship between the size of the organization and the initial green learning of employees. As illustrated in Table 2, it is evident that nearly half of the employees (44.67%) have undergone initial pro-environmental learning, while 17% of the respondents did not respond to this question and 38% of the respondents did not receive any initial training on the environment. A higher proportion of respondents from large organizations (34%) had received initial training on the environment, compared to respondents working in medium organizations (10.67%). Despite a hypothesis about the relationship between the application of environmental aspects in employee training and the size of the organization is verified, another notable finding is that a significant proportion of employees in large organizations do not recall or are unaware of their initial green learning, a proportion that is substantially lower than that observed among employees in medium organizations.

Table 3. Regular environmental learning vs. organization size

Organization	Organizing the initial training on the environment	Initial training on the environment - respondent unable to comment	The initial training on the environment has never been organized.	Total
Medium-sized organization	5,33 %	1,33%	24%	30,67%
Large organization	29,33%	4%	36%	69,33%
Total	34,67%	5,33%	60%	100%

Source: calculations by the authors (questionnaire survey 03/2024)

The value of the chi-squared test was determined to be 9.51971 at degrees of freedom df=2, with a significance level of p<0.0086, which is above the selected α=5%. This finding indicates that there is a statistically significant relationship between the size of the organization and the regular green learning of employees. As illustrated in Table 3, it is evident that more than half of the respondents (60%) do not undergo regular environmental training. A mere 34.67% of the respondents reported undergoing regular pro-environmental training, while the remaining 5.33% did not provide a response regarding the existence of such training programs within their respective organizations. Further analysis reveals a significant disparity in the frequency of pro-environmental training among medium and large organizations, with the former conducting such training approximately five times less frequently than the latter. Large organizations are more likely to provide regular green-leaning activities to employees.

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Commencing with the primary objective of the research study, the following research question was formulated: What is the relationship between the application of environmental aspects in employee education and employee engagement? The findings revealed that there was no statistically significant difference between initial green learning and employee engagement, nor was there a statistically significant difference between regular green learning and employee engagement.

5. Discussion

The results of the study (Alqudah & Yusnita, 2024) demonstrated a positive correlation between green training and development and two variables: academic citizenship behavior and organization environmental performance. Additionally, the findings suggested a favorable correlation between green recruitment and selection and two variables: academic citizenship behavior and organization environmental performance. Additionally, a relationship was identified between academic citizenship behavior and organization environmental performance. Furthermore, the findings demonstrated mediating effects of academic citizenship behavior in the relationship between green training and development and organization environmental performance, as well as between green recruitment and selection and organization environmental performance. Other findings indicate that green training, green commitment, and green knowledge management play pivotal roles in promoting sustainable practices in the hotel industry. Investing in employee training to cultivate knowledge and skills, demonstrating robust management commitment to sustainability, and implementing effective knowledge management are foundational to cultivating a work environment that fosters sustainability and environmental responsibility. The managerial implications of these findings suggest that hotels should focus on developing policies and programs that encourage sustainable practices. This entails enhancing educational and training initiatives, fortifying organizational commitment, and embracing effective knowledge management methodologies. By implementing these strategies, hotels can enhance their sustainability performance, thereby strengthening their reputation and competitiveness in an increasingly eco-conscious market (Lubis et al., 2024). The economic recovery of the tourism industry following the pandemic is accompanied by the adoption of modern and efficient trends to increase profitability. These trends include comprehensive accommodation approaches towards resilience and environmental sustainability. The objective of the study was to examine the implementation of environmental management elements and measures across all categories of accommodation facilities in the Czech Republic (n1 = 1,016). The findings suggest that the number of environmental measures implemented by monitored hotels and guesthouses remained relatively consistent. Conversely, the star rating of accommodation facilities emerged as a non-instrumental parameter in the environmental impact assessment. The most prevalent environmental measures included the installation of devices aimed at reducing electricity consumption (94% of hotels and guesthouses), implementing waste separation protocols (88% of hotels and 89% of guesthouses), and decreasing water consumption (85% of hotels and 86% of guesthouses). Conversely, measures aimed at curbing chemical consumption (23% of hotels and 22% of guesthouses), along with the communication and environmental education of employees and guests (32% of hotels and 18% of guesthouses), were found to be the least implemented (Vrabcová et al., 2024).

The significant proportion of negative responses regarding regular environmental learning may suggest a lack of opportunities for employees to expand their knowledge in this area, as environmental learning is not a prevalent component in the organization's curriculum. Conversely, the involvement of managerial staff in training programs focused on environmental issues has been shown to yield positive outcomes, as evidenced by the findings of Noor et al. (2023). These results suggest that the integration of managerial personnel in training initiatives pertaining to environmental concerns can effectively enhance employees' environmental promotion awareness and behavior. The integration of Job Demands-Resources (JD-R) theory and sustainability theory, which served as the foundation for the development of the concept of sustainable leadership, facilitates the comprehension of how the role of a leader can influence the level of sustainable engagement and performance and generate a healthier and more motivating work environment to achieve sustainable goals (Winarno et al. 2025). Additionally, heightened environmental awareness among executives and higher educational qualifications among employees serve to strengthen the relationship between corporate ESG behaviors and employee satisfaction (Zhang et al., 2024).

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In essence, employees' pro-environmental behaviors within their professional settings have the potential to contribute to a reduction in organizations' environmental impacts by integrating environmental practices into their daily routines. This study examined the role of a green climate at the organizational and co-worker levels, as well as supervisor support, in predicting employees' voluntary green behaviors, particularly with regard to waste separation. The mediating role of organizational identification in these relationships was also examined. The findings indicate a substantial positive association between employees' perceptions of a green organizational climate and their reported pro-environmental behaviors. However, organizational identification does not mediate the relationship between green climate and pro-environmental behaviors. Additionally, the impact of supervisor support on pro-environmental behaviors was found to be only marginally significant. These findings underscore the significance of organizational-level initiatives in promoting green behaviors within workplaces. However, further exploration is necessary to gain a more profound understanding of the mechanisms that generate these relationships. Practical implications of this study include the necessity for increased investment in initiatives that prioritize integrating environmental concerns into the daily procedures and routines of organizations (Leitão et al., 2024).

Conclusions

A survey of respondents employed in large and medium-sized enterprises across various sectors in Slovakia revealed that green training programs are implemented in less than half of the enterprises. Our quantitative research revealed that there is no statistically significant relationship between initial or regular green training and employee engagement (the first hypothesis has been denied). The authors consider this finding to be novel and innovative, and it represents a practical contribution to green human resource management. However, a notable distinction emerged concerning the correlation between the size of the organization and the implementation of initial and regular employee environmental training. The hypothesis about the statistically significant relationship between the application of environmental aspects in employee training and the size of the organization in our study has been verified.

The prevalence of unfavorable responses regarding initial and regular training on the environment may signify a lack of opportunities for employees to develop their environmental knowledge, as such training is not widely available within their respective organizations. The findings of numerous studies underscore the imperative for managerial engagement in green learning activities, a factor that has been demonstrated to foster an enhancement in employees' pro-environmental awareness and behavior. This recommendation by the study's authors underscores the significance of incorporating environmental training into the professional development of employees. We investigated the extent to which green human resource management is implemented in Slovakia, but the results indicate that just under half of businesses have green human resource management in place. This is a limitation of our research. The issue necessitates a systematic investigation, with a focus on systemic solutions that organizations can implement to enhance environment promotion awareness and behavior among employees, drawing upon exemplary practices.

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SUSTAINABLE OPEN INNOVATION INTERACTIONS IN INDUSTRIAL SECTOR PARTNERSHIPS*

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Abstract. The adoption of open innovation (OI) practices emerges as a key catalyst for sustainable innovation, generating multiple organizational advantages in industrial sectors. This study examines how OI outcomes derive from the configurational effects of interconnected OI interactions. Through fuzzy-set qualitative comparative analysis (fsQCA) examining 48 European innovation partnerships in industrial sectors, the research identifies two distinct configurational pathways to achieve elevated sustainable innovation output: the Broad approach and Platform-targeted approach. Conversely, two configurations result in low innovation output: the Isolated and Platform-missing approaches. The study establishes that platform and complex systems engagement represents a fundamental condition for high sustainable OI output - though insufficient in isolation, the results suggest its robust connection with sustainable open innovation. The findings establish that OI outcomes depend on interaction configuration effects and present a framework for analyzing pathways to enhance OI effectiveness in industrial sectors. Additionally, the paper provides managerial guidance for optimizing sustainable innovation outputs based on distinct OI interaction strategies.

Keywords: green technology adoption; fuzzy-set qualitative comparative analysis; sustainable open innovation; innovation outcomes; industrial sectors

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JEL Classifications: O36, L26, Q55

1. Introduction

The transition towards sustainable industrial practices is a pressing challenge in the face of accelerating climate change and environmental degradation. The adoption of open innovation (OI) practices is argued to be a driving force of green/sustainable innovation, providing multiple organizational advantages (McGahan et al., 2021), but also enabling industries to develop eco-friendly technologies, reduce carbon footprints, and enhance circular economy practices (Urbinati et al., 2023). Organizations can enhance their sustainability practices and innovation processes through OI implementation, enabling them to maintain competitive advantage and technological currency (Obradovic et al., 2021). Though concepts linking openness with sustainability have emerged recently, such as "sustainable open innovation" (Bigliardi et al., 2020; Bogers et al., 2020), Kimpimäki et al. (2022) note that thorough investigation of this research domain remains limited. This study addresses this gap by exploring the role of OI interaction pathways in climate-resilient industrial practices. Organizations can pursue global sustainability objectives while maintaining market competitiveness by implementing OI within

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environmental contexts. This makes the topic particularly relevant for both organizational leadership and policy stakeholders across industrial sectors.

OI interactions consist of inbound, outbound, and coupled processes that reflect diverse organizational functions and relationships (Bogers et al., 2017; Audretsch & Belitski, 2023). They manifest through various channels including academia-industry collaborations, user innovation, crowdsourcing, licensing, and open data utilization (Beck et al., 2022). Throughout this paper, the term "interaction channels" is used to refer to the specific mechanisms through which organizations engage in OI activities. These channels serve as conduits for knowledge flow and collaborative innovation efforts between an organization and its external environment. Configurations, in contrast, refer to the particular combinations of these interaction channels that organizations implement in their OI strategies. These interaction channels (in different configurations) aim to create an environment conducive to innovation success. Platform-based systems, crowdsourcing communities, and open data represent key constructs for network-level research (Bogers et al., 2017), with channel selection contingent on industry specifications and needs. The decision to choose particular channels is influenced also by partnership characteristics and stakeholder preferences. These interaction channels facilitate sustainable business models and technological advancement, enabling organizations to maintain competitiveness (Obradovic et al., 2021). The OI - sustainability relationship is complex and multifaceted, spanning multiple industries and research domains. While interaction channels for promoting sustainability may vary, evidence indicates that OI practices effectively drive sustainable innovation and environmental solutions (Milana & Ulrich, 2022).

Current OI research emphasizes sustainability, although studies primarily examine individual interaction channels'' effects on organizational performance (Ogink et al., 2023). This singular focus fails to capture the complex interplay of factors influencing environment-related innovation. Regional variations in OI implementation, sustainability development, and resource distribution require an understanding of how multiple interaction channels collectively shape innovation outcomes to develop effective, sustainable innovation strategies. Simple cause-effect analysis proves insufficient for comprehending the mechanisms driving sustainable OI results. While previous studies have acknowledged the importance of various interaction channels in OI, there is a lack of comprehensive analysis on how different configurations of these channels impact green innovation outcomes. Understanding how these configurations affect the degree of innovation—incremental versus radical—could yield insights into optimizing collaboration strategies for enhanced sustainable innovation outputs.

Furthermore, research has indicated that the connection between green process innovation and effectiveness may be non-linear, yet this aspect has not been thoroughly investigated within the context of OI. Specifically, how varying levels of engagement in OI influence the outcomes associated with sustainable innovations remains unclear. This gap suggests a need for studies that explore potential tipping points or thresholds in OI engagement that lead to significant improvements in sustainable innovation performance. Considering the above, this study investigates the following research question: How do different configurations of open innovation interaction channels influence sustainable innovation output in industrial partnerships?

Through this paper, we develop a framework for configuring OI interactions leading to high (and non-high) green OI output, which facilitates an understanding of the systemic dynamics and multifaceted structure of OI efforts toward green innovation. This research, therefore, contributes to the ongoing discourse on sustainable innovation by highlighting the role of OI in enhancing environmental performance. Given the urgency of climate mitigation and adaptation efforts, understanding the optimal pathways for sustainable open innovation is essential for policymakers, industry leaders, and research institutions working towards a low-carbon future.

2. Theoretical background

Open innovation has gained considerable attention in recent years as a catalyst of sustainable innovation. Bogers et al. (2017) expand on the traditional OI model by introducing the concept of Sustainable Open Innovation, which integrates sustainability objectives into the OI framework. This approach emphasizes that innovation efforts should not only focus on economic gains but also consider mental impacts. OI facilitates a dynamic

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innovation process by breaking down organizational silos and fostering collective intelligence, allowing companies to accelerate growth and tackle complex challenges more effectively, facilitating collaboration that is essential for addressing environmental challenges. This decentralized approach to innovation is especially valuable for fostering green technologies and sustainable practices. The integration of OI into sustainable practices has been recognized as vital for organizations aiming to enhance their environmental performance. By leveraging external collaborations—such as partnerships with stakeholders, crowdsourcing, and co-creation—companies can develop innovative solutions that address sustainability issues more effectively (Strazzullo et al., 2025). In the green innovation context, ecosystems are therefore crucial for pooling diverse expertise and technologies to tackle multifaceted environmental issues.

In this paper, we build upon the research of McPhillips et al. (2024), which highlights the various interaction channels in OI, such as platforms, technology transfer, crowdsourcing, user engagement, and external knowledge sourcing, all of which play a pivotal role in advancing sustainability goals. These channels enable firms to leverage diverse sources of knowledge, increasing their capacity for green innovation. External knowledge sourcing is one of the most widely studied OI interaction channels. It involves collaborations between universities, industries, and other organizations to exchange knowledge and spur innovation (Radziwon & Bogers, 2019). These collaborations not only lead to the successful development of sustainable products but also create opportunities for dealing with global challenges, including energy constraints. External knowledge sharing is critical in industries with fast-paced innovation cycles, as it allows firms to stay competitive while contributing to sustainable development. Platforms have become essential for firms engaging in OI, offering a structured means to integrate external knowledge and foster collaboration. These digital ecosystems facilitate the co-creation of innovation by connecting diverse stakeholders, including users, developers, and external organizations, allowing them to share knowledge and resources more efficiently (Cenamor & Fris-Hammar, 2021). Platforms offer modularity and interoperability, enabling organizations to scale their innovation efforts while maintaining control over intellectual property (Gawer & Cusumano, 2014). This modular approach is especially beneficial for sustainability initiatives, where innovation often requires collaboration across sectors to address environmental challenges. Digital platforms enable firms to build and manage collaborative networks that can accelerate the development of environmentally friendly products and processes (Obradovic et al., 2021). These platforms often incorporate features such as open data sharing, which supports sustainable innovation by giving access to valuable environmental information that can be used in the design of greener technologies (Bertello et al., 2024). Additionally, platform-based systems can support sustainability by facilitating the integration of circular economy practices, enabling firms to develop innovations that minimize waste and promote resource efficiency (Urbinati et al., 2023).

Technology transfer is another key OI interaction channel that accelerates the development of sustainable innovations. Gawer & Cusumano (2014) discuss the role of technology transfer in enabling firms to access and apply cutting-edge technologies, which is particularly important for sustainability-oriented projects. However, challenges such as intellectual property concerns and knowledge leakages often hinder technology transfer efforts. Despite these obstacles, technology transfer remains crucial for sustainable innovation, as it helps organizations capitalize on new technologies while maintaining their competitive advantage (Fernandes et al., 2021). Crowdsourcing, another significant OI channel, taps into the collective intelligence of a broad audience to generate ideas and solutions. This approach is especially valuable for sustainable innovation, allowing firms to gather diverse perspectives on environmental challenges. Literature highlights the role of crowdsourcing in generating funding for environmentally sustainable projects (Testa et al., 2023). The integration of crowdsourcing in OI partnerships facilitates the development of more inclusive and impactful sustainable innovations.

Overall, the literature supports the idea that different OI interaction channels play a crucial role in driving sustainable innovation. However, the effectiveness of these channels depends on the collaboration mechanisms in place, including cross-sector partnerships and stakeholder engagement (Mcphillips et al., 2024). The complexity of managing diverse stakeholder expectations and the risks associated with intellectual property remain significant challenges. Nonetheless, orchestrating OI interaction could provide a strategic framework for organizations aiming to integrate sustainability into their innovation processes and address pressing global environmental issues. On the other side, some researchers explore the "dark side" of openness (Dahlander et al.,

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2021), discussing how excessive openness can lead to issues such as knowledge leakage and loss of control over innovation processes. This perspective provides an interesting lens through which to view our fsQCA results, particularly the absence of certain OI practices in some sufficient configurations. It suggests that organizations may need to adopt a selective approach to OI, carefully balancing the benefits of external collaboration with the need to protect core competencies and intellectual property.

In the context of OI targeting sustainable solutions, Resource-Based View (RBV) framework highlights the significance of strategically managing valuable, inimitable, and non-substitutable resources (Barney et al., 2010; Marzi et al., 2023). OI interactions serve as valuable resources by creating synergies that enable firms to innovate and respond to environmental challenges effectively. However, their true potential is realized when combined with inimitable resources, such as organizational culture, specialized knowledge, or unique stakeholder relationships. The non-substitutability of these assets ensures that firms can maintain their competitive edge even as market conditions evolve. This study integrates RBV into the analysis of OI interactions, exploring how the interplay of these resource gateways contributes to achieving high (or low) levels of green innovation output.

Research on innovation interactions, particularly in the context of OI and green solutions, has traditionally relied on linear models and regression analyses. However, the fsQCA methodology offers a robust alternative that is particularly suited for addressing the complexities inherent in these interactions. FsQCA is designed to handle causal complexity by recognizing that multiple conditions can lead to the same outcome (equifinality). This means that different combinations of factors can result in similar levels of innovation output, making it ideal for studying OI interactions where various elements contribute to success. This is particularly relevant in green solutions, where diverse technological, organizational, and environmental factors interplay. By integrating qualitative insights with quantitative rigour, fsQCA enables a nuanced analysis that captures both the richness of qualitative data and the systematic nature of quantitative methods. This duality facilitates a deeper exploration of how specific conditions combine to foster innovation (Pappas et al., 2021).

3. Methodology and research design

3.1 FsQCA analysis

To address the research question of evaluating different configurations of the influence of OI interaction channels on sustainable innovation output, we employ fuzzy-set qualitative comparative analysis (fsQCA) to examine 48 European industrial partnerships. FsQCA is a confirmatory method using set theory and fuzzy algebra (Ragin, 2008). The method presumes that causal variables (conditions) function interdependently, allowing for the identification of diverse yet equally valid routes to achieve identical outcomes (Fiss, 2011; Douglas et al., 2020; Pappas et al., 2021). Through case comparison, researchers can identify logical relationships between variable patterns and results (Rihoux & Lobe, 2009). Using fsQCA 3.0 software to analyze multiple conditions' synergy involves three phases. Phase one is variable calibration: Assigning set membership to cases. Phase two is a necessity analysis: using Boolean algebra for consistency and coverage calculations. Consistency shows the importance and determines configuration consideration. Coverage indicates configuration significance (Ragin, 2008). Conditions with consistency ≥0.9 are necessary.
The consistency formula is (Eq.1):

$$Consistency(\mathrm{X_i} \geq \mathrm{Y_i}) = \frac{\sum[\min(\mathrm{X_i}, \mathrm{Y_i})]}{\sum(\mathrm{Y_i})} \quad \text{(Eq.1)}$$

The coverage formula is (Eq.2):

$$Coverage(\mathrm{X_i} \geq \mathrm{Y_i}) = \frac{\sum[\min(\mathrm{X_i}, \mathrm{Y_i})]}{\sum(\mathrm{X_i})} \quad \text{(Eq.2):}$$

Where X_i is the calibrated antecedent condition, Yi is the calibrated result condition for unit i.

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The third phase is a sufficiency analysis; it reveals sufficient condition combinations for results. First, truth tables show if cases with specific condition combinations lead to the same outcomes (Hartmann et al., 2022). Truth tables display all logical configurations between causal conditions. Second, tables are reduced using frequency threshold (in our study 2) (Schneider & Wagemann, 2012) and consistency threshold (in our study 0.8). Finally, Boolean minimization and Quine-McCluskey algorithm determine configurations. Consistency and coverage indices for adequacy analysis are defined as follows (Eq.3 and Eq.4):

$$Consistency(X_i \leq Y_i) = \frac{\sum[\min(X_i, Y_i)]}{\sum(X_i)}$$

$$Coverage(X_i \leq Y_i) = \frac{\sum[\min(X_i, Y_i)]}{\sum(Y_i)} \quad \text{(Eq.3, Eq.4)}$$

Where X_i is the calibrated antecedent condition, Yi is the calibrated result for unit i.

3.2 Sample

The fsQCA analysis was applied to European OI partnerships in industrial sectors to uncover the OI interaction channel combinations that lead to high (or low) innovation outputs regarding sustainable solutions. We employed a multi-stage sampling strategy to ensure a robust and representative sample of European OI partnerships. We first identified a preliminary pool of 110 partnerships from publicly available databases (e.g., EU-funded project directories, industry association listings, and national R&D registers). These partnerships were screened based on the following criteria: (a) multi-partner, R&D-oriented collaborations; (b) involvement of at least one research institution; (c) establishment beyond the initial formation stage, ensuring at least one year of collaborative activity; and (d) a stated objective focusing on green or sustainable innovation. Applying these criteria yielded 48 qualified cases. Our sample meets the recommended minimum ratio of 2 cases per condition for 6 conditions (Marx, 2010). While a larger sample would be ideal, our current sample size is sufficient for exploratory fsQCA analysis. To ensure data quality and reliability, we collected information through multiple sources: questionnaires, semi-structured interviews with partnership coordinators, internal project documents (e.g., meeting notes, technical reports), public deliverables, patent databases, and government R&D records. This mixed-method approach enabled triangulation, reducing the risk of measurement error and increasing confidence in our dataset.

The analysis was based on a model that considered six potential conditions representing interaction channels in an OI partnership (McPhillips et al., 2024): sourcing external knowledge (ExterKnowl), technology transfer (TechTrans), platforms and complex systems (PlatfAndComplSys), user-driven activity (UserDriv), crowdsourcing (Crowdsour) and utilizing Open data (OpenData). Only interaction channels that demonstrated theoretical connection with existing literature, as explored in empirical OI studies and confirmed by the initial background, were included in this analysis. Each construct was defined and aggregated, based on the foundation of extant literature on OI partnerships.

Given the requirement of an outcome measure for fsQCA, our research aimed to evaluate the impact of the six interaction channels as conditions for the success of OI output. We adopted the definition of innovation output (Bacon & Williams, 2022), which refers to "active interaction between organizations, leading to measurable and effective application by the recipient organization." Such an approach enables us to compare diverse cases across industrial sectors and geographical locations in OI collaboration, focusing on innovation performance (Audretsch & Belitski, 2023). In our article, we focus primarily on OI processes with a higher level of impact on the innovation output, dealing with complex, multi-sided problems that require the integration of diverse knowledge domains (Ooms & Piepenbrink, 2021). Such processes facilitate radical innovation and are not limited to the bounds of an individual partner, making OI essential in addressing these challenges. In contrast, we define not-high innovation output as incremental innovation, which is typically constricted by the product's structure (e.g., modularity) and does not involve revolutionary solutions. To distinguish "high innovation output" from "not-high innovation output," we established data-driven thresholds: cases in the top quartile of

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the composite innovation score were coded as high, while those in the bottom half were coded as not-high. The fsQCA allowed us to compare and contrast these outcome sets. The reported solution coverage and consistency measures (e.g., coverage exceeding 0.85 and consistency often above 0.80 in complex solutions) reinforce that the outcome calibration effectively discriminates between higher and lower-performing OI collaborations.

Each OI interaction condition—Sourcing of External Knowledge, Technology Transfer, Platforms and Complex Systems, User-Driven Activity, Crowdsourcing, and Open Data—was operationalized with reference to validated scales from prior open innovation research. We developed a structured questionnaire with Likert items, where higher scores signified greater intensity of involvement in the respective OI activities. Before fielding the questionnaire, a pilot study was conducted with five industry managers and two academic experts to refine item wording and ensure conceptual clarity. We evaluated scale reliability using Cronbach's alpha and found values above 0.70 for all constructs, indicating acceptable internal consistency. Confirmatory factor analysis further supported the discriminant and convergent validity of the operationalization. These steps ensured that the conditions used in fsQCA were grounded in sound measurement principles. Descriptive statistics were used to indicate that the six conditions in the model vary across cases, with ExterKnowl having the highest mean and Crowdsour having the highest standard deviation. The results, therefore, highlight the variability of the conditions across cases. An assessment of individual condition necessity was performed prior to analyzing their influence on outcomes, demonstrating the complexity of the OI process.

This study employed direct calibration to translate the Likert-scale measures into membership values that span from 0, indicating complete non-membership, to 1, representing full membership in the set. Drawing on established guidelines (Fiss, 2011) and expert feedback from the pilot phase, we set the full membership at the upper end of the observed distribution (approximately the 95th percentile), the set's full non-membership threshold near the lower end (approximately the 5th percentile), and a cross-over point (0.5) reflecting the qualitative midpoint. We performed sensitivity checks by slightly adjusting these calibration thresholds to verify that the solution patterns remained stable. The high consistency and coverage values for both high and not-high innovation output solutions indicated that these calibration decisions were robust. For instance, the identified parsimonious and complex solutions consistently demonstrated solution coverage above 0.77 and solution consistency values around or above 0.75, confirming the reliability of the chosen calibration benchmarks.

Following calibration, we constructed truth tables by listing all configurations of the six OI interaction conditions and assigning cases to each configuration according to their fuzzy-set memberships. We applied a frequency threshold of two cases per configuration to ensure that the patterns identified were empirically grounded. Consistency thresholds were selected to strike a balance between stringent selection of configurations and retaining meaningful patterns. The reported solutions—both complex and parsimonious—exhibited high coverage and acceptable consistency values, indicating that the identified causal configurations reliably explain the presence or absence of high innovation output. Robustness checks, including adjusting calibration thresholds and removing borderline cases, confirmed that the identified core conditions remained stable. This internal consistency across analytic variations bolsters the credibility of our findings.

4. Results

The conditional configuration results reveal paths explaining both high and low OI output levels, with each column representing a possible configuration. For high OI output, the four configuration conditions show 0.939 solution consistency, meaning 93.9% of cases meeting these configurations demonstrate high OI output levels. The solution coverage of 0.779 indicates these configurations explain 77.9% of high OI cases. Similarly, for low OI output level configurations, solution consistency is 0.963, with solution coverage of 0.824. Both solutions' consistency and coverage exceed critical threshold, confirming the empirical analysis's validity.

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Table 1. Configuration result of OI output levels

Conditions	High level of OI output				Low level of OI output			
	H1	H2	H3	H4	L1	L2	L3	L4
ExterKnowl	•	•	•	Ø	•	•	Ø	•
TechTrans	•		Ø	Ø	Ø	Ø	•	•
PlatfAndComplSys	•	•	•	•		Ø	Ø	Ø
UserDriv	•	•	Ø	Ø	Ø			Ø
Crowdsour		•	Ø	Ø	Ø	Ø	Ø	Ø
OpenData	Ø	•	Ø	•	Ø	Ø	Ø	•
consistency	0.928	0.932	0.966	0.907	0.948	0.929	0.966	0.998
raw coverage	0.432	0.346	0.197	0.245	0.567	0.412	0.331	0.268
unique coverage	0.174	0.138	0.038	0.147	0.048	0.097	0.065	0.095
solution coverage	0.779				0.824			
solution consistency	0.939				0.963			

In data tables: "•" shows condition is present; "Ø" shows condition is absent; blank spaces indicate "do not care" conditions (irrelevant to outcome).

We categorized the four high-level OI output paths into two categories (Table 1):
- Broad approach to OI interactions (paths H1 and H2) indicates engagement in multiple OI interaction channels, which may be particularly important for high technology and science-based sectors that greatly rely on such input. Therefore, OI-implementing companies in these sectors should formulate approaches that capitalize on the exchange of knowledge, encompassing both the inflow and outflow of insights within these knowledge-rich ecosystems.
- Platform targeted approach (paths H3 and H4) encompasses two variations that similarly result in high levels of innovation output. These two share the condition connected to using platforms and complex systems and only differ in the presence of one other channel of OI interaction (sourcing of external knowledge or utilizing open data). The proposed solutions imply that, in many cases, it's important to organize OI efforts around using platforms and complex systems, but it may be beneficial to limit the engagement in many other interactions and thus optimize resource and time allocation.

We categorized the four low-level OI output paths into two categories (Table 1):
- Isolated approach (paths L1, L2, L3) indicates engagement in only one of OI interaction channels, which seems not enough to yield high OI output.
- Platform missing approach (path L4) makes it apparent that engaging in multiple Oi interaction channels but without including the platforms and complex systems may result in low level of OI outputs.

5. Discussion

Our fsQCA findings highlight that multiple configurations of OI interaction conditions can lead to similar outcomes (causal asymmetry). The nuanced configurations reflected in the complex, intermediate, and parsimonious solutions demonstrate that no single OI practice is universally effective—rather, effectiveness depends on a tailored combination of conditions. For example, the presence of Platforms and Complex Systems emerged repeatedly as a central condition in configurations tied to high innovation output, showing strong coverage and consistency in the identified solutions. In contrast, the absence of platforms and certain OI activities characterized not-high innovation output solutions. For instance, "Platform-Missing" pathways demonstrate that interaction channels such as external knowledge sourcing and user-driven innovation often fail to achieve synergy without a centralized coordinating mechanism. The findings suggest that the inefficacy of such pathways lies in fragmented resource utilization and insufficient collaboration. Organizations can address these shortcomings by adopting modular platform designs that allow gradual integration of interaction channels, ultimately transitioning toward higher output configurations. In an expanding trend, numerous industries are structuring their operations around core platforms, which are further accompanied and complemented by networks or constellations of partner organizations. In the present-day landscape, the influence of digital transformation has further intensified the adoption of platform-centric approaches (Bogers et al., 2017). Hence, platformization emerges as a crucial facilitator for OI by simplifying the onboarding and collaboration of diverse

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new participants. It also seems to serve as a pertinent variable influencing the efficiency of OI toward green solutions.

Additional sources used for the triangulation of the research show that in the studied cases, platforms seem to act as hubs that centralize diverse interaction channels: enable organizations to source and share knowledge efficiently across boundaries, leveraging external expertise; facilitate the collection and integration of ideas from external contributors like customers, researchers, or the public; offer structured mechanisms for capturing user feedback and co-creating solutions. This centralized integration reduces inefficiencies and creates synergies between interaction channels, amplifying their collective impact on innovation. Moreover, platforms inherently foster scalability through network effects: as more users and partners engage, the value of the platform grows exponentially, leading to richer interactions and more robust innovation ecosystems. For example, a platform connecting multiple organizations can exponentially increase the diversity of knowledge inputs, which is an important driver of radical innovation. Platforms also enable seamless coordination among multiple stakeholders: streamline the management of complex, multi-partner projects by offering shared tools and workflows, optimize resource distribution, ensuring that inputs like data, funding, and expertise are directed where they are most needed, act as orchestrators, aligning the goals of various participants and fostering collaboration. This capability is especially critical in large-scale partnerships involving diverse sectors, as seen in green innovation efforts. Platforms are often digital, leveraging advanced technologies like data analytics and artificial intelligence to: extract actionable insights from large datasets, facilitate real-time decision-making based on user behavior, market trends, and environmental conditions. Platforms often reduce costs and simplify access to shared resources, including intellectual property, technical expertise, and funding opportunities. Empirical evidence from fsQCA analysis serves as the backbone of high-performing innovation systems, not only enhancing the effectiveness of existing innovation efforts but also unlocking new possibilities for radically sustainable solutions. Their role in green innovation is particularly pronounced, as they bridge the gaps between diverse stakeholders and ensure efficient use of resources. The study analysis underlines their necessity but also their insufficiency when isolated. Moreover, while platforms are presented as critical enablers of green innovation, there are potential challenges, such as high costs of implementation, dependency risks, and privacy concerns. SMEs, for instance, may face barriers to adopting platforms due to limited financial and technical resources. Future research should explore modular platform designs or shared ecosystems to reduce costs and encourage broader participation. Governance frameworks to ensure data security and equitable access could further mitigate risks.

The rest of the conditions, namely sourcing of external knowledge (ExterKnowl), engaging in technology transfer (TechTrans), user-driven activity (UserDriv), utilizing open data (OpenData) and crowdsourcing (Crowdsour), are of a much less significance and in some cases engagement in those interaction channels without utilizing platforms and complex systems (PlatfAndComplSys) might lead to lower levels of innovation output. These findings are noteworthy as they underscore the significance of strategizing the OI effort. They reveal that, even at elevated levels of a specific channel of OI interaction, low innovation outputs can be obtained when crucial conditions are lacking (Marzi et al., 2023). It has to be noted, however, that despite evidence of the contribution of singular OI interaction channels to OI performance, decision-makers often underestimate the share of each contribution as a source of innovation and that error can have severe consequences for firms' competitiveness and innovation policies.

These results indicate that the configurations of OI interaction channels can differ in their capacity to efficiently and effectively coordinate resources within specific OI partnerships. Embracing the somewhat risky adoption of OI interaction pathways compels organizations to make present commitments and resource allocations, even when the outcomes may be realized in the long term (Bigliardi et al., 2020). Organizations engaging in OI partnerships must remember that utilizing an effective interaction channel is not enough. Seizing the effect of organizational learning on innovative behaviour typically involves the combined evaluation of different factors that include the support of managers and boundary-spanning leadership, employee training, promoting experimentation, fostering risk-taking, and cultivating an attitude that values self-efficacy (Obradovic et al., 2021; Ogink et al., 2023).

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This study draws on RBV to explore how organizations combine and utilize interaction channels as competitive resources to drive green innovation. When applied to sustainable OI, RBV highlights that interaction channels like platforms, external knowledge sourcing, and user-driven activities serve as strategic resources that enhance an organization's innovation capabilities. These channels enable access to diverse know-how bases, cutting-edge technologies, and collaborative possibilities that would otherwise remain inaccessible. By strategically configuring these resources, firms can optimize their innovation outputs and align them with sustainability goals (Marzi et al., 2023). The findings underscore the importance of RBV's dimensions in driving high levels of green innovation output, ultimately contributing to both academic literature and practical strategies for sustainable OI. Platforms and complex systems emerged as central elements in successful configurations, serving as valuable resources facilitating knowledge exchange and co-creation among stakeholders. Non-substitutability was evident in cases where alternative resources failed to match the functionality or impact of the existing configurations, reinforcing the necessity of strategically managing unique assets within OI ecosystems.

From a method perspective, while some configurations show low unique coverage, they still contribute to explaining the outcome in combination with other conditions. For instance, configuration H3 has a unique coverage of 0.038, indicating that while it explains a small portion of the outcome by itself, it's part of a larger explanatory model when combined with other configurations. By reporting the specific coverage and consistency values associated with each configuration, we underscore the reliability and explanatory power of these patterns. Recent studies confirm that there are multiple configurations or "causal recipes" that facilitate high levels of green innovation. Our fsQCA analysis identifies combinations like high external knowledge sourcing, platform use, and user engagement as significant drivers. This reflects findings in sustainability research, highlighting that firms often combine different strategies based on their specific resources and market conditions to achieve green innovation (Borah et al., 2023).

Conclusions

This study set out to explore how different OI interaction configurations shape sustainable innovation outcomes. By applying fsQCA, we identified multiple pathways leading to both high and low innovation outputs, addressing our research question: "How do different configurations of open innovation interaction channels influence sustainable innovation output in industrial partnerships?" The findings underline that the role of using platforms and complex systems holds specific significance as it is a common factor in both types of engagement, leading to high OI output. Even though this OI interaction channel is not sufficient to on its own generate high OI output for green solutions, the results suggest a more robust connection with green open OI than what previous empirical work had presumed.

Organizations implementing OI maintain competitive advantages over those using closed innovation systems. Research and practice demonstrate OI's positive contribution to sustainability outcomes, though establishing and leveraging various interaction channels remains challenging. The sustainability context introduces additional complexities to OI processes, with each partnership developing distinct pathways toward sustainability goals (Bogers et al., 2020; McGahan et al., 2021). By examining the interplay between OI and sustainability-focused innovation, this research extends existing models and introduces a novel approach designed to analyze pathways for enhancing the effectiveness of OI. First, our study emphasizes the configurational effects of OI interactions. Utilizing the fsQCA method, we identify specific conditions under which OI interactions lead to high versus low innovation outputs. This approach is significant as it moves beyond linear models, highlighting the importance of complex condition configurations in achieving successful innovation outcomes (Radziwon & Bogers, 2019; Ogink et al., 2023). Such an analysis not only demonstrates the multifaceted nature of OI but also addresses the issue of causal asymmetry, where different configurations can lead to similar outcomes, underscoring the non-linear relationships that typify OI interactions.

Moreover, the framework proposed in this study deepens the systematic understanding of OI-driven pathways by showing how certain configurations of conditions facilitate the effectiveness of green innovation strategies. This introduces a fresh perspective to OI effectiveness research, as limited knowledge exists regarding the factors contributing to low levels of innovation output amidst extensive OI engagement (Marzi et al., 2023).

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This is particularly important as it provides actionable insights for managers and policymakers looking to optimize OI processes under varying conditions. Managers should prioritize the adoption and integration of platforms that facilitate collaboration across diverse stakeholders. These platforms enable resource pooling, knowledge sharing, and modular innovation, which are essential for tackling complex environmental challenges. The findings highlight that isolated engagement in a single OI interaction channel, or a lack of platform-based collaboration, is insufficient for generating high innovation outputs. Managers should avoid relying exclusively on singular approaches, such as technology transfer or crowdsourcing, and instead adopt a more integrative strategy that combines multiple complementary channels. This study also suggests creating transitional pathways that allow organizations to move from low to high output configurations. Strategies could include phased investments in platform infrastructure, targeted training for stakeholders, or pilot programs to test new interaction channels.

Our findings underline the pivotal role of digital technologies and platforms in shaping OI strategies. Emerging technologies, including artificial intelligence and blockchain, hold transformative potential for enhancing platform capabilities in green innovation. AI-powered platforms can optimize the allocation of resources in real-time, enabling organizations to reduce waste and increase efficiency. Blockchain, on the other hand, ensures transparency and accountability, particularly in sustainable supply chains. For example, platforms leveraging these technologies can facilitate circular economy practices by tracking materials through their lifecycle and enabling their reuse or recycling. Integrating these advancements into platform ecosystems will further strengthen their role in achieving green goals. By analyzing how digital tools facilitate or hinder sustainable OI practices, these findings contribute to the evolving discourse on the digital transformation of both innovation and sustainability processes (Cenamor & Fris-Hammar, 2021).

Platforms can also serve as critical enablers for policy frameworks promoting sustainability. By fostering transparency and traceability, platforms can help organizations monitor compliance with environmental regulations and incentivize sustainable practices. For example, blockchain-enabled platforms can track carbon footprints across supply chains, ensuring adherence to global climate goals. Policies that support platform adoption, such as subsidies for digital infrastructure or mandates for open data sharing, can amplify these benefits, making platforms integral to achieving national and international sustainability targets. SMEs often face challenges in accessing and utilizing platforms. Policymakers could develop programs to reduce these barriers, such as subsidized platform access, technical training, and the creation of shared innovation infrastructures tailored to SMEs and resource-constrained organizations.

In terms of limitations, the study analyzes industrial sectors. A multi-sectoral breakdown would allow researchers to identify best practices and challenges specific to each context. Tailored recommendations for sectors could maximize the applicability of findings and inform more precise strategies for achieving high innovation outputs in green innovation efforts. Similarly, while this study touches on the concept of ecosystems, a deeper integration of ecosystem theory could enrich the analysis. Ecosystem theory provides a lens to understand how platforms orchestrate diverse interaction channels, enabling synergies across organizational boundaries. Embedding these frameworks into future studies would deepen theoretical insights and strengthen the foundation for understanding the role of platforms in sustainable innovation.

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ARTIFICIAL INTELLIGENCE (AI) USE IN BUSINESS: ARTIFICIAL NEURAL NETWORK MODELLING FOR PREDICTING COST, MINIMISING WASTE AND OPTIMISING RESOURCE UTILISATION IN FURNITURE INDUSTRY

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Abstract. The primary objective of this study is to develop a predictive model for estimating the cost of kitchen cabinets prior to the production process by employing artificial neural networks (ANN). The proposed model is structured with five input parameters related to kitchen cabinet specifications, a hidden layer comprising ten neurons, and a single output node representing the predicted cost. The model was trained using the Neural Fitting Tool available in the MATLAB environment. The MATLAB code and the dataset utilised in the study are also provided for reproducibility. Upon completion of the training phase, the model achieved a coefficient of determination (R-value) of 0.9716. Subsequent testing of the model yielded an R-value of 0.9682, indicating a high level of predictive accuracy. Corresponding regression plots are presented and discussed within the study. This approach demonstrates the potential of ANN-based models to improve cost estimation processes in the furniture manufacturing industry. Furthermore, by enabling data-driven decisions prior to production, such models contribute to sustainability efforts by minimising material waste, optimising resource utilisation, and reducing associated carbon emissions. The study also suggests that the methodology can be expanded by training the network with different types of data relevant to other segments of the furniture industry.

Keywords: AI; sustainability; cost; Artificial Neural Network; business; furniture industry; kitchen cabinet

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JEL Classifications: Q56, M11, D24

1. Introduction

Making cost calculations before production takes place provides advantages for businesses in the sector. Today, researchers prefer artificial intelligence-based applications as an alternative to traditional methods of cost calculations. There are different studies in various scientific fields based on artificial intelligence. A growing body of literature examines the use of artificial intelligence (AI) across multiple sectors. AI has found widespread application in diverse domains such as finance, logistics, manufacturing, education and many others (Mugunzva & Manchidi, 2024; Pechová et al., 2024; Dubauskas & Išoraitė, 2025; Mabungela et al., 2025).

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2. Literature Review

To provide a comprehensive perspective on the multifaceted applications of AI, relevant studies are reviewed in the literature review section.

Trstenjak et al. (2025) investigated the integration of AI within the framework of Industry 5.0, focusing on sustainability, ergonomics, and human factors. Their findings indicate that AI positively contributes to the optimisation of workplace conditions. Similarly, Clark et al. (2025) explored AI-based applications in food waste management, demonstrating that AI can effectively monitor and manage waste processes, significantly reducing food waste.

Naghipour et al. (2024) examined the use of AI in agriculture. They found that their AI model achieved an accuracy rate exceeding 90%, underlining its reliability and potential for broad application in the sector. Corrigan and Ikonnikova (2024) highlighted AI's importance in the mining industry, particularly for its role in reducing carbon emissions and operational costs.

Nazarenko et al. (2024) studied the application of AI in the education sector, supported by a European Union project and an innovation centre, aiming to improve educational outcomes. In the automotive industry, Sontag et al. (2023) emphasised the role of AI-based chatbots in customer relationship management, noting that these tools can simulate expert opinions and engage with customers on topics such as design, thereby enhancing customer interactions.

Na et al. (2023) conducted a comparative study on AI adoption in the construction sector, focusing on South Korea and the United Kingdom. Their research offered insights into cross-cultural perceptions and acceptance of AI technologies. Sardar et al. (2023) developed an AI application for maritime trade using an ant colony optimisation algorithm, which they found effective in reducing human error and increasing productivity.

Gupta et al. (2023) conducted a study involving 26 participants using an AI-powered facial recognition model. The study suggested that this technology could benefit the tourism sector by accurately identifying tourists' needs and enhancing personalised services. Ossa-Cardona (2024) proposed the development of an AI-based decision support system for managerial selection in family businesses. Based on the review of 65 academic articles, her study emphasised that such systems can lead to more objective and data-driven decisions.

In addition, Lopes et al. (2020) developed a deep convolutional neural network model to detect wood knots, utilising a dataset of 921 images. Akyüz et al. (2024) applied machine learning techniques to forecast the forest, paper, and printing index values in Borsa Istanbul. Li et al. (2025) investigated the energy intensity of AI in manufacturing firms in China, analysing annual data from 2006 to 2020. Their study concluded with strategic recommendations for energy savings and emission reduction.

Brunello et al. (2025) explored AI trends in the furniture industry, providing insights into both traditional and robotic manufacturing processes. Dirican (2015) addressed the broader implications of AI and robotic processes for the economy and business. Kaplan and Haenlein (2020) discussed both the opportunities and challenges presented by AI technologies.

Mumali (2022) reviewed 99 scientific publications published between 2011 and 2021, focusing on artificial neural networks applied in manufacturing processes. The study concluded that neural network models offer advantages in terms of cost efficiency and sustainability.

Xin (2025) conducted an empirical study on the impact of AI on financial risk, using data from 2010 to 2023. The findings demonstrated that AI can effectively reduce financial risks within institutions. Camacho et al. (2025) examined the role of AI in cybersecurity risk analysis. In contrast to many studies emphasising the positive aspects of AI, Galaz et al. (2021) also discussed potential systemic risks posed by AI, such as complex ecosystems and rapid climate change.

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Baum and Owe (2023) emphasised the necessity of environmental ethics in response to the ethical challenges posed by AI. Several other researchers have explored ethical issues related to AI in various domains: López González et al. (2024) in cybersecurity, Terrones Rodríguez (2022) in sustainability, Savulescu et al. (2024) in medicine, Carillo (2020) in law, Fulmer et al. (2021) in psychology, Jackson et al. (2021) in pathology and laboratory medicine, and Iphofen and Kritikos (2021) in ethical design for digital societies.

Moodaley and Telukdarie (2023) conducted a literature review on AI and sustainability reporting. They emphasised that the intersection of AI and sustainability remains an underexplored area. Their study contributes to the literature by highlighting the significance of AI for advancing sustainability goals. Most studies in the literature focus on the positive contributions of AI in areas such as sustainability, efficiency, and cost reduction.

The common theme across these studies is the contribution of AI-based applications to businesses in terms of sustainability and other operational benefits. In line with this, the present study focuses on modelling kitchen cabinet costs in the furniture manufacturing sector using artificial neural network (ANN) techniques.

The primary objective of this study is to contribute to the extent of research by offering a practical example to estimate the production costs of a business operating in the furniture industry by employing artificial neural networks, a branch of artificial intelligence, prior to the commencement of manufacturing.

Conducting cost estimations before production not only facilitates effective cost management for businesses but also positively impacts sustainability and environmental outcomes.

The findings of this study demonstrate that artificial intelligence contributes to multiple dimensions—both directly and indirectly—benefiting organisational efficiency as well as environmental stewardship. The artificial neural network used in this study is a technique that involves artificial intelligence-based modelling.

3. Methodology

In this study, the dataset outlined in Appendix 1 was developed and analysed using MATLAB software. After importing the data into the model as inputs, an artificial neural network (ANN) was implemented. Mimicking the learning and adaptation mechanisms of human brain neurons, the ANN was trained to accurately model the relationship between input and output variables.

Neural Network Fitting application within the scope of Artificial Neural Networks using MATLAB R2022b version was used to create and solve the model. Kitchen countertop type, countertop type, kitchen cabinet door type, refrigerator slot and pantry are the inputs of the model. The total cost amount constitutes the output of the model. The total cost amount is verified by experts in the field. There are 10 hidden layers in the model. Out of 414 data; 70% of the data was used in the training phase, 15% in the verification of the data and 15% in the testing of the data. The data used in the model are given in Appendix 1. The visual form of the model is in Figure 1. The summary of the model is given in Table 1.

Table 1. Model Summary

Data division	Random
Training algorithm	Levenberg-Marquardt
Performance	Mean Squared Error
Layer Size:	10
Training data observations (%70)	290
Validation data observations (%15)	62
Test data observation (%15)	62

Source: Created by the author

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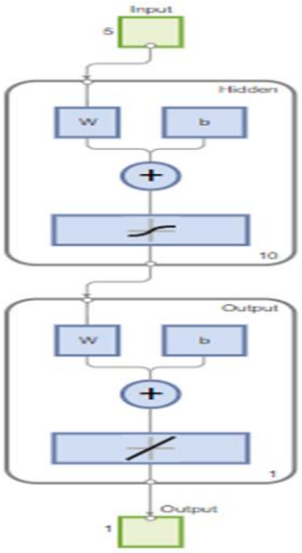


Fig. 1. The Artificial Neural Network Model
Source: Created by the author using MATLAB software

Limitations. In the fictional example presented within the methodology section of this study, the cost estimation model for kitchen cabinets can be further refined and expanded to achieve a more detailed and realistic structure. However, to enhance the model's accuracy and practical applicability, collaboration with expert academicians and professionals specialised in furniture production is deemed essential. This necessity represents one of the primary limitations of the current study.

Moreover, in today's market, where consumer preferences are highly diverse and virtually limitless, personalised production has become increasingly prominent. This trend requires cost estimation models to be adaptable to individual customer needs and product customisations. Consequently, general models must evolve into more flexible systems that accommodate personalised variables.

This study highlights the strategic importance of integrating artificial neural networks into the early stages of production planning, particularly in terms of advancing sustainable manufacturing practices. By enabling predictive cost analysis prior to production, such AI-driven approaches contribute to more efficient resource utilisation, waste reduction, and environmentally conscious decision-making in the furniture industry.

4. Results

When the model created through artificial neural networks for estimating the cost of kitchen cabinets was analysed in MATLAB program, the training results were obtained (see Table 2).

Table 2. Training Results

	Observation	**MSE***	**R****
Training	290	2.2052e+07	0.9716
Validation	62	1.0819e+07	0.9816
Test	62	1.7767e+07	0.9776

Source: Created by the author using MATLAB software
* MSE: Mean Squared Error **R: Correlation coefficient

When the training results in Table 2 are analysed, the regression graphs of the test results are presented in Figure 2 and Figure 3. The best validation performance was realised at the 25th iteration. As a result of training the data, the training R values were above 0.97. This value shows that the model is well-trained. The distribution of the data in the regression graph in Figure 2 reflects the visualisation of the training of the model.

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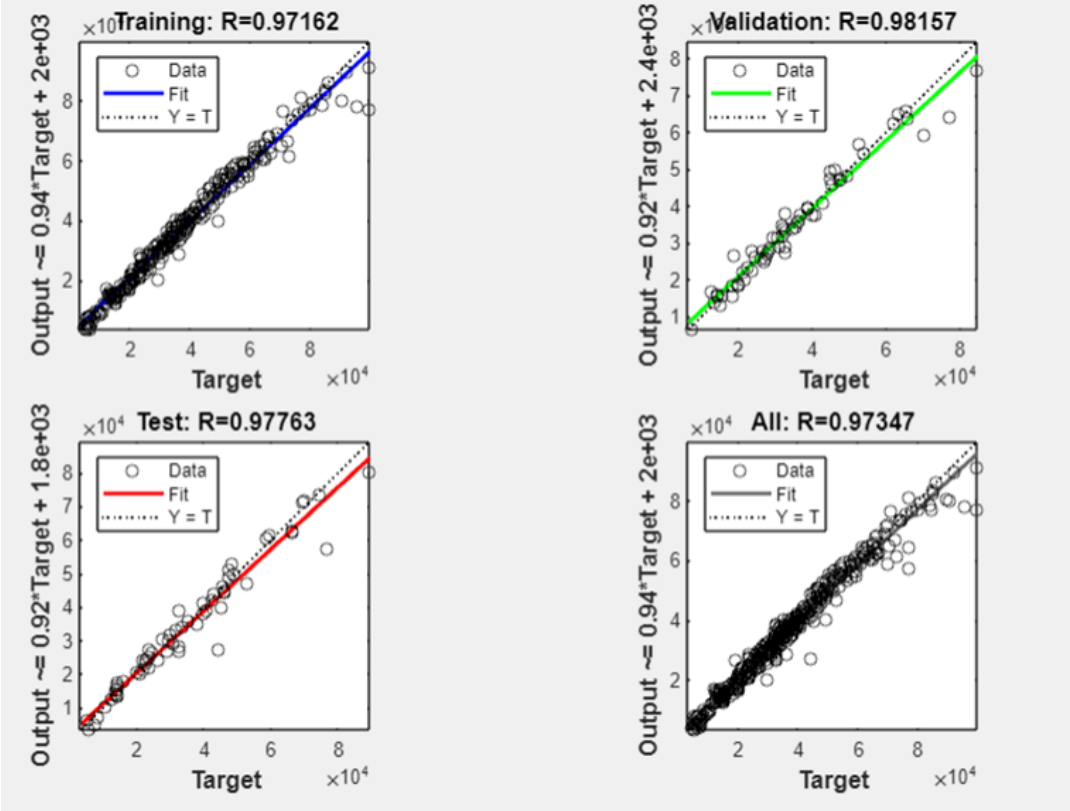


Fig. 2. Training Result Graph
Source: Created by the author using MATLAB software

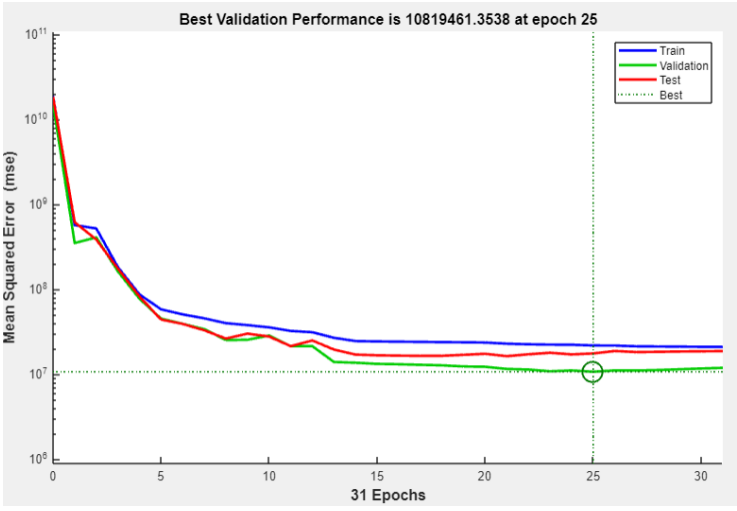


Fig. 3. Training Performance Graph
Source: Created by the author using MATLAB software

MATLAB program codes are available in Appendix 1. After the model training was completed, the relevant model was tested in the MATLAB program Neural Fitting Tools application with 100 data. As a result of the test, the R value was determined as 0.9682. The regression graph of the relevant test result is shown in Figure 4. It shows that the prediction results are highly consistent in the model.

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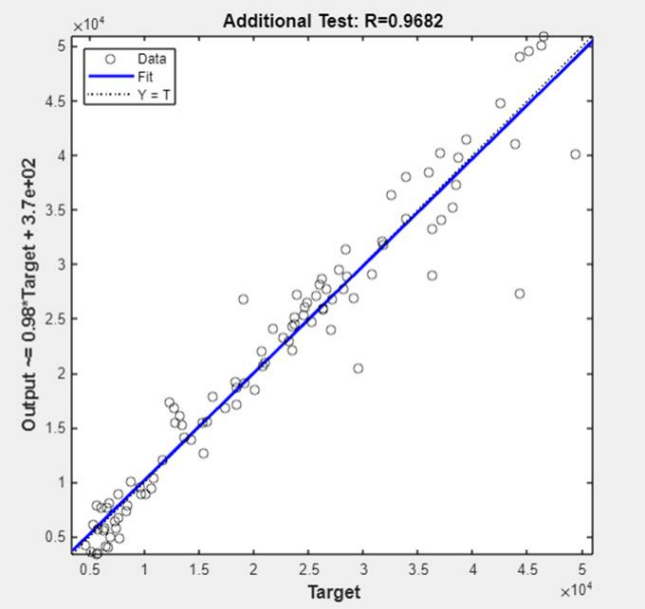


Fig. 4. Additional Test Regression
Source: Created by the author using MATLAB software

In this study, the dataset was constructed and analysed using MATLAB software (see Appendix 1). Once the data were loaded into the model as inputs, the artificial neural network (ANN) was executed. Similar to the learning and adaptation processes of neurons in the human brain, the ANN was trained to achieve the targeted relationship between input and output values. Upon completion of the training phase, the model was tested and demonstrated a high level of consistency, yielding a strong correlation coefficient (R = 0.9682), as illustrated in Figure 4.

Conclusions

In this study, an artificial neural network (ANN) model was developed to estimate the cost of kitchen cabinets prior to the production process. The model utilises five distinct input variables—kitchen model, worktops, cabinet door, refrigerator slot, and pantry—and includes a hidden layer with ten neurons. The output of the model is the predicted total cost. Visual representations of the model architecture and associated regression graphs are included in the study. The MATLAB codes used for model development and training are also provided.

The model achieved a coefficient of determination (R) of 0.9716 during the training phase, demonstrating a high level of fit between predicted and actual values. Following training, the model was tested with independent data, yielding an R value of 0.9682. These results confirm the model's high predictive accuracy and reliability.

Beyond cost estimation, the model offers practical utility in decision-making processes such as profit margin analysis, break-even point calculations, and overall financial planning in furniture manufacturing operations. By enabling accurate pre-production cost assessments, this approach supports improved resource allocation and waste reduction.

From a sustainability perspective, the integration of artificial intelligence (AI) into production planning contributes to more efficient material usage and lower carbon emissions. As highlighted by Vaio et al. (2020) and Enholm (2022), AI-driven tools in industrial applications enhance organisational value while aligning with sustainable development goals (SDGs). The use of predictive modelling in the furniture industry, as demonstrated in this study, represents a meaningful step toward smart manufacturing and sustainability-driven business practices.

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Future research can build upon this model by incorporating additional input parameters or expanding its application to other furniture types. The continued development of AI-based systems in manufacturing will play a critical role in achieving economic and environmental sustainability across the sector. As highlighted in the literature review, the use of artificial intelligence across various sectors today provides significant advantages.

This study emphasises the positive aspects of implementing artificial intelligence within the furniture manufacturing industry. It is posited that industries adapting AI applications while prioritising sustainability within ethical standards are more likely to achieve success.

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Appendix 1. Input and Output Data Table

Input Data A: Kitchen Models* B: Kitchen Worktops** C: Cabinet Door*** D: Refrigerator Slot**** E: Pantry*****					**Output Data** F: Cost (Turkish Liras)	**Input Data** A: Kitchen Models* B: Kitchen Worktops** C: Cabinet Door*** D: Refrigerator Slot**** E: Pantry*****					**Output Data** F: Cost (Turkish Liras)	**Input Data** A: Kitchen Models* B: Kitchen Worktops** C: Cabinet Door*** D: Refrigerator Slot**** E: Pantry*****					**Output Data** F: Cost (Turkish Liras)
A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
1	1	1	2	2	13629	2	1	1	2	2	35920	3	1	1	2	2	20381
1	2	1	2	2	15746	2	2	1	2	2	40154	3	2	1	2	2	23345
1	3	1	2	2	18447	2	3	1	2	2	45556	3	3	1	2	2	27126
1	4	1	2	2	19141	2	4	1	2	2	46943	3	4	1	2	2	28097
1	5	1	2	2	23594	2	5	1	2	2	55849	3	5	1	2	2	34331
1	6	1	2	2	19105	2	6	1	2	2	66872	3	6	1	2	2	42047
1	1	2	2	2	15315	2	1	2	2	2	39569	3	1	2	2	2	22941
1	1	3	2	2	16279	2	1	3	2	2	41654	3	1	3	2	2	24404
1	1	4	2	2	18447	2	1	4	2	2	46345	3	1	4	2	2	27695
1	1	5	2	2	33945	2	1	5	2	2	79877	3	1	5	2	2	51224
1	1	6	2	2	27039	2	1	6	2	2	64935	3	1	6	2	2	40740
1	2	2	2	2	17432	2	2	2	2	2	43803	3	2	2	2	2	25905
1	2	3	2	2	18396	2	2	3	2	2	45888	3	2	3	2	2	27368
1	2	4	2	2	29564	2	2	4	2	2	50579	3	2	4	2	2	30659
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1	2	6	2	2	29156	2	2	6	2	2	69169	3	2	6	2	2	43704
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1	3	3	2	2	21097	2	3	3	2	2	51290	3	3	3	2	2	31149
1	3	4	2	2	23265	2	3	4	2	2	55981	3	3	4	2	2	34441
1	3	5	2	2	38763	2	3	5	2	2	89513	3	3	5	2	2	57969
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1	3	5	1	1	23802	2	3	5	1	1	59586	3	3	5	1	1	40030
1	3	6	1	1	20066	2	3	6	1	1	48945	3	3	6	1	1	32716
1	4	2	1	1	13725	2	4	2	1	1	31296	3	4	2	1	1	20299
1	4	3	1	1	14246	2	4	3	1	1	32781	3	4	3	1	1	21320
1	4	4	1	1	15419	2	4	4	1	1	36121	3	4	4	1	1	23616
1	4	5	1	1	23802	2	4	5	1	1	60002	3	4	5	1	1	40030
1	4	6	1	1	20066	2	4	6	1	1	49361	3	4	6	1	1	32716
1	5	2	1	1	13725	2	5	2	1	1	33968	3	5	2	1	1	20299
1	5	3	1	1	14246	2	5	3	1	1	35452	3	5	3	1	1	21320
1	5	4	1	1	15419	2	5	4	1	1	38793	3	5	4	1	1	23616
1	5	5	1	1	23802	2	5	5	1	1	62674	3	5	5	1	1	40030
1	5	6	1	1	20066	2	5	6	1	1	52033	3	5	6	1	1	32716
1	6	2	1	1	13725	2	6	2	1	1	37275	3	6	2	1	1	20299
1	6	3	1	1	14246	2	6	3	1	1	38759	3	6	3	1	1	21320
1	6	4	1	1	15419	2	6	4	1	1	42100	3	6	4	1	1	23616
1	6	5	1	1	23802	2	6	5	1	1	65981	3	6	5	1	1	40030
1	6	6	1	1	20066	2	6	6	1	1	55340	3	6	6	1	1	32716

* (1): Linear Type (2): Parallel Type (3): L Type
** (1):Chipboard (2):Mdf Lam (3): High-gloss (4):Membrane (5): Solid / Veneer (6): Lacquer
*** (1): Laminate (2): Solid (3):Granit (4): Quartz (5):Marble (6):Corian
****(1): available (2): unavailable
***** (1): available (2): unavailable

Appendix 2. MATLAB Program Code

```
% Solve an Input-Output Fitting problem with a Neural Network
% Script generated by Neural Fitting app
% Created 21-Feb-2025 20:37:25
%
% This script assumes these variables are defined:
%
%   input - input data.
%   output - target data.
x = input;
t = output;
% Choose a Training Function
% For a list of all training functions type: help nntrain
% 'trainlm' is usually fastest.
% 'trainbr' takes longer but may be better for challenging problems.
% 'trainscg' uses less memory. Suitable in low memory situations.
trainFcn = 'trainlm';  % Levenberg-Marquardt backpropagation.
% Create a Fitting Network
hiddenLayerSize = 10;
```

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```
net = fitnet(hiddenLayerSize,trainFcn);
% Setup Division of Data for Training, Validation, Testing
net.divideParam.trainRatio = 70/100;
net.divideParam.valRatio = 15/100;
net.divideParam.testRatio = 15/100;
% Train the Network
[net,tr] = train(net,x,t);
% Test the Network
y = net(x);
e = gsubtract(t,y);
performance = perform(net,t,y)
% View the Network
view(net)
% Plots
% Uncomment these lines to enable various plots.
%figure, plotperform(tr)
%figure, plottrainstate(tr)
%figure, ploterrhist(e)
%figure, plotregression(t,y)
%figure, plotfit(net,x,t)
```

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EDUCATION OF MANAGERS USING MANAGEMENT GAMES IN COMPANIES: A CASE OF SLOVAKIA*

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Abstract. Developing human capital through education and motivation is key to company success in a rapidly evolving business environment. However, only a few studies have dealt with using management games in Central and Eastern European companies, including Slovakia. This article examines the current state of using management games and simulations for manager education in Slovakia, focusing on their adoption by Slovak companies. The research aims to identify which tools and techniques are used by Slovak companies to train managers, specifically looking at the use of management games, the reasons for their adoption or lack thereof, and the perceived benefits. A questionnaire survey was conducted with 300 companies from various competitive sectors, resulting in 60 valid responses. The findings reveal that while a few companies use management games, the overall adoption rate in Slovakia is low, primarily due to a lack of awareness and knowledge of such educational methods. However, companies implementing these games report significant improvements in creativity, problem-solving, communication, and teamwork among managers. The article concludes that while traditional training methods dominate, there is a growing interest and willingness among Slovak companies to invest in more active, experiential learning tools like management games to enhance managerial capabilities. The findings of this study have practical implications for a wide range of fields, such as education, sports management, manufacturing, and services, where they can support efforts to enhance organisational performance.

Keywords: management games; education process; managers; companies; Slovakia

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JEL Classifications: M15, M21, M53

1. Introduction

Every successful company must have educated, motivated employees in today's rapidly developing world. Therefore, companies must invest in their employees and managers' growth and education (Al-Dosari, 2024; Sorensen & Lindholst, 2024).

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For a company, this means that it can expect efficiency and sufficient performance from its employees, which ultimately leads to achieving and fulfilling company goals. Sustainable management is then crucial for both public and private sectors (Fuka & Bat'a, 2022). The competitive advantage for companies in a wide range of activities, from non-profit sectors and sports organisations to manufacturing or service providers, is no longer only machines, technologies, know-how, and innovations but, above all, their people. Human capital is the most valuable asset of a company. Therefore, a company must train and support its human capital, as managers serve as representatives of the organisation, interacting with competitors and all other stakeholders (Varmus et al., 2018).

According to Striteská & Jelínková (2015), the issue of defining performance indicators in the area of employees also remains problematic, even though previous research has shown that one of the most common reasons for performance management is influencing employee behavior, motivation, and remuneration. Motivating individuals to pursue personal growth and education has become increasingly challenging. To address this, companies must embrace innovative and engaging educational strategies that inspire their workforce and deliver lasting impact. One such modern approach, both today and in recent years, involves using management games. These tools allow individuals to test, practice, and enhance their skills in a risk-free environment without disrupting real business operations or processes. Managerial decision-making is becoming increasingly challenging today. An example of this can be the issue of corporate behavior when making decisions about capital structure (Heckenbergerova & Honkova, 2023), questions related to the financial health of the company, financial analysis and its complexity (Kubenka, 2015) and others.

In today's world, it is evident that many modern managers lack practical experience upon graduation. The rising importance of management simulation games underscores the need to incorporate them not only within companies to enhance the education of current managers but also in schools to equip students with practical skills before assuming such demanding roles. Applying theoretical knowledge in practice during school years can serve as a strong foundation for greater success in securing employment. Emerging trends in education highlight the growing adoption of management games in corporate and educational institutions (Bach et al., 2023; Nosková & Jelínková, 2023; Lean et al., 2023; Bach et al., 2025).

This article focuses on the current state of utilising manager games in the educational process for managers in Slovakia.

2. Theoretical background

2.1 The educational process

Education plays an essential role in human development and involves various activities related to the process of education, character development, or discipline of the mind to influence the behaviour of the educated person. Education deals with activities aimed at human learning, imparting knowledge, training ability, and developing skills. It is a framework for formal school education and extends to non-formal and informal learning. Education goes beyond the acquisition of information to include the development and nurturing of critical thinking, as well as creativity, problem-solving, and ethical decision-making skills. Education is acquiring knowledge through study or transferring knowledge through particular instructions or other practical means. It also brings about a natural and permanent change in the abilities of individuals to achieve their goals. The educational process not only fulfils the goals of education, but also has an impact on the overall development of personality, abilities, qualities, attitudes, behaviours, values, etc. (Shevtsova et al., 2024)

Education and the educational process are mostly associated with educational institutions. The importance and influence of educational institutions in the educational process are confirmed. However, education is not only the dominant feature of schools, educational facilities, or specialised institutions but is also becoming an increasingly important part of corporations. In the context of corporate learning, it is a fundamental process for any company aiming to enhance prosperity, maintain competitiveness, and aspire to market leadership. Implementing employee training, education, and employee development serves to achieve a wide range of goals for both employees and the business. Brush et al. (2024) reveal the important role of entrepreneurship educators in the educational process. However, corporate learning is not a short-term effort. Instead, it is a long-term

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process that requires careful implementation in well-defined stages to ensure effectiveness and sustainability. An organisation that seeks to increase its competitiveness is an organisation that can train its employees in the most effective and efficient ways (Brabete et al. 2024). Training and employee development programs thus represent key organisational growth and employee retention tools by increasing job satisfaction and performance. (Gebrehiwot & Elantheraiyan, 2023; Kanuto, 2024) Companies may use various training methods and tools; previous research has shown that these methods improve employee engagement (Alhowaish, 2024).

Education is a structured system of teaching and learning activities to achieve educational goals. Education methods can be either active or passive (traditional) (Kooloos et al., 2019). The primary distinction between these methods lies in employee involvement – whether they actively engage in learning or act as passive recipients of information. Previous research showed that traditional and active learning methods can produce different outcomes, and the most effective is a combination of these approaches. (Yu & Zin, 2023)

2.1.1 Traditional methods of education

Traditional teaching methods are still used in schools, where students mostly listen to the teacher's explanation. The teacher can be seen as an instructor responsible for conducting lectures. Students are considered "objects" that need to be filled with information. Technology's constant development is also changing how information is received today. Traditional teaching methods are gradually being replaced by digitalisation. Traditional methods include lectures, seatwork, listening and observation, and many others.

Lectures are a basic educational method of traditional methods. Lectures are associated with didactic teaching, where we can talk about an authoritative approach, where employees or students are passive. While there is an option to ask questions to the lecturer, the approach is typically one-sided, with information flowing primarily from the lecturer to employees or students. Lecturing is the most effective teaching method (Georgieva, 2022), mainly due to the ability to convey concepts and knowledge and allow them to utilise the human ability to learn from the spoken word.

Another traditional method of learning is mentoring. Companies use mentoring for its benefits; effective mentoring is seen as an avenue for workforce development, skills transfer and continuous training. Mentoring encourages and supports employees' self-development and increases their performance and potential (Chen, 2013). It is described as a slow process, but it can improve the abilities and skills of employees. A relationship between the mentor and the employee must be based on trust and respect. The mentor helps the employee find the right direction, helps him with his career problems, does not provide answers to problems, and shows him ways to work towards the answers. The employee perceives the mentor as a source of information, wisdom, inspiration, and expertise in the given field. A mentor is an individual who has extensive experience and knowledge in a particular field and seeks to help the mentee achieve goals (Sarabipour et al., 2021). A mentor also teaches the employee how to act professionally, treat others, or admit his own mistakes. He also performs various tasks based on the requirements of the employee. A mentor must possess specific competencies, with the key being communication, responsibility, and independence. Additionally, the mentor should be capable of evaluating the employees they are mentoring. Mentors and mentoring are key to stimulating the growth and success of entrepreneurial activities (Yani et al., 2024).

The advantages of traditional methods include obtaining formal education and focusing on specific subjects. Today's technologies are making education more interactive and fun. Therefore, it is also possible to talk about the disadvantages arising from technological advancement. The disadvantages include that traditional methods are limited, focused only on the teacher and his lectures and not on ensuring students have sufficient interaction. Students only obtain information on a theoretical level and are subsequently tested. Since traditional methods have advantages and disadvantages, even with increasing technological progress, it is impossible to talk about completely eliminating these methods. It is necessary to enrich them with active ones (Yu & Zin, 2023).

2.1.2 Active learning methods

Active learning is an approach to education involving employees or students' or students' active involvement in learning through various methods. Great emphasis is placed on the responsibility of each participant in the learning process using an active method (Mondragon et al., 2023). Active learning helps to support thinking

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and analysis and, most importantly, helps to transform their knowledge into practice; this makes students more effective thinkers and better arguers.

Active learning can be defined as any educational activity in which the employee interacts with the learning process, unlike traditional forms where they only receive information. Active learning stimulates the brain, as multiple sensory and neural networks are activated, which helps to process and work with information more effectively. Active learning strategies must be designed to stimulate and engage students' thinking.

The advantages offered by active learning methods include the development of teamwork, communication development, long-term memorisation of information and, above all, they are effective because they require active participation and involvement of all participants. This active participation of students in the learning process is the most critical indicator of success (Verdiyeva, 2021). Many other active learning methods are already widely implemented, whether in companies or schools. Active learning methods include mind maps, role-playing, jigsaw techniques, game-based learning, and virtual classrooms. An active learning method that is currently gaining more and more importance is management games and simulations. (Maurya et al., 2024)

2.2 Management games and simulations

According to Stan (2024), a game cannot be strictly defined, any attempt to define a game is only partial and also requires further explanation, but the game can be analysed. Management games simulate strategic thinking (Ghasemi et al., 2024; Langley, 2024). They facilitate active social interaction among players, creating conditions that closely resemble real-life scenarios. Management games are used to develop managerial abilities, skills, and knowledge. The core of these games lies in creating an environment that closely mirrors real-life situations. In this setting, managers gain valuable experience, enabling them to respond flexibly to various future changes and challenges within companies. They help develop all the qualities of managers. Such a development of experience is very effective because managers learn from practical problem situations, allowing managers to make decisions under pressure (Mohammed et al., 2022).

Management games also support entrepreneurship by developing competencies, creativity, competitiveness, cooperation and communication. They can teach game participants self-control and leadership. Damastuti et al. (2024) cite the challenge of using management games to maintain player engagement over a more extended period. In management games, a referee is used to interpret the rules and evaluate the results achieved based on the alternative solutions proposed by the participants. The essence of the game lies in the discussion, where each team must defend, justify, and critically assess their approaches, as well as the reasons for choosing a particular variant. However, the use of management games has drawbacks from an educational perspective, as players make decisions that are limited by the number of options they can make in the game; some decisions are rewarded more than others (Czauderna & Budke, 2020).

Business simulations offer an interactive learning experience that challenges participants to apply their training in a risk-free environment. These simulations help build specific skills, enhance conceptual knowledge, and allow participants to evaluate different strategies better. As a result, they can lead to an overall improvement in performance. Interpretive simulations, in particular, bridge theoretical learning and real-world experiences, providing a valuable transition from study to practice (Singh-Pillay, 2024).

There are numerous benefits and barriers associated with using management games and simulations. (Almohaini, 2016) the following advantages can be pointed out:

- A large number of participants can be involved, who cooperate in making decisions,
- Learning creates cohesion,
- Abstraction of reality,
- Growth of participants,
- Preparation of students for the real world (when used in schools),
- Rich discussions in teams,
- Creation of good relationships.

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Other reasons or benefits that arise from the use of management games and simulations are (StratXsimulations, 2024):

- Imitation of learning in the workplace,
- Risk-free decision-making,
- Realistic conditions,
- Timing,
- Teamwork,
- The Big Picture means that participants make their own decisions in a team, and their task is to read and analyse information and see the results in the end.

The above shows numerous benefits and compelling reasons for using management games and simulations in companies or schools. It is important to emphasise that this active educational method can effectively prepare future managers for real-world situations they will encounter. When used within companies, it tests and refines the experience and skills of managers and executives, helping them develop the expertise needed to navigate complex challenges in their roles.

Through such an educational process, they can increase their performance, make better decisions, analyse the necessary information more effectively, and reduce the risk of decisions. An active educational method, such as management games and simulations, is suitable for forming future managers and current ones.

So, what methods or tools do current managers in Slovakia use in their education? What is the current state of management games used by companies in Slovakia? Do managers use these games for their further development and education? What specific games do they use? What benefits do they experience when using them? How much do they invest in education through these active methods?

3. Research objective and methodology

The aim of the questionnaire survey, which targeted companies, was to determine what specific tools or techniques are currently used by companies in Slovakia to train their managers. The research focused on whether companies use management games with simulations, why some do not, and conversely, the benefits observed while using this active educational method. The research was conducted in several steps.

In the first step, a basic set of companies needed to be created, consisting of all companies from the Slovak Republic. Given that specific selection criteria were applied, purposive selection was used, meaning companies were carefully chosen based on these criteria. Companies were identified online, primarily through portals that provide information about the financial status of Slovak companies, with the Finstat.sk website being the main source. The companies were selected to meet the established criteria, including the number of employees, annual turnover, and the industry in which they operate.

The target group consisted of companies within the Slovak Republic operating in specific industries, including automotive, mechanical engineering, wholesale, electrical engineering, chemistry and plastics, metal production and metallurgy, IT, and transport and logistics. These companies were selected based on their annual turnover, categorised into two intervals (up to 50 million euros and over 50 million euros) and their number of employees, with two groups (50-249 employees and 250 or more employees). The sectors were selected based on the most competitive industries in Slovakia. The criterion of the number of employees was chosen because larger companies typically have more developed departments, particularly the education department, making them better employers. The annual turnover was selected to ensure that the companies are financially stable, not loss-making, and capable of allocating funds to implement management games and simulations.

After characterising the target group, the second step was determining the sample set. The sample set consisted of 300 companies from the Slovak Republic. It was impossible to confirm whether these companies use management games and simulations as part of their educational methods. These were only preliminary estimates suggesting that these companies may have incorporated such educational tools into the training process for their employees and managers.

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After specifying the sample, it was possible to conduct a primary survey. Before collecting data in the questionnaire survey, a pilot study was carried out on a sample of 10 companies to determine the questions' comprehensibility. The questionnaire survey was conducted from March to June 2020 and was created electronically using the Google form application. It consisted of 16 questions, divided into two sections. The first section aimed to gather information on why certain companies do not use management games and simulations. The second section focused on companies that use them, aiming to identify the observed benefits of these educational methods. The return rate of the questionnaires reached only 20%, i.e. 60 companies were willing to participate in the survey. This is a very low return rate, but certain conclusions can be drawn even with a given return rate.

Respondents/companies that participated in the survey are from the following areas: automotive, electrical engineering, IT, mechanical engineering, chemistry and plastics, transport and logistics, wholesale, metalworking and metallurgy. The most respondents were from the IT sector (29), followed by electrical engineering (8), automotive (7), chemistry and plastics (6), transport and logistics (5), mechanical engineering (4), metalworking (1) and wholesale (0). The highest number of respondents was from the Žilina region (28), from the Bratislava region (15), from the Trenčín region (7), from the Trnava region (4), from Banská Bystrica (2), from Prešov (2) and from Košice and Nitra (1) each came with (1) answer. More than half of the respondents (39) achieved an annual turnover of up to 50 million Euros. The rest of the respondents (19) achieved an annual turnover of over 50 million Euros, and 2 companies did not state an annual turnover. As for the number of employees, more than half of the respondents (32) have 250 or more employees (large company), (28) companies have 50-249 employees (medium-sized company).

4. Analysis and results

A questionnaire survey of Slovak companies revealed that training and workshops are the most commonly used traditional educational methods for training managers. In contrast, the least used methods are lectures and case studies. Respondents selected from four offered specific options: case studies, lectures, training, and workshops. They rated these methods on a scale from 0 to 5, where 0 meant “not used” and 5 meant “most used.” Detailed results are presented in Table 1.

Table 1. Training techniques/methods

Educational methods	0 - they do not use	1	2	3	4	5 - they use the most
Case studies	18	16	4	10	5	7
Lectures	9	14	13	10	7	7
Trainings	4	1	4	11	16	24
Workshops	9	6	6	7	14	18

Source: Authors' own creation

Another option was the “others” option with an open answer. Only 9 of the surveyed companies mentioned other educational methods or specific tools, including:

- E-learning, bar camps, coaching, micro-learning
- Games based on an experiential form for soft skills development
- Personal consultations
- Coaching, mock training, leadership development, rotation programs
- E-learning, language courses, conferences
- Brainstorming sessions
- Self-education for managers
- Webinars, video and traditional conferences, self-study, benchmarking
- Visits to other companies, various courses (aside from regular training)

Based on the findings, companies in Slovakia are relatively selective and deliberate in choosing the training methods they adopt. They also show creativity, as evidenced by a company that trains its managers using the

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form of experiential games. However, these innovative practices are still relatively rare among businesses in Slovakia.

As for modern active education methods, specifically management games and simulations, only 11 out of the 60 surveyed companies use them to educate their managers. Although this is a relatively small number, it is evident that companies are gradually becoming more aware of how to utilise their employees' potential better and improve their education. This reflects the understanding that relying solely on knowledge or expertise from one department is insufficient, especially when employees work in teams on diverse projects. Companies are beginning to see the value of cross-departmental collaboration and broader skill development. With this active method of games/testing themselves, they can also strengthen relationships in the team, improve communication, etc.

Companies recognise several benefits associated with the use of management games and simulations. Those who utilise these tools observe significant improvements in their managers. The following Figure 1 presents that most respondents (11) indicated that their managers are better equipped to handle problem situations and do so more effectively. Additionally, the quality of work, analytical skills, and overall performance show notable improvement. However, companies report the least progress in team dynamics, skill development, communication, and management.

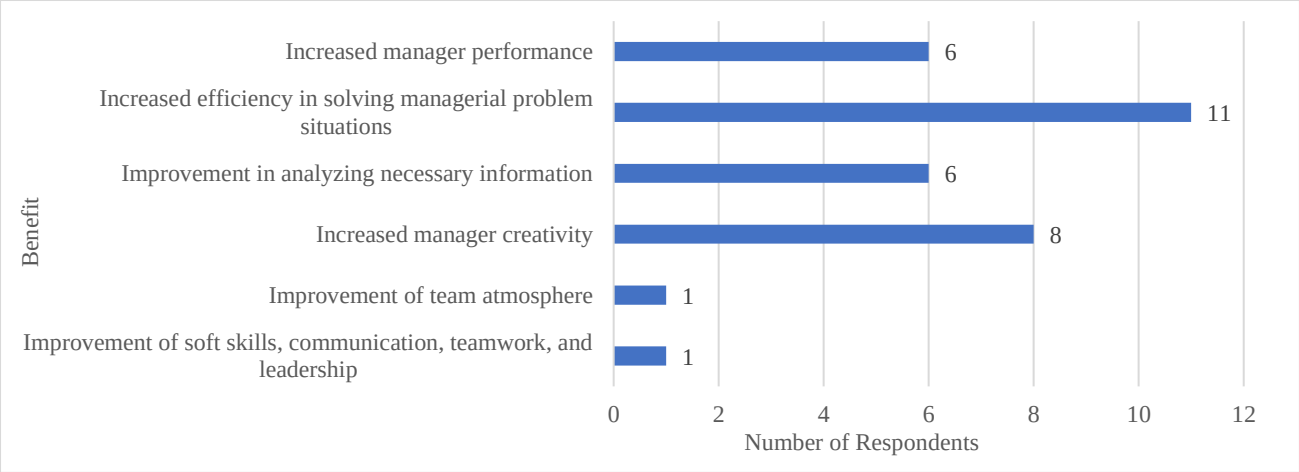


Figure 1. Benefits of using management games and simulations

Source: Authors' own creation

Based on the above data, it is crucial to focus the educational process on management games and simulations that are more comprehensive. These should emphasise teamwork, communication, management, role distribution, and other key areas supporting team collaboration and leadership. The implementation of more comprehensively focused management games and simulation improvements are likely to be seen in the two places where the least progress was reported.

The most frequently cited reasons why companies do not use management games and simulations are presented in Figure 2.

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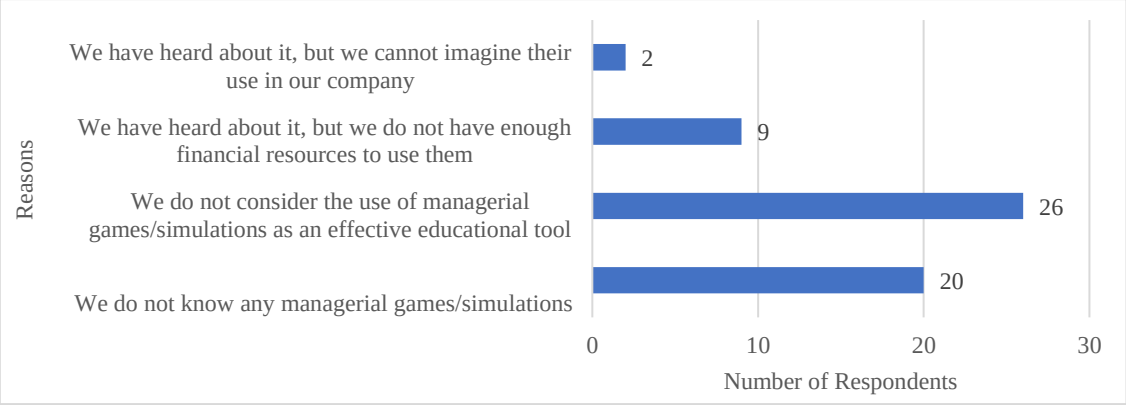


Figure 2. Reasons for not using management games and simulations

Source: Authors' own creation

Almost half of the surveyed companies (26) cannot imagine how they would use the given management game in their company. On the other hand, many companies (20) are still unfamiliar with management games or simulations. Additionally, fewer companies (9) cited a lack of funds as the reason for not using these tools. We can link this to the fact that the company has no reference to the management game (1) and also that the company management does not have time to think about the given training method (1). Another answer (1) was that the training concept is not set up appropriately, followed by the answer that there are other training priorities for managers, mainly focused on soft skills (1).

The response is, "There is no time for fun in practice, and we have to focus on work to survive; we have no time for games" (1). This answer suggests that the respondent may not fully grasp the value of management games and simulations. It's possible they did not carefully read the accompanying text in the questionnaire, which clearly defines the purpose and benefits of management games and simulations. This highlights the need for better communication about the importance of such educational tools and their role in enhancing real-world managerial skills. It is, therefore, possible to state that the respondent does not strive at all to diversify the educational process of the company and educate its managers or executives with an active educational method and not a "game".

Based on the responses collected, a recommendation could be made to appoint a responsible person with dedicated time to analyse the issue. This person could develop several options, such as purchasing a license or establishing cooperation with a university. Afterwards, they would submit proposals to top management, who would review the results and select the most suitable option for implementation. Responsibility for overseeing the entire process could remain with the designated individual, ensuring accountability and a clear path forward for introducing management games and simulations.

The additional reasons indicated by respondents not included in the questions were: "We have no references to any management game" and "The management does not have time to consider the proposals." These responses suggest that a lack of familiarity with management games and time constraints within the management team are significant barriers to adopting these tools in some companies.

Among the companies that use management games and simulations, 6 out of 11 stated that they use their management games and simulations combined with external ones, i.e. those created by a third party (purchase of a license). Three companies use only existing external management games, and only two use their own. The management games reported as being used by companies include Manahra and Stratis Game and other training methods classified as management games.
These are the following forms, tools, and methods of education:

- E-learning,
- Team educational games, role-playing,

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- Focusing on individual needs through an external company, in the case of development centres, they are focused on difficult conversations with employees (target group = junior superiors),
- Brainstorming activities, presentations, case studies, team building activities, charity events, lectures, physical activities,
- Own improvisation – "They are not games in the true sense of the word"; these are workshops and valuable conversations among themselves,
- Solving logical tasks simulating a particular situation, psychological and sociological games, various scenes with later analysis, group activities and team building,
- Leadership competencies, production situations (quality, technology),
- Prioritisation, teamwork.

This indicates that, while these companies may be using specific games, their understanding of what constitutes a "management game" could be broader and encompass various training tools beyond traditional simulations. Some companies use only two types of management games, namely Manahra and Stratis. These two games fall within the realms of research and strategic management. However, they are not comprehensively focused management games, meaning they cannot involve all managers or employees. Despite this, it was found that these active methods provide better employee benefits than traditional training methods.

The other respondents who listed different forms of training cannot be considered management games or simulations but rather "team building" methods. These methods help strengthen relationships, promote logical thinking, and improve communication. However, they do not integrate the theoretical knowledge across all departments or replicate decision-making processes like those in real corporate settings. As a result, while they offer valuable benefits, they do not provide the same comprehensive educational experience as management games and simulations.

Multiple factors influence the use of management games and simulations. The survey included companies that have implemented management games (Table 2) and those that have not (Table 3). This approach aims to gather insights from a broad range of companies to understand better the decision-making process and the factors that impact their choice of educational tools. The response options were structured on a scale, where 1 indicated minimal influence and 5 represented maximum influence on selecting or using a specific management game or simulation.

Factors influencing the choice of management games and simulations in companies that do not use management games are presented in Table 2.

Table 2. Factors influencing the choice of management games and simulations (companies do not use games)

Factors	Number of Respondents				
	1 Minimal Impact	**2**	**3**	**4**	**5 Maximum Impact**
Price	5	6	19	10	9
Quality of the game	4	2	12	10	21
Interest from managers	4	7	9	14	15
Time demand	4	5	12	14	14
Difficulty of the game itself	10	10	19	4	6
Choice of the game focus on a specific industry	4	3	13	13	16
Complexity of game focus (multiple industries together)	6	12	16	10	5

Source: Authors' own creation.

Based on the above data, companies that do not use management games and simulations have very different attitudes towards the factors that influence the choice of management games and simulations. The most important criterion for companies when choosing a management game and simulation, if they were to use them,

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is the quality of the game (21 respondents). Other significant factors with medium influence are the price and difficulty of the game. 19 respondents chose both options. These three initial factors greatly influence the choice of management games and simulations. There seems to be a contradiction. The most influential criterion for selecting a game is the quality of the game itself. However, if companies are unfamiliar with games, this creates a contradiction between their priorities and their experience or knowledge of available options. Companies might be prioritising a quality they haven't yet had the opportunity to assess, which presents a barrier to adoption. This means they cannot evaluate quality since they do not have sufficient knowledge and references in this area. The criteria related to the game's complexity and focus on the industry achieved higher values. Companies are looking for games tailored to specific industries and designed for particular managers rather than one-size-fits-all solutions. The aim is to align the games with the unique needs of different managerial roles and departments, allowing participants to integrate their knowledge and utilise their skills for success and self-improvement.

Factors influencing the choice of management games and simulations in companies that use management games are presented in Table 3.

Table 3. Factors influencing the choice of management games and simulations (companies use games)

Factors	Number of Respondents				
	1 Minimum Impact	**2**	**3**	**4**	**5 Maximum Impact**
Price	1	2	6	2	0
Quality of the game	0	0	1	5	5
Interest from managers	0	0	1	3	7
Time demand	0	0	3	6	2
Difficulty of the game itself	1	4	2	4	0
Choice of game focus on a specific industry	0	0	1	7	3
Complexity of game focus (multiple industries together)	1	1	5	3	1

Source: Authors' own creation

The findings showed that companies that use management games generally agreed on most of the criteria. Price is not a decisive factor for them; instead, those with expertise in the relevant educational area place greater emphasis on the quality of the game, the level of interest it generates among their managers, the time required, and the overall complexity of the game. They are also focused on a specific industry and place a lower priority on the education of their managers in a comprehensive focus. Companies want to educate managers in particular areas of the company more than whether they can connect knowledge from all areas.

Table 4. Annual costs of management games and simulations

Annual costs in Euros	Number of respondents
< 5 000	3
5 000 – 10 000	2
10 000 – 20 000	3
> 20 000	3

Source: Authors' own creation

Companies that use management games invest considerable amounts in them. The costs associated with purchasing management games and simulations vary, depending on factors such as the game's focus, complexity, and difficulty in terms of content and time required. Table 5 presents the annual costs related to purchasing and maintaining management games in companies that use them.

Management games and simulations have been used to train company managers for many years, especially abroad in developed countries. Company management quickly understood that training through this active method is effective; it trains employees in every business area and teaches teamwork, openness in

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communication and complex thinking. The result is an increased performance for employees and the entire company.

The main identified deficiency in the use of management games and simulations for the training of managers in companies in Slovakia is primarily low awareness and lack of knowledge about this active educational training method. Based on a questionnaire survey, it was found that the number of companies in Slovakia that use management games is very low. Out of 60 companies that participated in the questionnaire survey, only 11 companies use management games.

On the other hand, companies that use management games or are thinking about implementing them see fundamental benefits in their use, such as increasing the manager's creativity, the effectiveness of solving problem situations, increasing their performance, improving communication, teamwork, etc.

Unfortunately, companies in Slovakia still mostly use traditional educational methods, such as training and workshops, where employees are only passive listeners. The positive thing is that at least nine companies stated they also use other methods to educate employees, such as e-learning, brainstorming, coaching, and conferences. However, it is still impossible to consider these as purely active education methods.

Only two companies in the questionnaire survey wrote that they use a specific management game, namely the Manahra game and the Stratis game. The remaining companies listed more or less traditional methods they consider management games. On the other hand, some companies are attempting to create their active methods, which is a very positive development. These companies identified various forms of role-playing, soft skills training through experiential methods, and production simulations as examples of these approaches. Another positive finding is that companies are willing to invest considerable funds in management games and simulations, with investments ranging from 5,000 to over 20,000 Euros.

Conclusions

In conclusion, while management games and simulations have proven to be effective tools for training and developing managers globally, their adoption in Slovakia remains limited. The survey findings indicate a lack of awareness and understanding of these innovative educational methods among Slovak companies. However, the benefits observed by the few companies that do implement such methods as enhanced creativity, problem-solving, communication, and teamwork highlight their potential to improve managerial performance and contribute to organisational success significantly. The application of management games and simulations has been proven to be valuable tools for organisations operating in diverse sectors, such as non-profit, sports management, or manufacturing. While traditional training methods still dominate in Slovakia, there is a growing recognition of the value of active, experiential learning. With increased awareness and investment, management games and simulations could play a pivotal role in the future development of Slovak companies, fostering a more dynamic and capable workforce. Moreover, according to Koman et al. (2024), the use of modern technologies can significantly contribute to the creation of sustainable and effective personnel management.

The research was constrained by the lack of information obtained through the survey. On the one hand, few companies participated in the survey; therefore, acquiring more detailed information from individual companies would be appropriate. Future research should aim for a more thorough exploration of this issue, using qualitative data from interviews with managers, such as semi-structured interviews. Topics for further research should be, for example, a deeper examination of the benefits of management games for the educational process of managers, specific measurement of benefits over time, identification of factors influencing these benefits, etc.

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IMPACT OF ESG PERFORMANCE ON THE QUALITY OF CSR REPORTING*

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Abstract. The research aims to analyze the role of the three pillars of sustainability, namely social, environmental and governance (ESG), in the quality of corporate social responsibility (CSR) reporting and how sustainability reporting increases the perceived importance of transparency, relevance and consistency of CSR communication. The research methodology consists of applying a questionnaire on a sample of 141 respondents, employees of companies in Romania, whose answers were analyzed by a multiple linear regression model. The results indicate that all three ESG dimensions have a positive impact and contribute to the improvement of CSR quality, with the most marginal effect being the environmental dimension ($\beta = 0.294$, $p < 0.01$), followed by the social dimension ($\beta = 0.275$, $p < 0.01$) and governance ($\beta = 0.189$, $p < 0.05$). The model explains about 49.7% of the variance in the quality of reporting ($R^2 = 0.497$), and statistical validity tests confirm the robustness of the estimates. The study's novelty lies in highlighting the impact of each ESG dimension on CSR quality in the context of Romanian firms, where research is limited, providing an empirical framework adapted to the specific Romanian legal and cultural context. The research results emphasize the importance of the balanced integration of environmental, social and governance practices in communication policies to meet stakeholder expectations and increase the transparency, quality and credibility of corporate reporting.

Keywords: ESG reporting; CSR; corporate governance; sustainability; transparency; quality

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1. Introduction

Globalization and increasing stakeholder pressure on companies to act responsibly have highlighted the need for sustainability reporting and disclosure. Sustainability reporting is a tool that contributes to enhancing corporate transparency and accountability, being a link between the firm-investors-society and, in general, between all stakeholders (Sabauri & Kvatashidze, 2023). Thus, the concept of ESG (environment (E), social (S) and governance (G)) has become a standard framework for assessing firms' corporate sustainability performance and for integrating sustainability principles into decision-making processes. In this sense, Corporate Social Responsibility (CSR) statements are the main channel through which companies communicate their commitments and actions in these three areas. At the same time, emphasizing the role of sustainability reporting

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also comes in the context of the introduction of the EU Corporate Sustainability Reporting Directive, which superseded the Non-Financial Reporting Directive (NFRD), being transposed into the national legislation of EU member countries and gradually applied from 2024, with the implementation of the directive to be completed in 2028 (Melega & Boghean, 2024).

In terms of transparency, coherence, relevance and accessibility of information, the quality of CSR reporting is a key determinant of corporate reputation, stakeholder trust and potential for attracting investment. However, despite the growing importance of sustainability reporting, how the different dimensions of ESG performance contribute to the quality of CSR reporting is still not fully explored.

The relationship between the quality of corporate reporting and ESG performance has been extensively analyzed in the literature. Some researchers argue that firms that implement well-informed governance, environmental protection and social responsibility policies tend to adopt reporting practices that are more transparent, consistent and relevant to stakeholders. For example, according to a study by Imperiale et al. (2023), who analyzed firms in the utilities sector, there is a significant, though sometimes non-linear, relationship between the quality of sustainability reporting and ESG scores, especially in industries exposed to reputational risks.

Similarly, recent research shows that ESG performance positively affects the application of green accounting and transparency in CSR disclosures, improving the image of firms and contributing to more effective environmental management (Darsono et al., 2024). Another study confirmed that a CSR committee and board characteristics can directly influence ESG scores and reporting quality, emphasizing the importance of corporate governance in this process (Amara & Ahmadi, 2022). Moreover, according to Khichi (2024), applying digital technologies and artificial intelligence in reporting processes improves the quality of reported data and reduces uncertainties in the accuracy and consistency of information.

However, little research in the literature has analyzed the role or contribution of each ESG dimension on the quality of CSR reporting, especially in the context of emerging economies, where the level of disclosure of sustainability information is relatively low. In countries such as Romania, where regulations and practices in corporate sustainability reporting are still maturing, an empirical analysis of how the ESG pillars influence the quality of CSR communication is needed. Gense et al. (2024) argue that the lack of a robust standardization framework and the uneven application of ESG principles across firms of different sizes emphasize the need for contextualized and country-specific research.

In this vein, the research aims to analyze the influence of ESG indicators on the quality of CSR reports in Romanian firms. The study is based on the hypothesis that each ESG dimension has a positive impact and contributes to improving the quality of corporate sustainability reporting, a hypothesis based on the literature. In other words, this paper aims to highlight the role of each ESG dimension on the quality of reporting and how they can improve the content of CSR communications to better respond to stakeholders' needs and expectations.

2. Literature Review

Corporate social responsibility (CSR) and corporate sustainability reporting are key elements contributing to assessing firm performance, going beyond the economic sphere alone. The introduction and consolidation of the ESG concept and the new EU Directive on corporate sustainability reporting have redefined the criteria by which firms are judged by stakeholders, investors and regulators, emphasizing transparency, ethics and sustainability principles. The literature confirms that firms implementing ESG practices produce higher-quality sustainability reports, thus increasing stakeholder trust, organizational transparency, and legitimacy (Darsono et al., 2024; Imperiale et al., 2023). According to researchers, increased ESG performance contributes to improved CSR reporting. Firms with good ESG performance produce more transparent, reliable and detailed sustainability reports (Tohang et al., 2024; Wang et al., 2025). The relationship between ESG performance and CSR reporting is further substantiated by signalling theory, according to which reliable ESG behaviour sends signals of corporate integrity to stakeholders (Yavuz et al., 2025).

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According to studies in the literature, the three pillars of ESG (environmental, social and governance) influence CSR reporting, each in specific and complementary ways. Some researchers often consider corporate governance the determining factor in corporate sustainability reporting. According to Melega and Boghean (2024), corporate governance refers to the set of principles, rules and actions of a firm by which the enterprise is managed to promote transparency and accountability to increase stakeholder trust and achieve sustainable development goals. Hamza and Jarboui (2024) and Al-Sanasleh et al. (2025) argue that corporate governance practices, such as board independence, dedicated social responsibility committees, and ethical oversight, significantly influence the quality of CSR reporting disclosures. Moreover, effective governance structures, CSR committees and ethical compliance mechanisms contribute to enhancing the clarity and reliability of sustainability reporting (Monteiro et al., 2024; Aldogan Eklund & Pinheiro, 2024), helping to reduce the risks of greenwashing and increase trust and satisfy the information needs of stakeholders. For example, Monteiro et al. (2024) show that the presence of a CSR committee is associated with greater stakeholder engagement and more detailed reporting, while Aldogan Eklund and Pinheiro (2024) highlight that the consistent application of ethical rules in corporate governance contributes to the standardization and verifiability of ESG information. In this respect, corporate governance, on the one hand, supports ethical decision-making processes. Still, on the other hand, it also plays a key role in integrating ESG aspects into the firm's overall development strategy, which is directly reflected in the quality and relevance of sustainability reporting.

Social responsibility plays a key role in strengthening the relationships between the firm and its stakeholders, directly influencing the content and quality of sustainability reports. Abu Afifa et al. (2025) and Paleni et al. (2024) argue that the social dimension of ESG drives companies to adopt human-centred communication that reflects values such as equity, inclusion, health and safety at work. In this context, reports emphasize social engagement initiatives, such as corporate volunteering, support for education and partnerships with NGOs, which contribute to increasing the social legitimacy side of the firm. Moreover, ESG-oriented firms are delivering economic performance and integrating social goals such as workforce diversity, inclusion of vulnerable groups, and support for local communities into their development strategies (Maji & Tiwari, 2025). Such firms develop mechanisms to listen to stakeholders actively, use social performance indicators, and constantly monitor the impact of their activities on the well-being of their employees and the communities in which they operate. The result is CSR reporting that is more solid, contextualized and aligned with the real needs of society, which contributes to increasing the value of the information and, implicitly, its quality.

Environmental indicators, i.e. those aimed at reducing carbon emissions, efficiency, effectiveness and economy in the use of resources, and eco-innovation, have a clear impact on increasing the relevance and quality of CSR reporting. Environmental responsibility practices indicate the commitment adopted by firms to sustainability and environmental protection, leading to more rigorous and results-oriented reporting and impact. According to Zhang and Liu (2023), ESG performance is a driver of green innovation, contributing to improved human capital and reduced financial constraints, outcomes reflected in more relevant and consistent reporting. Some research highlights that ESG performance is influenced by decreasing carbon intensity, and the implementation of green credit contributes to this effect by supporting green innovation and sustainable practices (Kong et al., 2024; Xie et al., 2024). Other studies show that ESG reporting facilitates green innovation in industry and helps align corporate strategies with national and international environmental goals (Yang et al., 2024; Rauf et al., 2024). Also, integrating digital technologies and artificial intelligence into carbon accounting improves the accuracy and transparency of environmental reporting, reducing the risk of greenwashing and facilitating compliance with international regulations (Ogunyemi et al., 2023). Also, Cai and Hao (2025) argue that ESG performance has positive effects not only on exports and financial performance but also on environmental responsibility by reducing emissions and increasing resource efficiency. Environmental performance, on the one hand, reflects the operational sustainability of firms. On the other hand, it improves the quality and credibility of CSR reporting, especially in sectors with high environmental footprints.

Although there is a plethora of studies that have examined the role of integrating ESG criteria into sustainability reporting, most of them have focused on developed economies or highly globalized emerging regions. Although a member state of the European Union and subject to recent regulations such as the CSRD Directive, Romania remains underexplored from the perspective of scientific research on the quality of ESG reporting. Despite recent progress, corporate sustainability reporting in Romania is still characterized by a low degree of

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standardization, a reliance on voluntary initiatives and an uneven understanding of sustainability concepts at the firm management level (Ogrean, 2017; Frecea, 2016). Recent studies highlight that the Romanian banking sector and listed companies are showing a growing interest in sustainability. However, implementing ESG principles is uneven and often driven by external pressures such as EU regulations or investor requirements (Tudorache, 2024; Vasiu, 2023). In this context, analyzing how the three pillars of ESG influence the quality of social responsibility reporting in Romania is not only timely but also necessary to understand the ability of local firms to respond to the new European requirements, as well as to identify the institutional and cultural factors that condition the success of this process.

In this vein, studies consistently point to a direct and positive link between ESG dimensions and the quality of CSR reporting. However, although the general trend is clear, the studies do not provide firm conclusions on the relative weight or impact of each ESG pillar. Thus, as found in the literature, the research hypothesis is:

H1: Dimensions of ESG (Environmental, Social and Governance) positively influence the quality of CSR (Corporate Social Responsibility) reporting.

In practical terms, this hypothesis aims to address existing gaps in the literature, focusing on the distinct contribution of each ESG component to the perception of CSR quality, especially in less explored regional contexts such as Romania.

3. Methodology

Quantitative research was used using a structured questionnaire to test the hypothesis and achieve the research goal, namely, to identify and analyze the influence of ESG dimensions on the quality of CSR reporting in the context of Romanian firms. The questionnaire was structured in 7 sections, which focused on (1) general data about the sample, i.e. about the company and the respondent; (2) the company's involvement in social actions; (3) the company's involvement in environmental actions; (4) governance actions in the company; and (6) organizational values. A total of 41 questions were asked regarding companies' experience in the CSR reporting field and the ESG measures implemented within the companies.

Data collection was conducted online between February and April 2025 by distributing the questionnaire (Google Forms) to companies in Romania. The questionnaire was distributed to companies via email and social networks like Facebook and LinkedIn. The online distribution was chosen because it offers greater accessibility and coverage. Still, we recognize that this method may limit the generalizability of the results due to the sample being non-probabilistic.

Following the questionnaire distribution, 141 responses were collected from respondents working in various firms with different specificities, of which 24 were in trade, 14 were in manufacturing, and 103 were in services. Of the 141 respondents, the majority (55) work in medium-sized and 39 in small firms. According to the European Commission, company size has been classified into micro companies (up to 10 employees), small companies (between 10 and 49 employees), medium-sized companies (between 50 and 249 employees) and large companies (more than 250 employees).

Respondents are active in both the public and private sectors, covering 22 domains of activity stipulated in the Classification of Activities in the National Economy (NACE) of Romania. Subsequently, these fields of activity were grouped into three samples: production, services and trade.

Data analysis was performed using the SPSS statistical program to identify the impact of independent variables on the quality of the reports. To determine these influences, the questions asked in the questionnaire were categorized according to their affiliation to classic and extended ESG indicators, according to the data presented in the table below and appendix.

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Table 1. Description of variables and how they are formed

Variable code	Full name	Variable type	Description/Dimension ESG	Number of items	Measurement scale
Q_R	Reporting Quality Index	Dependent	CSR reporting quality	6	Nominal
E	Environmental Indicator	Independent	Environmental (E)	7	Nominal
S	Social Indicator	Independent	Social (S)	10	Nominal
G	Governance Indicator	Independent	Governance (G)	6	Nominal
D	Firm Size	Control/descriptive	Demographic	1	Ratio
V	Tenure in firm	Control/descriptive	Demographic	1	Ratio

Source: developed by the authors

To prepare the data for the multiple linear regression model, each set of items in the questionnaire was aggregated into a composite indicator. The Q_R reporting quality index consists of 6 items (see Annex), which measure the consistency, relevance and accessibility of the information in the CSR reports. The index was computed as the arithmetic mean of the respondents' answers (Likert scale 1-5) as follows:

$$Q_{Ri} = \frac{1}{6}\sum_{j=1}^{6} Q_{Ritemij} \quad (1)$$

In the same way, the environmental indicator (E) was formed based on the arithmetic mean of the answers to 7 items on environmental policies and practices $E_i = \frac{1}{7}\sum_{j=1}^{7} E_{itemij}$, and the social indicator (S) was calculated by the mean of the answers to 10 items on social responsibility, as follows: $S_i = \frac{1}{10}\sum_{j=1}^{10} S_{itemij}$. The governance indicator (G) was constructed based on the average of the responses to 6 items related to governance structures $G_i = \frac{1}{6}\sum_{j=1}^{6} G_{itemij}$. The reliability of the composite scales was tested using Cronbach's Alpha coefficient. The assumptions of multicollinearity and normality of errors were also tested to validate the application of the regression model. To ensure the comparability of coefficients in multiple linear regression, all composite variables were standardized (Z-score). The following multiple linear regression model was then applied:

$$Q_R = \beta_0 + \beta_1 E + \beta_2 S + \beta_3 G + \beta_4 D + \beta_5 V + \varepsilon \quad (2)$$

Multiple linear regression was selected as the data analysis method because most of the variables included in the analysis are continuous or ordinal. At the same time, multiple linear regression is a tool that estimates the simultaneous influence of several predictors on a single dependent variable, in our case, the reporting quality. Linear regression also allows us to test hypotheses of a direct and quantifiable relationship between each ESG pillar and the level of detail and consistency of CSR reporting. Linear regression is commonly used in the literature in similar studies. For example, Siminică et al. (2020) applied multiple regression to analyze the impact of non-financial reporting on stock prices in Romanian and Bulgarian companies, showing a positive correlation between reporting detail and investor confidence. Also, Bogeanu-Popa and Man (2023) used regression to assess the link between integrated reporting, including ESG components, and the financial performance of Romanian banks. In a broader framework, Gabr and ElBannan (2024) apply linear regressions to analyze the effects of ESG scores on carbon emissions and financial performance in emerging economies.

At the same time, in addition to theoretical validation, multiple linear regression provides high interpretability on the estimated coefficients and allows for efficient testing of the hypothesis regarding the distinct influence of each ESG dimension on the quality of CSR reporting. At the same time, multiple linear regression was applied as it allows for controlling demographic variables such as respondents' positions, levels of education, and seniority in the firm.

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4. Results and Discussions

The analysis was structured in two steps to study the influence of ESG dimensions on the quality of CSR reporting in Romanian firms: assessing the bivariate correlations between variables through the Pearson coefficient and testing causality relationships through a multiple linear regression model.

The Pearson correlation matrix presents an overview of the relationships between the dependent variable, the quality of sustainability reporting, and the independent variables, represented by the social (S,) environmental (E), governance (G), company size (D) and age (V).

Table 2. Pearson Correlations between Q_R and independent variables

	Q_R	E	S	G	D	V
Q_R	1.000	.604	.600	.531	.321	.102
E	.604	1.000	.610	.502	.227	-.015
S	.600	.610	1.000	.59	.206	-.058
G	.531	.502	.596	1.000	.252	.112
D	.321	.227	.206	.252	1.000	.444
V	.102	-.015	-.058	.112	.444	1.000
Note. All correlations are based on N = 141. * Correlation is significant at the 0.05 level (1-tailed). ** Correlation is significant at the 0.01 level (1-tailed).						

Source: developed by the authors

According to the data in Table 2, it can be observed that there are significant positive correlations between the dependent variable quality of sustainability reports and the analyzed independent variables, with a strong level of statistical significance ($p < 0.01$). The interpretation scales proposed by Obilor and Amadi (2018) were used to analyze the Pearson correlation results and rank the intensities of correlations. The E variable, represented by environmental indicators ($r = 0.604$), is associated with higher quality reporting, confirming the importance of environmental responsibility in generating quality reports. Zhang and Liu (2023) emphasize that ESG performance stimulates eco-innovation, which leads to more consistent and relevant reporting. Also, the implementation of green crediting and digital carbon accounting are mentioned as factors that improve the transparency of reporting (Xie et al., 2024; Ogunyemi et al., 2023).

At the same time, a significant but already moderate correlation is found between social indicators ($r = 0.600$) and the quality of CSR reporting, which is influenced by indicators such as energy reduction, resource consumption reduction, alternative energy sources, etc. Similar results are also supported by research by Abu Afifa et al. (2025) and Paleni et al. (2024), which show that the social ESG dimension promotes empathetic and, equity and inclusion-oriented reporting, enhancing the social legitimacy of the firm.

The influence of governance indicators (G) on the quality of CSR reporting is also confirmed, with a correlation of 0.531. This effect was also determined in the study by Gerwing et al. (2022), which found that governance measures improve transparency and credibility in reported information. The research conducted by Adel et al. (2019) emphasizes the importance of a sound governance framework and the implementation of effective governance measures to achieve high-quality reporting.

To sum up, the Pearson correlation matrix demonstrates the relevance of each ESG pillar in improving corporate reporting.

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Table 3. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.705[a]	.497	.478	.739328164746307	1.68
a. Predictors: (Constant), E, S, G, D, V					
b. Dependent Variable: Q_R					

Source: developed by the authors

According to the data presented in Table 3, the correlation ratio R value is 0.705, indicating the strong association between the independent variables of the model and the quality of CSR reports. At the same time, the determination ratio suggests that 49.7% of the variance in the quality of reports can be explained by the ESG factors included in the model. The reasonable value of the standard error of the estimation reveals moderate variability in the errors; thus, the generated forecasts are considered credible. As regards the autocorrelation of the residuals, the value of the Durbin-Watson statistic is within the recommended range of 1.5-2.5, which indicates the absence of autocorrelation and the assumption of independence of the errors.

Table 4. ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	72.780	5	14.556	26.630	.000[b]
	Residual	73.792	135	.547		
	Total	146.571	140			
a. Dependent Variable: Q_R						
b. Predictors: (Constant), E, S, G, D, V						

Source: developed by the authors

The results of the ANOVA analysis (Table 4) testing the overall validity of the regression model revealed that the model can be considered statistically significant, considering that the p-value is 0.000, i.e. a value below the significance threshold level of 0.005. The above findings are supported by the Fisher coefficient of 26.630, which suggests that at least one of the ESG measures contributes significantly to explaining the variance in the quality of CSR reporting.

Table 5. Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.587	.342		1.713	.089	-.091	1.264
	E	.294	.073	.294	4.038	.000	.150	.438
	S	.275	.084	.275	3.294	.001	.110	.440
	G	.189	.092	.189	2.055	.041	.007	.371
	D	.136	.076	.137	1.791	.075	-.014	.287
	V	.058	.084	.057	0.689	.492	-.108	.224
a. Dependent Variable: Q_R								

Source: developed by the authors

Based on the unstandardized coefficients highlighted in Table 5, the equation of the multiple linear regression model was designed, which has the following structure:

$$Q_R = 0.587 + 0.294 * E + 0.275 * S + 0.189 * G + 0.136 * D + 0.058 * V \quad (3)$$

According to the regression model equation, the positive influence of all ESG factors can be emphasized, confirming their contribution to improving disclosures in corporate annual reports. At the same time, the ESG variables included in the model are significant at a significance level of up to 0.05.

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Thus, if the E value (environmental indicator) increases by 1%, the quality of CSR reporting increases by 29.4%. Corporate practices that support the environment are considered to be effective measures in increasing the quality of CSR reports due to the diversity and completeness of the data published in the reports. Out of the 7 indicators included in the questionnaire, the reduction of energy and natural resources consumption had a significant impact, with more than 65% of the respondents expressing their agreement with implementing these measures in their companies. Other authors also identified a similar effect, with environmental indicators positively influencing the quality of corporate reports (Șeker & Șengür, 2021).

If the value of S (social indicator) increases by 1%, the quality of CSR increases by 27.5%. The obtained result demonstrates that applying social measures in the entity is a sure way to increase the quality of reporting, thus gaining benefits such as stakeholder interest and appreciation. Moreover, the presentation of qualitative ESG information improves the quality of sustainability reports and ensures a favourable positioning of the company in the group of those with outstanding reputations (Odriozola & Baraibar-Diez, 2017). In the work of Amran et al. (2014), similar conclusions are highlighted, with social responsibility practices being perceived as catalysts in generating high-quality reports.

If the G value (governance indicator) increases by 1%, the quality of CSR reporting increases by 18.9%. Indicators targeting corporate governance have the potential to improve the data included in sustainability reports by highlighting the quality of management and governance practices in place. Out of the total number of respondents, more than 60% confirmed the promotion of honesty and ethics in their company's operations, with this indicator having a substantial influence on the quality of the reports. Researchers Erin et al. (2021) reached similar conclusions, identifying a positive and relevant association between effective corporate governance and qualitative sustainability reporting in their study. Moreover, digital innovation, as a component of corporate governance strategies, is found to be an effective tool in managing the quality of ESG disclosures (Cui, 2025).

The control variables, represented by firm size and age, were insignificant in the context of the formulated regression model. Thus, it is possible to assume that small and large companies with extensive or less experience can present quality CSR reports.

Considering the results obtained, it is possible to confirm the research hypothesis that all ESG measures positively impact the quality of integrated reports. The obtained results align with the view of authors Lin et al. (2023), who consider ESG performance to be a relevant impact factor in publishing comprehensive and informative CSR reports, thus improving interaction with stakeholders. The results are also consistent with the research of Darsono et al. (2024) and Tohang et al. (2024), who emphasize that higher ESG performance positively correlates with more transparent and detailed CSR reporting. Also, research by Maji & Tiwari (2025) argues that integrating social aspects into corporate strategy impacts the legitimacy and transparency of CSR communication.

In conclusion, the statistical results confirm hypothesis H1: Dimensions of ESG (Environmental, Social and Governance) practices positively influence the quality of CSR (Corporate Social Responsibility) reporting. The dimensions of ESG reporting. The results align with the literature, highlighting that high ESG performance signals integrity and accountability, which contributes to increased organizational legitimacy.

Conclusions

The research aims to analyze the role of the three pillars of sustainability, namely social, environmental and governance (ESG), on the quality of corporate social responsibility (CSR) reporting and how sustainability reporting increases the perception of the importance of transparency, relevance and consistency of CSR communication. Based on a sample of 141 respondents and the application of a multiple linear regression model, the results confirmed the research hypothesis: all three ESG dimensions contribute positively and significantly to the quality of CSR communications.

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The results show that the environmental dimension (E) has the highest marginal influence, followed by social indicators (S) and corporate governance measures (G), indicating that community involvement, managerial ethics and social equity are perceived as key factors for credible and relevant reporting. These results support the literature emphasizing the complementary role of the three ESG pillars in creating a coherent sustainability framework (Darsono et al., 2024; Monteiro et al., 2024; Monteiro et al., 2024; Zhang & Liu, 2023).

Thus, the study confirms the relevance of integrating the three ESG dimensions in enhancing the quality of CSR reporting and provides a useful empirical framework for understanding this phenomenon in the context of Romanian firms.

The study's novelty lies in highlighting the distinct contribution of each ESG dimension (environmental, social, governance) on the quality of CSR reporting in the specific context of Romanian firms. The research shows that although all ESG dimensions significantly improve the consistency and transparency of non-financial disclosures, the environmental dimension has the strongest effect on the quality of reporting. At the same time, from a methodological point of view, Cronbach's Alpha-validated composite indicators were integrated into the research, and standardized multiple linear regression was applied, thus providing a replicable framework for further research and informing corporate and regulatory policies.

The research's limitations are that the data were collected through an online questionnaire distributed through professional networks. This may introduce a selection bias, especially in favour of companies already familiar with ESG concepts. Also, the sample is non-probabilistic, which reduces the generalizability of the results to the entire Romanian economy. At the same time, another limitation is that the quality of CSR reporting was assessed based on respondents' subjective perceptions and not on external audits or objective indicators of actual reporting, which may influence the accuracy of the conclusions regarding the correlation between perceptions and actual practices.

The research can be taken further by extending the sample at the sectoral and regional levels to allow comparisons between industries with different environmental footprints. Objective indicators such as ESG scores, GRI audits, and databases such as Bloomberg ESG can also be used to validate correlations between stated perceptions and actual performance.

Annex

Composite variable	Items related to each composite variable
Q_R - Reporting Quality Index	The company communicates its CSR actions through its website.
	The company communicates its CSR actions through marketing campaigns.
	The company communicates its CSR actions through internal communication channels.
	The company uses CSR tools such as the Accountability 1000 AA1000 Stakeholder Engagement Standard (AA1000SES).
	The company uses CSR tools such as the international SA 8000 Social Accountability Standard.
	The company uses CSR tools such as EMAS (Eco-Management and Audit Scheme).
E - Environmental Indicator	Employees are encouraged to develop their skills/skills and long-term careers (through assessment procedures, training, etc.)
	Working hours can be customized according to employees' needs
	The firm offers employees the opportunity to work from home
	Employees are consulted on important issues concerning the firm's business
	The firm protects its employees through health, safety and relaxation programs
	The firm applies policies/measures to avoid discrimination (gender, ethnicity, nationality, etc.) at the recruitment stage and subsequently in day-to-day work
	The company ensures a balanced work climate for all employees
S - Social Indicator	The company tries to minimize the negative impact that some of its operations can have on the environment by reducing energy consumption
	The company seeks to minimize the negative environmental impact that some of its operations may have by reducing the consumption of natural resources
	The company seeks to minimize the negative environmental impact that some of its operations may have by reducing and recycling waste
	The company seeks to minimize the negative environmental impact that some of its operations may have by using alternative energy sources
	The company seeks to minimize the negative environmental impact that some of its operations may have by using renewable energy

Composite variable	Items related to each composite variable
	The firm seeks to minimize the negative environmental impacts that some of its operations may have on the environment through the use of transport alternatives with lower environmental impact
	The firm seeks to minimize the negative environmental impacts that some of its operations may have on the environment through qualitative and quantitative records/evidence of pollutant emissions
	The firm assesses the potential environmental impacts when designing/introducing new products and services
	The firm uses certified environmental management systems
	The firm carries out environmentally friendly production processes
G - Governance Indicator	The firm promotes honesty and ethics in all the transactions/contracts/partnerships it enters into
	The firm adheres to a set of ethical rules in terms of promotion/advertising
	The firm honours all its contractual obligations to suppliers and customers on time
	The firm periodically clearly defines a number of key values (which are at the core of the organizational culture) and a number of rules of conduct
	The firm communicates to employees, customers, suppliers, business partners the values that govern its business
	The firm communicates to employees, customers, suppliers, business partners the standards/rules that govern its activities
	The firm encourages/supports the development of an organizational culture that integrates CSR practices
	The firm regards knowledge as a value in itself for both employees and the organization
	The firm supports continuous learning by employees and groups as a distinct value of the organizational culture
	The firm supports innovation as a distinct value of the organizational culture
	The firm balances annually, through its strategy and proposed budget, the "good" of the organization with some social responsibilities that are explicitly accepted

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SENSORY MARKETING: THE INFLUENCE OF GLASS SHAPE ON THE PERCEPTION OF BEER BY THE CONSUMERS

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Abstract. In recent years, there has been a growing interest in the issue of how the quality characteristics of glassware affect the consumer experience of drinking. The material, shape and colour of the vessel are important organoleptic features that affect the consumption of beverages. Six types of beer purchased from different producers were selected for the study: light beer, dark beer, porter, castellan, wheat beer, and Ale. Beer samples for evaluation were served in three glass vessels, which differed in shape. The study used beer mugs with a handle, tall glasses for wheat beer, and beer goblets (also called tulip glasses). A trained team performed the sensory evaluation of the beer with appropriate, verified sensory sensitivity, meeting the selection criteria according to the standardized method. The results obtained in this study indicate that the sensory characteristics of beers were rated lower compared to the ratings made by other authors. In the case of light beer, differences in the ratings of taste, palatability and bitterness were noted depending on the type of vessel in which they were served. Light beers' taste, palatability, saturation, and total quality (WJC) were evaluated as lower when this beer was served in a tulip glass. In the case of wheat beer, differences in the ratings of palatability and saturation were noted.

Keywords: beer quality; glass quality; sensory evaluation

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JEL Classifications: L15, L61, L66

1. Introduction and review of literature

In recent years, there has been a growing interest in the issue of how the quality characteristics of glassware affect the consumer experience of drinking (Craine et al., 2022). The material, shape and colour of the vessel are important organoleptic features that affect the consumption of beverages. Research conducted by Guéguen (2003) has shown that the vessel's colour affects the drink's perception – its thirst-quenching properties. The study confirmed that carbonated drinks served in blue glass - which is associated with cold - were rated as more thirst-quenching than when the same drink was served in green, yellow or red glass. Only 15% of participants rated the drink in the red glass more thirst-quenching.

Similar studies were conducted by Piqueras-Fiszman et al. (2011), but the object of their interest was hot chocolate. The results confirmed that the perception of the drink's taste was influenced by the colour of the plastic cup in which the drink was evaluated. The drink served in a red cup was liked more by the evaluators than when

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served in a white cup. The results of subsequent studies by these authors show that the consumer's perception of the sensory properties of the container in which the drink is evaluated (e.g., its colour, weight, etc.) influences the experience of drinking the drink, which is often referred to as the "transfer of sensations" effects. Participants in the study rated hot chocolate samples on several sensory scales. The results showed that the evaluators rated the drink taste in orange and dark cream cups as more chocolatey. In addition, the hot chocolate consumed from the dark cream cup was rated as sweeter, and its aroma was more intense (Piqueras-Fiszman & Spence, 2012).

Research by Schifferstein (2001) clearly showed that participants' experiences of drinking from different cups were influenced by how the participants experienced the cup. Respondents rated carbonated drinks from plastic cups as more acceptable than from ceramic cups. In turn, drinks from pink cups were rated significantly sweeter than when the same drink was consumed from clear cups (Schifferstein, 2001).

Also, orange juice has been tested this way. The results revealed that the glass shape influenced the perceived sensory qualities of orange juice. The results also showed that bar workers and restaurateurs should provide orange juice in glasses with a round shape as it influences perceived sweetness and pleasantness (Wu et al., 2024). The characteristics of the cups made of different materials influenced the overall acceptability of the apple soft drink, so different drinks are affected by the shape of the cup (Tomic et al., 2024).

When it comes to tea, the teacups' height, width, thickness, and smoothness affect the tea's flavour. The shape and texture of the teacup influenced the preference for teacup, and the preference for teacup affected the tea perception's flavour (Yang & Hsu, 2024).

Similar conclusions were obtained in the case of experiments on the effect of the shape of glassware on the organoleptic properties of alcoholic beverages. Wansink and van Ittersum (2003) found that consumers consume up to 88% more alcoholic beverages when serving them in short and wide glasses than when the same beverage is served in tall and narrow glasses. Similar conclusions were drawn from research conducted by Mirabito et al. (2017). They found that panellists consumed alcoholic beverages 60% slower when served from straight-sided glasses compared to when they were served from sloping-sided glasses.

In a study conducted by Vilanova et al. (2008), six sweet wines were assessed, which were served in nine different glasses. Experts assessed the intensity and quality of the aroma and taste of the wine served in different glasses. Assessments were made on an 11-point scale. Depending on the type of glass in which the wine was served, the aroma assessments differed by 1.8 points. Experts assessed the aroma of the wine as the highest when it was served in bulbous glasses (Spence & Van Doorn, 2017). The shape of the glass had a slightly smaller effect on the assessment of the taste of the wine. The evaluation of the aroma and, to a lesser extent, the taste of the wine by social drinkers, students of oenology and professional wine tasters can be significantly influenced by the shape of the glass in which the drink is served.

The experiment confirms that the assessment of the aroma and taste of a wine that potential consumers and experts can consume can be significantly influenced by the shape of the glass in which the drink is served. As Gawel (20210) reports, the same wine served in different glasses will be assessed by respondents completely differently. When asked how many wines they had assessed, most of the participants in the experiment responded that they had two or three. This means that they believed they were evaluating different types of wine when they were served the same kind of wine, which was served in different glasses. The experiment was conducted in a sensory evaluation lab, where the participant did not know the vessel in which the wine was served for assessment. The tests did not indicate differences in the sensory perception of the wine consumed. Perhaps the most interesting result came when the participants were asked how many different wines they had tried during the experiment – most responded that they had two or three. This means they thought they were assessing a different wine when it was served in a different glass. However, in the strictly controlled laboratory conditions, where the participant did not know about

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the glass in which the wine was presented, no detectable differences in the perception of sensory properties by the assessors were reported. This is confirmed by research conducted by Delwiche & Pelchat (2002), who found that it is much more difficult for respondents to distinguish between wines served/stored in different glasses if they cannot see or touch these glasses.

Drinking, unlike eating, always involves direct contact between the drinker and the vessel in which the drink is served (Spence & Wan, 2015; Spence & Van Doorn, 2017). According to Vilanova et al. (2008), in the case of direct contact in the form of holding a glass in the hand of the person tasting the wine, a much greater influence of the glass on the sensory properties of the drink was observed. This insight aligns with the opinion that if the assessor can see and/or physically interact with the wine glass while assessing the sensory properties of the wine contained within it, then the shape and/or size of the glass will influence the assessment of the contents (Hummel et al., 2003). To highlight the intensity and elegance of the wine aroma, it is essential to choose a glass with a smaller cuppa height and a bigger ratio between the maximum and opening diameter, which is practical and instructive for wine practitioners (Bai et al., 2023). The glass's influence on wine perception may be psychological rather than chemical or physical in origin. Also, contextual conditions matter (Istiani et al., 2023a; Istiani et al., 2023b). The subjective evaluation of wine is a conscious multisensory process that includes the direct (visual and/or tactile) perception of the glass, as well as any awareness the participant may have of the meaning and associations associated with the glass itself (Piqueras-Fiszman et al., 2011). Barnett et al. (2016) showed that consumers rated the taste of beer served in a bottle better than the taste of the same drink served in a can. The same authors conducted a study in which several hundred people were asked to drink a bottle of beer and then fill out a survey about their impressions. The participants were divided into groups, and beer was served in different bottles. The results revealed that those who tried the beer from the bottle with yellow and green elements on the label rated the citrus notes as significantly more intense than drinking from an unmarked brown bottle. Also, the results obtained by Becker et al. (2011) confirm that changes in the tactile properties of the container in which the drink is placed have different effects on different people depending on their general preference for tactile stimuli. Meanwhile, research conducted by Casales-Garcia et al. (2023) suggested that the type of beer glass (e.g., Pilsner) and the colour of beer both influence participants' expectations, hedonic ratings and willingness to pay. Beers served in a Pilsner glass were rated as tasting sweeter than when the same beers were served in a mug instead.

The shape of the glass has an extremely high influence on the sensory evaluation of champagne. Research has been conducted for years on whether champagne tastes better when drunk from a flute or cup glass. The shape of the glass significantly impacts the release of carbon dioxide contained in the drink (Liger-Belair et al., 2024).

Some studies of drinking experiences examine the presentation of a beverage in a container that is perceived as appropriate versus one that is perceived as inappropriate. Studies have shown that respondents rate beverages more favourably when presented in containers perceived as suitable for the beverage (Spence & Van Doorn, 2017). Typically, what is considered “appropriate” here is often determined by a history of prior experiences with drinking certain beverages from certain types of glassware. Certain types of glassware are considered to be better suited for certain types of beverages (Casales-Garcia et al., 2023). A person's social, cultural, and cultural context also plays a role. People worldwide may have different ideas about the most appropriate glassware for a particular beverage. Consumers from different cultures and/or age groups may have very different views on the suitability of a specific container for a particular beverage (Standage, 2006; Henriques et al., 2022). It should also be emphasized that glassware affects not only a person's impression of what is in the glass but can also potentially affect their experience of the entire meal (Billing et al., 2008). New designs for the shape, appearance, and functionality of the vessels are constantly being tested. Studies show that the right design positively affects the experience of drinking beverages (Liu et al., 2023; Guo et al., 2024).

Advertising and marketing of glassware, including wine glasses, is so effective that most wine connoisseurs have clear prejudices about whether a glass is suitable for wine. Research conducted by Williams et al. (1984) showed

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that even experts involved in wine evaluation make different assessments of the sensory characteristics of port and Bordeaux wines depending on whether the drinks are served in red or clear glass. Unfortunately, the research results in this area are always difficult to interpret. It is unclear what effect the actual shape of the glass has on the consumer's feelings and what effect the associations generated by marketing activities on the glass market have. Some authors also indicate that it is not entirely clear whether research related to the effect of the shape of the glass on the perception of the organoleptic characteristics of wine will also be translated to other drinks, often of a less complex nature, such as drinks, Cola, beer (Spence & Van Doorn, 2017).

The above review of the literature indicates how many factors can influence the assessment of sensory impressions. New designs are constantly being created to complement previously known glass styles. The abundance of shapes and types of vessels can cause many doubts among consumers when choosing them. Researchers also indicate that it is not entirely clear whether the findings related to the influence of the shape of the vessel on the perception of the organoleptic characteristics of wine will also be translated into other beverages, often of a less complex nature, such as drinks, Cola, beer (Spence & Van Doorn, 2017). It is justified to conduct further research on the influence of the shape of the glass vessel on the impressions resulting from the consumption of various beverages. The results of such studies can be useful for consumers (when choosing glass) and for manufacturers of vessels (when creating marketing strategies). Aspects related to sustainable development are equally important today. Knowledge of the interactions between the drink and the vessel can lead to more thoughtful purchases, as it has been confirmed that consumers' perception of the quality of a drink is undoubtedly an important factor in their product-related decision-making (Mehta et al., 2022). Consumers who choose products closely tailored to their needs also contribute to lower consumption of natural resources.

2. Materials and methods

Six types of beer purchased from different producers were selected for the study: light beer, dark beer, porter, castellan, wheat beer, and Ale. Beer samples for evaluation were served in three glass vessels, which differed in shape. The study used beer mugs with a handle, tall glasses for wheat beer, and beer goblets (also called tulip glasses). Mugs are vessels with a classic appearance characterized by solid construction and a special handle. They are popularly used for beers such as Lager and Ale. A goblet is a vessel similar to a shot glass but with a short stem and a large bowl that narrows towards the top. For example, IPA beer is served in this vessel. The goblet's shape helps to bring out the full aromas of the beer. Glasses with a characteristic tall, elongated shape were designed for wheat beers.

A trained 10-person team performed the sensory evaluation of the beer with appropriate, verified sensory sensitivity meeting the selection criteria according to the standard PN-ISO 6658:1998 (Sensory Analysis – Methodology – General Guidelines) in conditions ensuring accuracy and repeatability of results meeting the requirements of the standard PN-ISO 8589:1998 (Sensory Analysis – Methodology – General Guidelines).

Beer samples for evaluation were poured into vessels of about 100 ml. They were prepared and given to the assessors anonymously. The temperature of the beer samples evaluated was 80C. Beer samples for sensory evaluation were taken and prepared according to PN-A-79095:2000 (Beer research methods - Sampling and preparation). The beer samples were assessed in two sessions. In the first session, 3 types of beer were assessed: light, dark and porter. The beer samples in the first and second sessions were served in three series, which differed in the type of container. In the first series, beer samples were poured into mugs, in the second into glasses, and the third into goblets. In the second session, castellan, wheat and Ale beers were assessed. In each session, each assessor assessed 9 beer samples. The assessment was aimed at determining the level of organoleptic characteristics of beer (odour, taste, palatability, saturation and bitterness) using a 6-point scale according to PN-ISO 4121:1998 (Sensory analysis - Methodology - Evaluation of food products using scaling methods) and

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determining on this basis the overall quality of the assessed beer types. Each point of the scale corresponded to a clear definition of quality. The scale included 6 quality levels of the assessed parameters:
High quality - very good - 6 points; good - 5 points.
Acceptable quality - average - 4 points; poor - 3 points.
Low quality - very poor - 2 points; bad - 1 point.

After each session, an individual sensory quality index was calculated for each type of beer using the following formula:
$WJC = \Sigma C_i * W_i$, in which:
WJC – total quality indicator
C_i – evaluation of the consecutive sensory features;
W_i – weighting coefficient of the consecutive sensory feature (smell – 4, taste – 8, palatability – 12, saturation – 2, bitterness – 4). The weighting coefficients were adopted according to Annex D of PN-A 79093-1-2000-P.

The study used beer mugs with handles (beer mugs), tall glasses for wheat beer (wheat beer glasses), and tulip glasses. The appearance of the glass used in the study is shown in Photo 1.



Photo 1. Glassware used in the study. Beer mug (left), glass (centre), tulip glass (right)
Source: own photography

The results were statistically analyzed using Statistica 13.3 software. The following methods were used in the analysis:

- calculation of basic statistical measures – arithmetic mean (M) and standard deviation (Sd),
- one-way analysis of variance – Fisher-Snedecor parametric F test combined with post hoc analysis, in which the least significant difference (NIR) test was used. These tests were used to examine the degree of differentiation of assessments between individual experts.
- Kruskal-Wallis nonparametric test for a one-way system was used to examine the difference in assessment results depending on the type of beer and the type of vessel used. In the case of rejecting the null hypothesis, an additional post hoc analysis was performed using Dunn's multiple comparisons test with Bonferroni correction

Verification of all hypotheses was performed at the significance level of $\alpha = 0,05$ based on the test probability value "p". It was assumed that $p \leq 0.05$ indicates significant differentiation of the dependent variable depending on the category of the qualitative factor (Stanisz, 2006).

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3. Results and discussion

The results of the organoleptic quality assessment (WJC; mean and standard deviation values) of the tested beers performed by individual experts are presented in Table 1.

Table 1. Results of organoleptic quality assessment (WJC) of the tested beers

Evaluator no.	Mean	Standard deviation
1	4,81	0,40
2	3,86	0,68
3	4,86	0,69
4	5,18	0,82
5	4,68	0,74
6	4,32	0,67
7	4,31	0,68
8	4,77	0,63
9	4,83	0,79
10	4,50	0,88

Source: own study

Test F showed that the average WJC score scores of all beers combined vary depending on the person performing the assessment (Table 1). The NIR test showed that the No. 2 and No. 4 evaluators were remarkably different from the team. Expert No. 2 assessed the organoleptic quality of beers at a significantly lower level than the others (3.86 on average). Expert No. 4 assessed the organoleptic quality of beers at a significantly higher level than the others (5.18 on average). Therefore, further analysis of the results was performed for a team of 8 people, omitting evaluators No. 2 and 4.

3.1 Results of organoleptic quality assessment of the tested beers depending on the type of vessel

The results of the organoleptic quality assessment of all beer samples evaluated in different vessels are presented in Table 2 (mean values for eight evaluators). The nonparametric Kruskal-Wallis test showed significant differences between organoleptic quality. A post hoc analysis of Dunn's test showed that beer served in a tulip glass was rated lower than beer served in a mug and a glass.

Table 2. Results of the organoleptic quality assessment (WJC) of all types of beer evaluated in different vessels

Glass type	mean
beer mug	4,90
tulip glass	4,45
glass	4,73

Source: own study

The study results show that the organoleptic quality of light, dark, and wheat beer is significantly influenced by the type of vessel in which the beer is served. Analysis by the Kruskal-Wallis test showed that the variation of the WJC parameter depending on the type of vessel occurs in relation to light beer, dark beer and wheat beer ($p<0,05$). The Dunn test allows us to conclude that the average WJC level of light beer is highest for samples served in a glass and lowest for samples in a tulip glass. The organoleptic quality of dark beer is lower when it is served in a glass and higher when it is served in a mug and a tulip glass. The organoleptic quality of wheat beer was assessed higher if the samples were given in a mug than other vessels (Figure 1).

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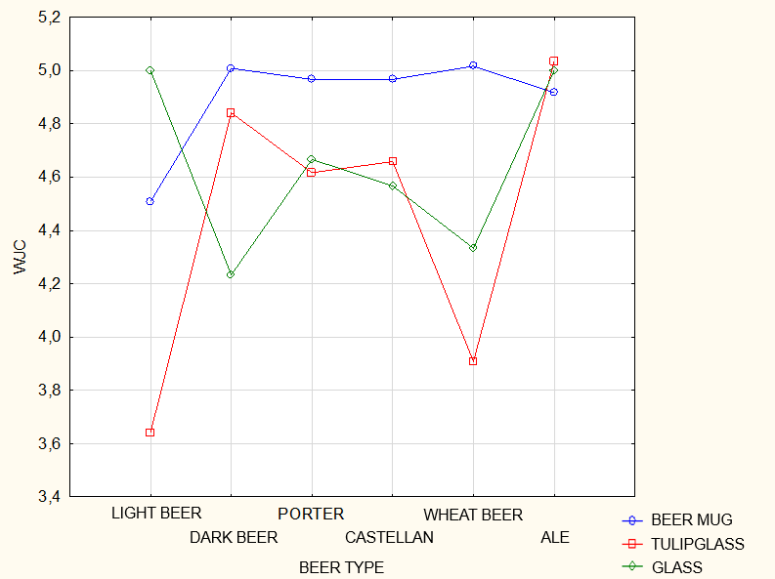


Figure 1. Organoleptic quality (WJC) of individual beer types assessed in different vessels
Source: own study

3.2 Results of the assessment of organoleptic characteristics of the tested beers depending on the type of vessel

The taste of light beer served in a tulip glass was evaluated at a lower level than that of the same beer served in the other vessels. The type of vessel had no impact on the assessment of the taste of other types of beer (Figure 2).

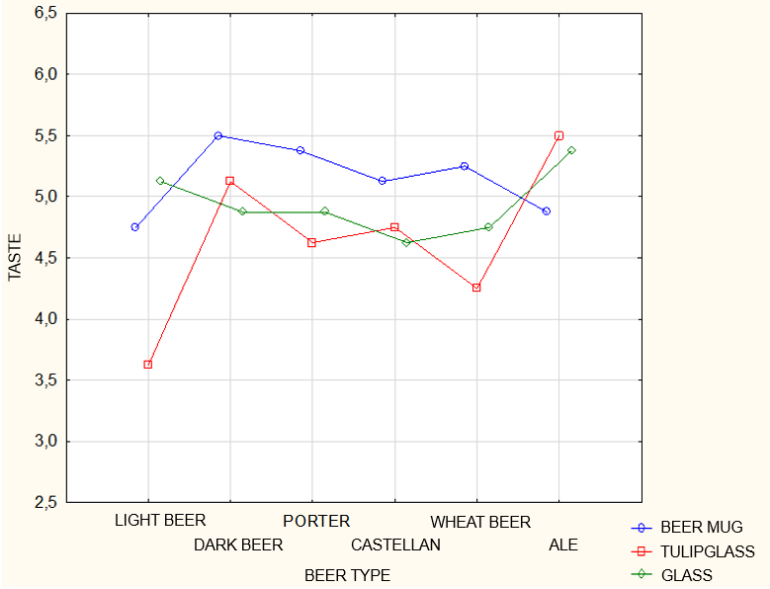


Figure 2. Taste of different types of beer evaluated in different vessels
Source: own study

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In the case of light beer, the palatability of this beer served in a tulip glass was assessed at a lower level than the palatability of the same beer served in a glass. On the other hand, in the case of wheat beer, the palatability of this beer served in a mug was assessed at a lower level than the palatability of the same beer served in a mug. The vessel type did not affect the assessment of the palatability of other types of beer (Figure 3).

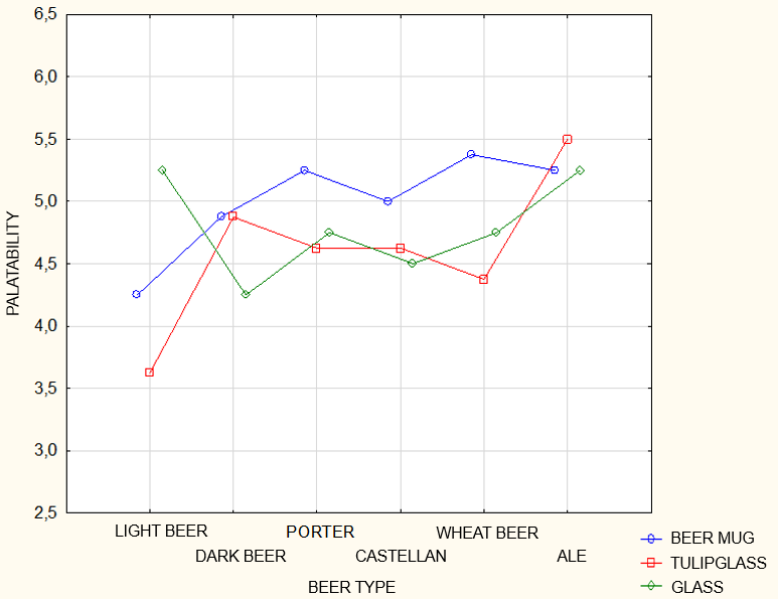


Figure 3. The palatability of different types of beer evaluated in different vessels
Source: own study

The saturation of wheat beer served in a tulip glass was assessed at a lower level than beer served in a mug. The type of vessel did not affect the results of the assessment of the saturation of other types of beer (Figure 4).

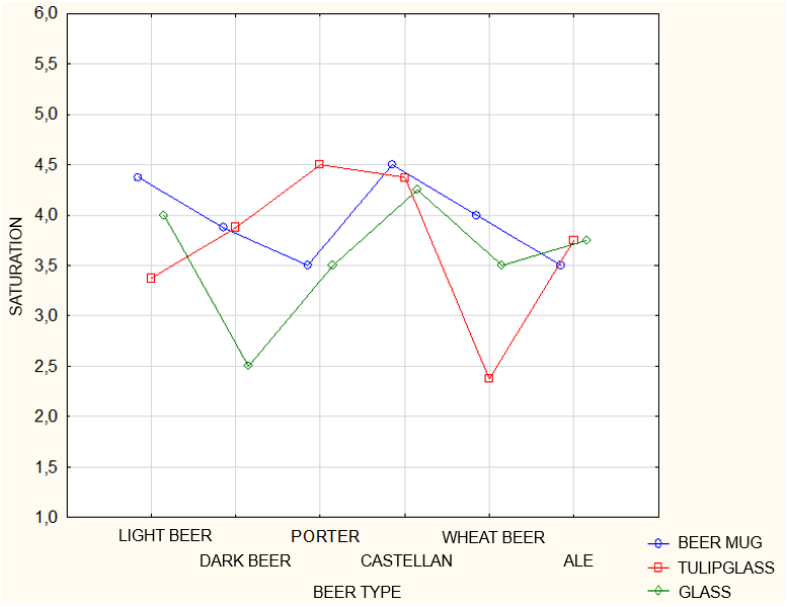


Figure 4. Saturation of different types of beer evaluated in different vessels
Source: own study

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The bitterness of a light beer served in a tulip glass was rated lower than beer served in a mug and a glass. The type of vessel had no impact on the results of the bitterness evaluation of other types of beer (Figure 5).

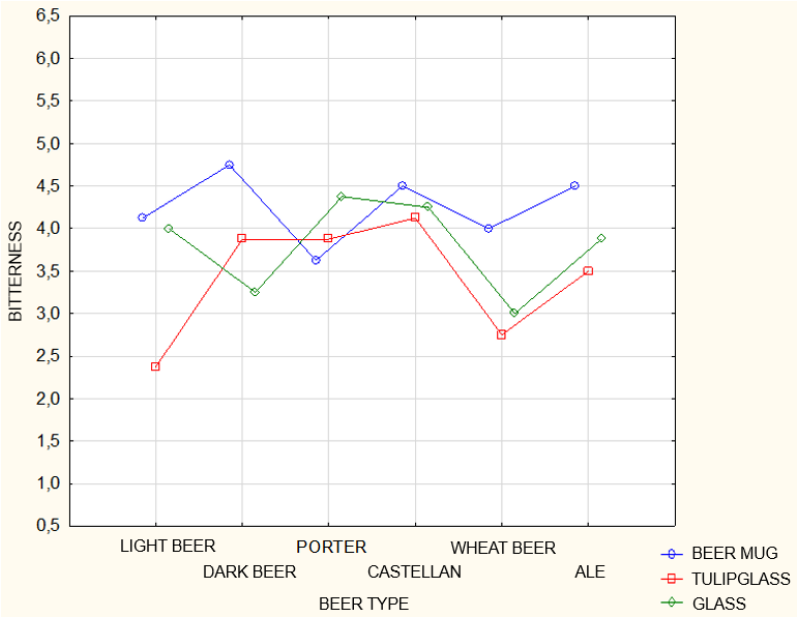


Figure 5. Bitterness of different types of beer evaluated in different vessels
Source: own study

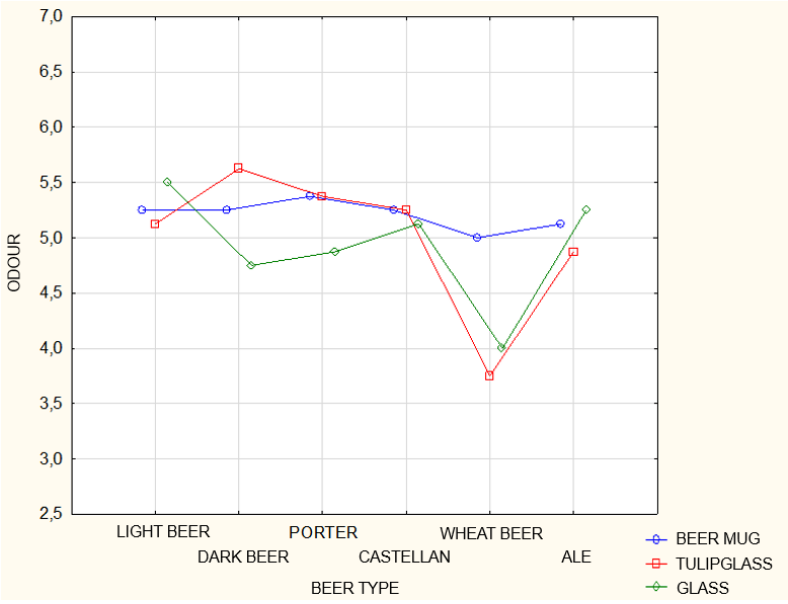


Figure 6. The odour of different types of beer evaluated in different vessels
Source: own study

The type of vessel had no statistically confirmed effect on the results of the odour assessment of any beer (see Figure 6 above).

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Conclusions

Many sensory evaluation methods serve samples in identical containers with the most "neutral" appearance possible. This procedure is used precisely to limit the influence of the container's appearance on the evaluation results. However, the results of such studies do not correspond to the situations in which beer is consumed every day. Therefore, It is justified to conduct studies in such a way as to consider the influence of glass on taste values because in "normal" everyday conditions, the consumer always consumes the drink in some container, and the form of this container will affect his or her experience. The studies described in this publication were conducted with this assumption in mind.

It turns out that respondents have expectations and associations even before they touch the glass in which the drink is served and before they taste the drink itself. These associations concern both taste values (bitterness, sweetness, acidity) and the general impression of the drink (whether it will be tasty). Consumers also tend to associate glasses with straight vertical walls as intended for drinking non-alcoholic beverages. In contrast, glasses with sloping walls are associated as intended for alcoholic drinks (Attwood et al., 2012). Other studies have shown that respondents claim that the drink tastes better when served in a glass appropriate for it (Wan et al., 2015). It seems reasonable to assume that the associations can modify the sensory evaluation results the assessors have before starting the evaluation (Casales-Garcia et al., 2023). Associations related to the respondent's personal life experiences will also be crucial (Wan et al., 2015).

It is commonly believed that the shape of the glass affects the perception of the drink's aroma. Glassware that widens upwards (such as a goblet or other "tulip" type glass) allows aromas to concentrate at the top, allowing for a fuller experience of rich aromas. Narrow, tall glasses, such as those for wheat beer, help maintain the foam, which retains the aromatic substances. However, these principles were not confirmed in the studies that were conducted. The results did not indicate statistically significant differences between the perception of the beer's aroma and the shape of the glass in which it was assessed.

The research conducted by Spence & Van Doorn (2017) showed that beer served in a mug was rated higher in terms of appearance than the same drink served in a different glass. In this study, beer served in a mug was also rated higher, considering that the evaluation was not about appearance but about tastiness. The conclusions from the research of Wan et al. (2015) also indicate that beer served in a mug is usually rated higher.

The same authors also report that the intensity of beer flavour was rated about 6% higher when participants tasted beers from a curved-walled vessel than when they were served in straight-walled vessels. In this study, however, the opposite result was obtained. Beers were rated higher when served in a mug with traditional straight walls with a handle. In most cases, the same beers were rated lower when tasted from an oval-shaped glass and a goblet. Results similar to those described in this publication were obtained by Casales-Garcia et al. (2023). They indicate that beers in a tall glass are perceived as less bitter than those served in a mug. This study also observed a similar relationship between dark beer and light beer, which was slightly weaker. The same authors also prove that beers served in tulip glass were rated higher. In this study, the opposite results were obtained – beer served in tulip glass is usually rated lower. Light beers' taste, palatability, saturation, and total quality (WJC) were especially evaluated when this beer was served in a tulip glass.

On the other hand, a significant variation in palatability and saturation was noted for wheat beer, depending on the type of vessel. No statistically significant differences in their parameters were recorded for the remaining beers depending on the type of vessel.

The results obtained in this study indicate that the sensory characteristics of beers were rated lower than those of other authors. In the case of light beer, differences in the ratings of taste, palatability and bitterness were noted

depending on the type of vessel in which they were served. In the case of wheat beer, differences in the ratings of palatability and saturation were noted.

The conducted research expands the current knowledge on the influence of the vessel's shape on the experience of drinking beer. It should be noted, however, that there is still much to be discovered in this area. The brewing industry and the glass industry are aware of the different requirements of modern consumers.

Therefore, they undertake activities related to introducing various new types of beer and different types of glass. These activities are related to the desire to stand out in the market and offer customers new, original products. However, such a large number of types of beer available on the market and an equally large number of different types of glass available means that there can be dozens or even hundreds of possible interactions between these products. Both customers and manufacturers should be aware of the relationships between individual products, as these relationships affect the use of material, production volume and consumption. In today's sustainable world, it's critical not to make purchases of things that aren't needed. Consumers who know the relationship between the characteristics of glass and beverage can make more informed and thoughtful purchases. They should buy glassware that best suits the drinks they consume.

On the other hand, manufacturers have more opportunities to offer products that will suit their customers. However, this study has some limitations. This study examined how the shape of the glass affects the drinker's perception. The thickness of the wall of the product is also a parameter that affects perception. The wall directly touches the mouth of the drinker. Therefore, it can affect its perception. It would be interesting to study how the vessel wall's thickness affects the drinker's perception. In this study, undecorated products were used. It is worth checking how decorations on the glass (for example, beer brands) affect the drinker's perception. This fact means that opportunities for new research on how different types of beer and different types of glass interact are constantly emerging.

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DIGITAL TRANSFORMATION: A COMPARATIVE ANALYSIS OF SME DIGITAL MATURITY MODELS*

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Abstract. Digital transformation is increasingly recognised as a critical driver for competitiveness and sustainability in today's digital economy. However, small and medium-sized enterprises (SMEs) often face significant resource constraints when implementing effective change. This paper undertakes a systematic review and comparative analysis of five prominent digital transformation maturity models. These models were selected for review based on their scholarly relevance, as determined through systematic filtering of relevance criteria within peer-reviewed academic sources. The study investigates the transformation process by examining models, thereby identifying common dimensions, varying maturity level structures, and implementation approaches that influence the process. A six-step framework was created to guide SMEs in selecting and tailoring a digital maturity model that aligns with their strategic objectives and operational realities. Following a thorough review and comparison of a range of models, a six-step framework was developed to assist SMEs in selecting and customising a digital maturity model aligned with their strategic objectives and operational realities. The framework under discussion places particular emphasis on three key aspects. Firstly, it is essential to undertake a thorough contextual analysis. Secondly, it is crucial to evaluate the available resources. Finally, the framework advocates a phased implementation strategy to ensure a sustainable digital transformation journey. The findings have implications for both academic discourse and practical application. They furnish SMEs with actionable insights that facilitate navigation of the challenges of digital innovation and enhancement of overall business performance.

Keywords: digital transformation; digital maturity; maturity models; SMEs; comparative analysis

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JEL Classifications: M10, M12, M13, L25, O32

1. Introduction

Digital transformation has become a fundamental driver of business growth and sustainability in the digital economy. The focus has shifted from merely implementing the latest information systems to necessitating a comprehensive restructuring of business processes, operational models, and corporate culture (Silva et al., 2025). Digital transformation is defined as integrating digital technologies across all business functions, with the fundamental purpose of reshaping operations, customer interactions and value delivery mechanisms (Dwivedi et al., 2020). Furthermore, digital transformation is linked to sustainable business practices. Scholars and practitioners alike assert that digital innovation should not be exclusively oriented towards the pursuit of profit. Instead, environmental sustainability and social responsibility should be considered (George & Schillebeeckx, 2022; Martínez-Peláez et al., 2023; Zhang et al., 2022).

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For organisations that successfully manage digital transformation, the rewards are significant. As Westerman et al. (2014) demonstrate, companies that effectively integrate technology and leadership capabilities tend to achieve higher profitability and competitive advantages over their peers. However, it should be noted that not all digital transformation strategies are equally effective. Indeed, research has shown that poorly executed digitalisation efforts can lead to substantial financial losses, devastatingly affecting small and medium-sized enterprises (Westerman et al., 2014).

The European Commission states that SMEs comprise over 99% of EU businesses and provide around two-thirds of all jobs (Brodny & Tutak, 2022). SMEs have fewer than 250 employees, a turnover of under €50 million, or revenues of under €43 million. They contribute over half of the EU's GDP and add over 50% of the value of the non-financial corporate economy. SMEs often struggle with financial constraints, lack of skilled staff, lower risk tolerance and limited access to funding. (Kádárová et al., 2023) (Nebati et al., 2023) Furthermore, their diminished scale and weaker financial reserves render them more susceptible to market fluctuations and technological transitions.

Notwithstanding the challenges SMEs face, the digital transformation process offers considerable opportunities for these enterprises. By leveraging digital tools, SMEs can optimise business processes and reduce operational costs through automation and digital workflow management. Li (2022) posits that a Digital Transformation Maturity Model (DTMM or DMM) constitutes an efficacious approach to facilitating digital transformation in SMEs. As Gollhardt et al. (2020) demonstrate, these models analyse multiple dimensions of digital transformation, including technology adoption, organisational strategy, leadership, culture, and ecosystem integration. These models enable SMEs to methodically evaluate their digital maturity and compare their progress with industry benchmarks (Blatz et al., 2018). Digital maturity models are of significance to companies as they provide a structured framework for assessing and identifying gaps, prioritising initiatives, and aligning strategies with long-term goals. In addition, they serve to reduce the risk of costly missteps during transformation.

Research shows that digitally mature organisations outperform their competitors financially. A Deloitte study found digitally mature companies are three times more likely to exceed industry averages in financial performance. This success is attributed to enhanced efficiency, improved quality, better customer satisfaction and increased employee engagement. Advanced digital maturity also enables innovation and adaptation to market changes (Gurumurthy et al., 2020)

To become a 'Digital Master', effective leadership and change management are key. However, some DMMs lack a comprehensive assessment framework. This makes choosing the right DMM crucial for SMEs to improve their digital transformation (Westerman et al., 2014). This article therefore, investigates the degree to which a DMM is required in the SME context and addresses the following research questions:

- RQ1: What are the most common dimensions of digital maturity models?
- RQ2: What maturity-level structures and assessment methods characterise each of the selected digital transformation maturity models, and how do these structural choices affect their complexity and suitability for resource-constrained SMEs?
- RQ3: Which organisational or local factors most strongly shape an SME's decision to adopt one digital maturity model over another?
- RQ4: Which of the reviewed maturity models provides SMEs with the most feasible, actionable and results-oriented path toward digital transformation?

The answers to these questions will generate an evidence-based decision framework that helps SMEs navigate the crowded landscape of digital maturity models. In doing so, the study aims to advance scholarly understanding of digital transformation while equipping practitioners with a pragmatic roadmap toward “Digital Mastery”.

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2. Theoretical Background

Digital transformation (DT) is the integration of advanced technologies, including artificial intelligence, big data analytics, cloud computing, the Internet of Things, and more, across an organisation (Vial, 2019; Henriette et al., 2016). This integration aims to reconfigure the processes of value creation and delivery. Integrating digital capabilities within products, processes, and business relationships enables firms to transition from automation to a novel operating logic that is data-driven, interconnected, and perpetually adaptive. DT has evolved from early IT-centric initiatives seeking process automation to enterprise-level programmes synchronising digital investments with business strategy (Fitzgerald et al., 2013; Matt et al., 2015). Organisations that effectively manage this transition gain a competitive advantage in innovation speed, operational efficiency, and customer relevance. Conversely, organisations that fail to do so face an increasing risk of becoming obsolete due to intensified competition.

Firstly, integrating technology, including cloud-based ERP systems, AI-driven analytics, and robotic process automation, underpins scalability and the capacity for real-time decision-making (Vial, 2019; Radicic & Petković, 2023). Secondly, cultural change is indispensable. A leadership-driven climate of experimentation, learning, and agility has been shown to mitigate resistance and unlock the full value of digital tools (Kotter, 2006; Kane et al., 2015; Goran et al., 2017; Hartl, 2019; Shin et al., 2023; Firican, 2023). Thirdly, business-model innovation leverages digital affordances such as platform plays, subscriptions, and data monetisation to create novel revenue streams and fend off disruption (Rogers, 2016; Lee, 2017; Vial, 2019; Lee & Mangalaraj, 2022; Rojas-Segura et al., 2023; Kao et al., 2024; Oncioiu et al., 2019; Robertsone & Lapiņš, 2023). Finally, the use of data and AI to personalise omnichannel journeys is a key element of customer-experience enhancement, driving loyalty and margin growth (Verhoef et al., 2015; Lemon & Verhoef, 2016; Verhoef et al., 2021; Aloysius et al., 2023; Li et al., 2023; Luo et al., 2023; Shi et al., 2024).

Despite encountering financial and human-capital constraints that hinder growth (OECD SME and Entrepreneurship Outlook, 2023), SMEs have the potential to leverage digital technologies to expand market reach, streamline operations, and fortify customer relationships (Telukdarie et al., 2022; Medina et al., 2024; Sagala & Őri, 2024; Silva et al., 2025). Empirical studies have confirmed a positive correlation between digital maturity and competitive performance in SMEs (Bouwman et al., 2019). The most significant challenges are as follows: high initial costs (Ferreira et al., 2019), workforce skill deficits (Telukdarie et al., 2022), cultural and organisational inertia (Kotter, 2006), and heightened cybersecurity exposure (Von Solms & Van Niekerk, 2013). These impediments have been shown to exacerbate one another, thereby impeding transformation efforts when not addressed holistically. SMEs that succeed in DT display strong commitment from the top of the management structure, an articulated digital vision, and sustained investment in workforce upskilling (Sebastian et al., 2017; Vey et al., 2017). Agile, iterative processes support rapid experimentation, while partnerships with technology providers and research institutions help compensate for internal resource constraints (Yoo et al., 2012).

Capability Maturity Models (CMMs) offer staged diagnostic frameworks that chart the progression from ad-hoc digital activity to optimised, continuously improving practice (Paulk et al., 1993; Wendler, 2012; Becker et al., 2009). As posited by Paulk et al. (1993) and de Bruin et al. (2005), the most common models delineate five levels – initial, managed, defined, quantitatively managed, and optimising – against which firms benchmark their digital capabilities and identify targeted improvements. Domain-specific variants, including the Digital Maturity Model and Industry 4.0 Maturity Model, adapt the CMM principles to evaluate the readiness for emerging technologies and effective resource allocation (Berghaus & Back, 2016; Katuu, 2020). Maturity models serve three primary functions: descriptive, prescriptive, and comparative. These models depict anticipated trajectories of capability growth (Roeglinger & Poeppelbuss, 2011). For resource-constrained SMEs, streamlined and flexible maturity models provide actionable roadmaps while avoiding the diagnostic overload common in enterprise-scale frameworks (Schumacher et al., 2016; Mittal et al., 2018; Gökalp & Martinez, 2021). Adopting such models has been demonstrated to facilitate incremental progress, cost-effective technology investment, and evidence-based monitoring of digital initiatives.

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From a foundational theory perspective, the concept of digital transformation capability is most persuasively illuminated by three complementary lenses. The Resource-Based View posits that sustainable competitive advantage is derived from possessing and exploiting information assets and analytics competencies that are valuable, rare, inimitable, and non-substitutable (Barney, 1991). The Dynamic-Capabilities school posits that firms perpetually discern, appropriate, and metamorphose these assets within volatile contexts (Teece et al., 1997; Eisenhardt & Martin, 2000). Finally, the Technology–Organisation–Environment (TOE) view situates adoption decisions at the intersection of perceived technological advantage, organisational readiness, and competitive pressure (Oliveira & Fraga Martins, 2011; Baker, 2012). The integration of these theories elucidates the rationale behind accumulating resources and implementing context-sensitive adaptation in the context of mature digital capabilities.

The successful execution of digital transformation is contingent upon implementing meticulous change management processes that align technology with human behaviour. As posited by Lewin, the three-stage model of unfreezing, changing, and refreezing is predicated on the importance of destabilising legacy routines prior to institutionalising digital ones (Lewin, 1947). As contemporary syntheses have highlighted, readiness, vision clarity, and participative communication are significant predictors of employee acceptance (Armenakis & Bedeian, 1999). A review of Kotter's eight-step model reveals that visible short-term wins and empowered coalitions accelerate digital uptake (Appelbaum et al., 2012). Table 1 synthesises common dimensions reported across the literature.

Table 1. Synthesises common dimensions

Dimension	Representative Definitions
Strategy & Governance	Vision, leadership, funding, KPIs
Processes & Operations	Standardisation, automation, integration depth
Technology	IT infrastructure, platforms, interoperability
Data Management	Quality, accessibility, analytics capability
People & Culture	Skills, change readiness, learning climate
Customer Value	Digital products, channels, experience

The integration of these strands gives rise to a multilevel conceptual model. Contextual antecedents and adaptation mechanisms mediate the relationship between the chosen digital maturity model and performance, innovation and customer experience outcomes. Constructive theorising encourages explicit mapping of the variables in question and the rationale behind their relationship. Recent papers advocate visual articulation to translate diagnostic insights into actionable roadmaps. Despite the rapid proliferation of models, systematic reviews have exposed two persistent research gaps. Firstly, empirically validated criteria are absent to match specific SME contexts with an appropriate DMM. Secondly, there is a paucity of cross-industry evidence on the performance payoff of progressing through maturity (Teichert, 2019; Gökalp & Martinez, 2021). The present study contributes to the existing literature in two ways. Firstly, it provides a selection framework for practitioners and offers a theory-driven agenda for scholars.

3. Methodology

The selected methodology is written consecutively in the following chapters as researchers proceeded.

3.1 Search Strategy

Following PRISMA guidelines, we executed a systematic search in Scopus, Web of Science, Google Scholar and ScienceDirect for the string ("digital transformation" OR "digitalisation") AND ("maturity model*" OR "self-assessment" OR "maturity") AND SME covering January 2010 – December 2024. An open-access filter maximised replicability while including grey literature and conference papers reduced publication bias.

3.2 Inclusion Criteria

Records were retained when they contained these factors:

1. proposed a digital-maturity model (DMM);
2. explicitly targeted SMEs or provided evidence of SME adaptability;
3. contained a complete model description (levels, dimensions, assessment method), and
4. were available in English under open access.

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3.3 Screening & Reliability

All 450 hits were exported to reference-management software. After automated and manual duplicate removal, 320 unique records remained. Reviewers then screened titles/abstracts and full texts against the criteria above. Inter-rater reliability exceeded $\kappa = 0.80$ at each stage; disagreements were resolved by authors' consensus. Sequential filtering (content relevance → applicability to resource-constrained settings → methodological rigour) yielded a final corpus of five DMMs (see Table 2).

Table 2. Stepwise selection of resources

Filtering Action	Number of Articles
Initial Search	450
Duplicate & Date Exclusion	320
Content Screening	150
Applicability Check	20
Final Fit & Rigor	5

3.4 Evaluation Framework

Multi-criteria decision (MCDA) rubric with four criteria—scope (weight = 0.25), complexity (0.25), validation evidence (0.25) and actionability (0.25) was developed. We centred the multi-criteria decision analysis on four factors, i.e. scope, complexity, validation evidence and actionability. Scope tells managers how many organisational domains the model covers (critical for seeing the "whole picture"). Complexity reflects the practical burden: the required number of questions, workshop time, and analytical skills. Validation gauges how rigorously the model has been empirically tested (case studies, surveys, Delphi panels), ensuring credibility. Actionability measures the clarity and granularity of the improvement guidance that follows the assessment—often the decisive benefit SMEs seek. To avoid embedding a priori bias in the analysis, each criterion was assigned an equal weight (0.25). A sensitivity test confirmed that moderate weight shifts (±0.10) did not materially change the model rankings. Each model was appraised with a multi-criteria decision analysis (MCDA) (see Table 3) rubric comprising four equally weighted dimensions:

Table 3. Multi-criteria decision analysis (MCDA)

Criterion	Weight
Scope (breadth of organisational areas covered)	0.25
Complexity (assessment workload, item count)	0.25
Validation evidence (empirical grounding)	0.25
Actionability (clarity of improvement guidance)	0.25

Items were rated on a 0–5 Likert scale and normalised to percentage scores to facilitate cross-model comparison and sensitivity analysis.

4. Summary of Reviewed Maturity Models

The five maturity models were chosen through a systematic screening of peer-reviewed sources to ensure scholarly relevance, yielding a balanced and methodologically sound comparison set that remains practical for resource-constrained SMEs while spanning the full conceptual breadth of the digital-maturity literature. First, three of the models—Medina et al. (2024), Blatz et al. (2018) and Schallmo et al. (2020)—were expressly designed for SMEs, meeting the study's primary inclusion criterion of direct small-firm applicability; the remaining two—Aras & Büyüközkan (2023) and Tubis (2023)—although sector-agnostic, provide flexible, multi-dimensional structures that empirical work has shown can be tailored to smaller enterprises, thus ensuring external validity without sacrificing SME relevance. Second, the set embodies methodological diversity: Blatz offers a lean three-level scheme suited to rapid baseline assessments, Medina and Aras employ richer five-level scales grounded in Design Science or systematic-review rigour, while Tubis adds a two-tier (organisational/process) lens that exposes intra-firm maturity gaps; this range of level structures and dimensional depths enables a nuanced analysis of complexity–benefit trade-offs. Third, all five models include self-assessment instruments and action-oriented roadmaps, satisfying the study's requirement that candidates

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support diagnosis and improvement—critical for SMEs that must quickly translate insights into concrete steps. Fourth, each model reports at least pilot-level empirical validation (e.g., cross-industry German survey data for Blatz, a French/Swiss SME pilot for Medina, and a manufacturing case for Tubis), allowing the researchers to compare evidence-based performance rather than purely conceptual propositions. Finally, the models collectively survived a transparent filtering pipeline—from an initial 450 articles to five finalists—based on open-access availability, recency, SME focus, and methodological rigour. This ensures the comparison rests on a systematically defensible foundation rather than convenience sampling. Together, these criteria are diverse yet comparable, empirically grounded yet adaptable, and universally accessible while remaining sharply focused on the digital transformation realities of SMEs. Table 6 summarises the key characteristics of models.

Table 4. Summary of key characteristics

Model	Levels	Items	Validation	Primary Strength
Blatz et al. (2018)	3	18	6 German SMEs (pilot)	Feasibility
Schallmo et al. (2020)	4–5	33	Workshops (n = 12)	Participatory design
Tubis (2023)	5	105	Survey (n = 42)	Process granularity
Medina et al. (2024)	5	27	Case studies (3 Swiss SMEs)	Diagnostic depth
Aras & Büyüközkan (2023)	5	24	Expert Delphi (15)	Holistic roadmap

The Digital Business Transformation for SMEs: Maturity Model for Systematic Roadmap - The model under scrutiny was analysed by Medina et al. (2024), who provided a self-assessment tool online and a structured roadmap to facilitate SMEs' digital transformation. Considering the rapid technological advancements and the heterogeneity of SMEs' digital literacy levels, this framework is designed to assist businesses in evaluating their current digital maturity and methodically enhancing their digital competence. The model synthesises theoretical and practical perspectives, thereby ensuring that businesses possess a clear strategic direction.

The Digital Business Transformation for SMEs: Maturity Model for Systematic Roadmap (Medina et al., 2024) is built upon (Berghaus & Back, 2016) and adjusted by using a Design Science Research (DSR) approach, which is widely applied in information systems and technology-driven studies. The DSR methodology is centred on the design, construction and evaluation of artefacts, ensuring that the model is practically relevant and scientifically rigorous.

The DMM, which has been meticulously designed for this purpose, enables the assessment of the digital maturity of an SME across nine distinct dimensions, encompassing a total of 27 maturity criteria. It is important to note that each criterion is comprised of five levels of maturity. The present study is subject to several constraints. While acknowledging the merits of drawing on the dimensions and criteria and their pertinence to the setting, they elected not to revisit the dimensions of digital maturity. In addition, the evaluation was conducted with a limited sample size of SME managers. Furthermore, it is important to acknowledge that all artefacts were conceived and evaluated in French within the Swiss Jura Arc region. This may limit the broader applicability of the findings.

Maturity Model of Digitization for SMEs - An analysis of the Maturity Model of Digitisation for SMEs (Blatz et al., 2018) provides small and medium-sized enterprises with a self-assessment tool and a structured roadmap to guide their digital transformation efforts. The overarching objective of this framework is to assist businesses in assessing their current digitisation status and methodically advancing towards higher levels of digital competence. The model synthesises insights from empirical research with practical implementation considerations, ensuring organisations possess a clear strategic direction. The Maturity Model of Digitisation for SMEs (Blatz et al., 2018) is a construct built upon prior maturity-model research and applies recognised academic methods for survey design and data analysis. To this end, they reviewed existing maturity models, subsequently developing a six-dimensional assessment tool and validating it through quantitative and qualitative means. This stepwise methodology is employed to ensure that the resulting maturity model is both relevant and empirically grounded.

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The model under investigation is composed of six core dimensions: (1) Strategy & Leadership, (2) Company Culture & Organization, (3) IT Infrastructure, (4) Data Maturity, (5) Processes & Operations, and (6) Product (Use-Phase). It is asserted that this structure facilitates a nuanced appraisal of a company's digital maturity. Each dimension is subdivided into a series of quantifiable elements, which are then typically evaluated using a five-point Likert scale. A weighted approach is then employed to produce an overall maturity score, which is subsequently mapped onto three maturity levels. This tiered structure provides SMEs with a straightforward means of identifying which areas, such as management buy-in, data governance, or process automation, require the most attention.

Notwithstanding the study's practical applications, it is important to acknowledge the limitations inherent to the research design. Notably, the authors collated 81 initial datasets but ultimately deemed only 55 suitable for analysis, a factor which may limit the generalisability of the findings. The participating firms were drawn from various sectors, including but not limited to industrial manufacturing, information technology and telecommunications, and consulting. This diversity necessitates a bespoke approach to weighting dimensions tailored to each industry's specific requirements. Moreover, the emphasis on German SMEs may restrict applicability to diverse cultural or regulatory environments. Nevertheless, by highlighting correlations across dimensions, particularly between senior leadership support and an organisation's openness to new technologies, this model underscores the interdependency of strategic, technological, and cultural factors in driving digital transformation among SMEs.

An Approach for a Digital Maturity Model for SMEs based on Their Requirements - Another model that has been analysed by Schallmo et al. (2020) proposes a Digital Maturity Model (DMM) that has been tailored to small and medium-sized enterprises (SMEs). The authors ensure that the model addresses practical requirements while remaining grounded in research by synthesising empirical insights derived from SME interviews and a systematic literature review.

The proposed Digital Maturity Model (Schallmo et al., 2020) does not adhere to a single design science research framework in the strict sense of the term. Instead, it employs a stepwise, deductive methodology. Initially, the authors collated SME-specific requirements for digital maturity through workshops and interviews. Subsequently, a comparison is made between these real-world needs and existing maturity models to identify gaps in coverage and usability. The analysis undertaken has resulted in the identification of six focal dimensions. It is vital to acknowledge the significance of the following aspects for the specific needs of SMEs: Digital Strategy, Partner Interface, Processes, Employees & Technologies, Products & Services, and Customer Interface. Each dimension comprises a series of pertinent questions or indicators, thus facilitating a comprehensive, systematic self-assessment of digital progress.

However, it should be noted that the study is subjected to several constraints. The recommendations are primarily derived from a restricted series of interviews conducted with SMEs in Southern Germany. This methodological approach may constrain the findings' generalisability across diverse regions or industrial domains. Furthermore, a clear, standardised questionnaire reflecting all six dimensions is still under development. Nevertheless, by emphasising direct input from SME stakeholders, the model offers a pragmatic pathway for smaller firms seeking to map their digital maturity and prioritise transformation initiatives.

Holistic Digital Maturity Model Based on a Systematic Literature Review - The present study analysed the holistic digital maturity model by Aras & Büyüközkan (2023), the objective of which is to guide organisations through their digital transformation journey by providing a comprehensive self-assessment framework and a structured roadmap for improvement. It is acknowledged that contemporary enterprises encounter intricate challenges pertaining to people, processes and technology. The model under discussion herein focuses on assisting businesses in evaluating their current level of digital maturity and systematically charting a course towards higher degrees of digital competence. Integrating theoretical insights from a systematic literature review and practical perspectives on organisational readiness ensures that companies possess a clearly defined strategic direction.

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The proposed Holistic Digital Maturity Model is predicated on a four-stage approach: Awareness, Readiness, Planning, and Execution, to capture an organisation's full transformation lifecycle. The authors have identified six core dimensions, which are further subdivided into 24 sub-dimensions. These dimensions are drawn from gaps identified in existing academic research and consultancy-based maturity models. The six core dimensions are as follows: Digital Strategy, Value, Processes, Technology, People & Culture, and Governance & Leadership. The model is sector-independent, thus allowing businesses of diverse sizes and industries to identify existing maturity gaps, prioritise digital initiatives, and align these with broader strategic goals.

However, the study acknowledges several constraints. While the conceptual design is comprehensive, further empirical validation is required across various organisational contexts to confirm its universal applicability. Furthermore, integrating dynamic cultural or regional factors may necessitate further customisation for specific sectors. Nevertheless, the holistic maturity model under discussion here offers a wide-ranging, methodical assessment tool enabling organisations to systematically evaluate their digital transformation readiness. In addition, it provides a framework within which they can develop an actionable roadmap for improvement and sustain long-term digital progress.

Digital Maturity Assessment Model for the Organizational and Process Dimensions - The final model examined in this study is the Digital Maturity Assessment Model for the Organisational and Process Dimensions (Tubis, 2023). This model offers manufacturing and service enterprises a two-level self-assessment tool and a roadmap to guide their digital transformation. It is acknowledged that digital initiatives can vary considerably in nature, whether targeting an entire organisation or specific operational processes (e.g. production, logistics). This model provides a structured approach for businesses to assess their current digital maturity and formulate a strategic plan to progress towards higher levels of digitalisation.

The Digital Maturity Model (DMM-OP) is predicated on the principle that digital transformation should be evaluated in two distinct yet interconnected dimensions:

1. The organisational dimension concerns company-wide aspects such as strategy, corporate culture, data management and business-partner relationships.
2. Process Dimension – This concept pertains to the digital transformation of operational levels, such as production or logistics processes. Sub-areas such as performance management, process management, employee behaviours, and the supporting technology infrastructure are assessed in detail.

Each dimension is divided into specific areas: data management, cyber security, performance management, and employee development. These areas are then subdivided into five maturity levels, ranging from "Basic" through "Discovery", "Developed", "Integrated" and "Leadership". The model employs a continuous representation approach, scoring each area independently. This, in turn, enables organisations to prioritise digital improvements in line with their strategic objectives. A diagnostic questionnaire comprising 105 binary items facilitates self-assessment, providing a comprehensive overview of each maturity area. This approach enables the establishment of clear benchmarks between different divisions within the same enterprise or across multiple organisations.

It is worth noting that the study incorporates an implementation example from a mid-sized electronics manufacturing company. The organisation's production division exhibited comparatively elevated degrees of digital maturity, predominantly attaining "Integrated" levels as indicated by the metrics. Conversely, the logistics division demonstrated a more pronounced presence of intermediate levels, categorised as "Discovery" or "Developed". These observations underscore the pivotal role of parallel improvements across various organisational divisions in facilitating comprehensive digital transformation.

Nevertheless, the study does consider several factors. Using a self-assessment tool necessitates establishing an evaluation team whose mission is to interpret the results. In some instances, the team may be supplemented by domain experts. Furthermore, organisations aspiring towards upper-echelon maturity ("Leadership") should proactively monitor emerging best practices and may find it advantageous to seek external guidance. The model provides companies with a clear roadmap by defining separate organisational and process-level assessments.

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This ensures that transformation initiatives are holistic (company-wide) and aligned with each division's operational realities.

4.1 Commonalities among the Models

All models use multi-dimensional structures (with 5–9 main or macro-dimensions). They typically employ a tiered (usually 3–5) maturity-level scheme. They offer self-assessment instruments (questionnaires or structured frameworks). Emphasis on roadmap or action-oriented guidance post-assessment. Each has at least some form of empirical illustration or partial validation.

Table 5. Commonalities of Analysed Models

Feature	Medina et al., 2024	Blatz et al., 2018	Schallmo et al., 2020	Aras & Büyüközkan, 2023	Tubis, 2023
Primary Purpose	Guide SMEs in assessing digital maturity and providing a structured roadmap.	Help SMEs measure digitisation progress and plan strategic improvements.	Propose a digital maturity approach tailored to SMEs' requirements.	Provide a holistic model to guide the digital transformation journey.	Offer a two-level (org & process) assessment for digital transformation.
Intended Audience	Multi-sector SMEs (though could be adapted to larger firms).	Mainly SMEs (multi-sector)	Primarily SMEs in diverse industries.	Cross-sector (public/private) – entire organisations.	Cross-sector, with an example from manufacturing SMEs.
Number of Core Dimensions	9 dimensions (each 5 levels).	6 dimensions (Strategy, Culture, IT Infra, Data Maturity, Processes, Product).	6 main dimensions (Strategy, Org., Tech, etc.)	6 main dimensions (e.g., Strategy, Value, Processes, Technology, People).	2 "macro-dimensions" (Org & Process), subdivided into 11 areas total.
Assessment Levels	5 maturity levels (from basic to advanced)	3 maturity levels (basic, moderate, advanced).	Varies (~5 levels), referencing a stepwise progression.	5-level scale (Basic → Discovery → … → Leading).	5 levels (Basic → Discovery → Developed → Integrated → Leadership).
Self-Assessment Tool	Yes: online or structured framework with 27 criteria (5 levels each).	Yes: 6 dimensions, multiple choice items; weighted dimension scoring.	Yes (conceptual plus partial validation in SME use-cases).	Yes: includes a 4-phase journey (Awareness→ Readiness→ …) and dimensions.	Yes: 105-question diagnostic; each dimension scored individually.
Focus on Implementation Roadmap	Yes: emphasises incremental steps for each dimension and each maturity level.	Yes: post-assessment recommendations for dimension-specific improvements.	Yes: addresses "where to start," especially crucial for SMEs.	Yes: 4-phase approach (Awareness, Readiness, Planning, Execution).	Yes: 4-phase PDCA-based approach (diagnosis, scoring, improvement steps)
Validation / Empirical Evidence	Small group tested (French/Swiss region) + constraints in generalising.	Survey-based results & cross-industry usage in Germany.	Concept tested among regional SMEs.	Illustrative example with sector-independent coverage; up-to-date references.	Demonstrated a manufacturing SME for verification & validation.

4.2 Differences among the Models

Some use just 3-6 main dimensions (Blatz et al., 2018; Schallmo et al., 2020), while others have more comprehensive breakdowns (Medina's et al. (2024) - 9 dims, Aras and Buyukozkan's (2023) - 24 sub-dims, Tubis's (2023) 2 macro + 11 total areas. Most are SME-focused, but (Aras & Buyukozkan, 2023) specifically addresses cross-sector public & private. Ranges from 3-tier (Blatz) to 5-tier (Medina et al. 2024; Aras & Buyukozkan, 2023; Tubis, 2023. Some rely on simpler questionnaires (Blatz's et al. (2018) approach), while

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others offer extensive question banks (Tubis, 2023 with 105 items). Varies from small pilot tests (Medina et al., 2024) to structured case studies (Tubis, 2023), with ongoing calls for broader empirical studies.

Table 6. Differences among the Models

Aspect	Medina et al., 2024	Blatz et al., 2018	Schallmo et al., 2020	Aras & Büyüközkan, 2023	Tubis, 2023
Number of Dimensions / Sub-Dims	9 dimensions, each has 3 maturity criteria (27 total) across 5 levels.	6 main dimensions (Strategy & Leadership, Culture & Org, IT Infra, Data, etc.).	Typically, 6 major categories, each broken down further.	6 dimensions (Strategy, Value, Processes, Technology, People & Culture, Governance), 24 sub-dims.	2 macro-dimensions (Organizational vs. Process) with 11 total areas (some has sub-areas).
Industry / Sector Focus	Primarily validated in French/Swiss SMEs; emphasis on small group constraints.	Cross-industry SME orientation (esp. Germany).	SMEs in different sectors, focusing heavily on SME needs and constraints	Broad cross-sector scope for both private and public organisations.	Example from electronics manufacturing; flexible enough for multi-sector.
Maturity-Level Details	Each dimension has a 5-tier scale from basic to advanced, referencing DSR approach.	3-tier scale (relatively simpler: basic, intermediate, advanced).	Usually 4–5-tier scale but flexible, as validated with SMEs	5-level scale from "Basic" → "Discovery" → "Developed" → "Integrated" → "Leading."	5-level scale from "Basic" → "Discovery" → "Developed" → "Integrated" → "Leadership."
Assessment Method	Structured self-assessment with 27 criteria. Includes small pilot with SME managers.	Weighted dimension scoring (6 sets of questions) leading to an overall average.	Proposes robust stepwise approach: workshop-based, interviews, readiness checks.	Dimension scoring approach; includes 4-phase journey	105 yes/no questions, each dimension scored. "Continuous representation" for each area
Main Uniqueness / Novelty	Integrates a Design Science Research methodology specifically tested in the French region.	Emphasises a shorter maturity scale (3 levels) and strongly focuses on SMEs.	Explicitly co-created SMEs: ensures the approach addresses their real-world constraints.	Holistic + sector-independent; merges organisational culture, governance, strategy, etc.	Two-tier approach (Org + process) ensures parallel sub-evaluations. 105-item tool.
Roadmap / Implementation Emphasis	Outlines a systematic plan for each dimension, but validation is constrained by a small sample.	Recommends dimension-wise improvement steps after diagnosing.	Stresses alignment with SME business strategy & constraints, with each dimension's roadmaps.	4-phase model (Awareness → Readiness → Planning → Execution) for a full digital transformation.	PDCA-like cycle for each dimension/area, bridging org-level strategy w/ process-level improvements.
Depth of Sub-criteria	27 total maturity criteria (3 per dimension).	6 main dims, further broken into items, but simpler vs 27 or 24 sub-dim.	Balanced (6 dims) approach, typically with detailed sub-criteria if needed.	24 subdimensions; quite detailed breakdown, requires structured team effort.	11 areas / some sub-areas. Some areas are quite extensive.
Validation / Case Examples	Pilot test in Swiss Jura Arc region with small group of SME managers.	Survey-based cross-industry pilot results in mid-sized German firms.	Qualitative pilot among local/regional SMEs, needs more large-scale validation.	Illustrative multi-sector potential; partial example usage from the authors.	Single electronics-manufacturing SME used for verification & improvement suggestions.

All five models aim to help businesses understand their digital maturity across multiple organisational and operational factors. Despite their shared goals (assessment plus improvement roadmap), they diverge in the number of dimensions, depth of sub-dimensions, and implementation details. Some take a holistic approach to an entire organisation; others also zoom in on specific processes (especially in manufacturing or logistics). Each

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includes a tiered maturity scale to show how organisations can evolve from relatively simple digitisation efforts to robust transformations that embed digital capabilities at all enterprise levels.

4.3 MDCA Results

Applying the four-factor MCDA rubric to the five shortlisted models produced the criterion-level scores shown in Table 7. These results quantify each framework's relative strengths and weaknesses along the dimensions of scope, complexity, validation evidence and actionability.

Table 7. MCDA results.

Model	Scope (%)	Complexity (%)	Validation (%)	Actionability (%)
Blatz et al., 2018	72	90	55	84
Schallmo et al., 2020	76	70	68	78
Tubis, 2023	80	60	72	81
Medina et al., 2024	88	50	75	66
Aras & Büyüközkan, 2023	85	55	80	69

The percentage scores derive from a 0–5 Likert rubric multiplied by 20. A score of 5 (100 %) indicates the model excels on that criterion; 3 (60 %) is adequate; 1 (20 %) is weak. For example, Blatz et al. (2018) earned 90 % on complexity because its three-level, 18-item survey can be completed in under an hour, whereas Medina's et al. (2024) richer 27-item, five-level tool scored 50 %. Conversely, Medina's et al. (2024) broad nine-dimension coverage pushed its scope to 88 %, eclipsing Blatz's et al. (2018) 72 %. Validation scores reflect the size and rigour of empirical testing: Aras & Büyüközkan (2023) (Delphi with 15 experts) reached 80 %, whereas Blatz et al. (2018) relied on a small pilot (55 %). Finally, actionability rewards models that translate scores into concrete roadmaps or PDCA cycles: Tubis (2023) (process-level prescriptions) and Blatz et al. (2018) (targeted next steps) scored above 80 %, while Medina's et al. (2024) academic depth but lighter implementation guidance limited it to 66 %. Each number mirrors a transparent, criteria-specific judgement grounded in publicly documented model attributes.

5. Discussion

Across Europe, small and medium-sized enterprises (SMEs) frequently encounter limitations due to constrained resources, smaller workforces, and more circumscribed profit margins. Nonetheless, an increasing number of studies are demonstrating that digital transformation is a key driver of competitiveness and operational efficiency, even for smaller businesses. In such circumstances, the selection of a digital maturity model that is appropriate to the situation becomes a pivotal decision. As demonstrated in the extant literature, the five models under discussion – namely, Medina et al. (2024), Blatz et al. (2018), Schallmo et al. (2020), Aras & Büyüközkan (2023), and Tubis (2023) – provide structured guidance. However, given the differing levels of complexity, focus areas and implementation approaches, the models may offer varying levels of benefit to SMEs.

SMEs characteristically function within the confines of stringent cost controls, necessitating that large-scale digital projects must demonstrate both quantifiable added value and manageable complexity. Whilst certain models – such as those proposed by Medina et al. (2024) or Aras & Büyüközkan (2023) – exhibit relatively robust, multi-layered dimensions (e.g., nine or more sub-dimensions) and a strongly research-based approach, it should be noted that these models may require additional time and expertise, which many SMEs may find challenging to acquire. Conversely, models like Blatz et al. (2018) offer a reduced set of dimensions (6) and a more straightforward three-level maturity scale. This leaner framework can be more accessible to SMEs with limited managerial capacity and fewer staff to devote to extensive audits. Schallmo et al. (2020) similarly emphasise a co-creative design with small businesses, ensuring that the maturity assessment aligns with real-world SME constraints. This is a considerable advantage in industrial environments. However, Schallmo's et al. (2020) approach may necessitate additional facilitation or workshops, which not all SMEs are equipped to host.

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In sectors such as automotive parts manufacturing or electronics, which are prevalent in Slovakia or Germany, logistics and production processes are already subject to significant competition and time constraints. In such cases, it is imperative to undertake a more profound process-level analysis. Tubis's (2023) two-tiered model, which differentiates between organisational and process dimensions, could prove valuable in situations where SMEs require a comprehensive analysis of the disparities between, for instance, well-digitised production lines and under-digitised logistics flows. However, the Tubis (2023) framework, which utilises a 105-item questionnaire, is moderately time-intensive, necessitating the presence of internal teams with the capacity to undertake structured self-assessment and data collection. Whilst it is acknowledged that some SMEs may not have ready access to specialised digital transformation experts, the step-by-step procedure (modelled on a continuous improvement cycle) has been shown to reduce confusion and aid the systematic planning of improvements (Smith, 2023).

RQ1: What are the most common dimensions of digital maturity models?

Analysis shows a clear core set of dimensions that recur in every model:

- Strategy/Leadership/Governance – the presence of a digital vision, top-management support and steering mechanisms
- Processes and Operations – how far routine activities are digitalised, automated and continuously improved
- Technology/IT Infrastructure – availability, integration and scalability of digital tools, platforms and data architectures
- Data and Information Management – quality, accessibility and analytic use of data (explicit in four models, implicit in Tubis (2023).
- People and Culture – employee skills, change readiness and innovation culture
- Customer/Value /Product and Services – the extent to which offerings and customer interfaces are digitally enabled

Some models add extra lenses (e.g., Customer-Interface, Governance, or a separate "Value" dimension), but the six elements above constitute the common denominator.

RQ2: What maturity-level structures and assessment methods characterise each of the selected digital transformation maturity models, and how do these structural choices affect their complexity and suitability for resource-constrained SMEs?

The number of levels and questions is the main driver of complexity. Three-level schemes such as Blatz cut preparation and scoring effort dramatically, whereas five-level, multi-sub-dimension tools yield deeper insights but demand more staff time, facilitation skills and analytic competence.

RQ3: Which organisational or local factors most strongly shape an SME's decision to adopt one digital maturity model over another?

The identified highlights of analysis are several contextual determinants:

1. Resource availability – budget, managerial time, in-house analytical skill; lean models win when these are scarce.
2. Primary transformation goal – a rapid company-wide snapshot vs. a deep process-level diagnosis (drives preference for Blatz et al. (2018) vs Tubis (2023).
3. Variation in maturity across departments – large intra-firm gaps push firms toward two-tier or process-sensitive models such as Tubis (2023).
4. Digital culture and employee readiness – if people & culture are the bottleneck, models that weigh those factors heavily (Schallmo et al., 2020; Aras & Büyüközkan, 2023) are favoured.
5. Sector or regional specifics – e.g., manufacturing SMEs in Slovakia or Germany needing logistics detail may lean to Tubis (2023); firms in the Swiss Jura Arc validated, as in Medina et al. (2024).
6. Tolerance for workshop or co-creation formats – organisations that value participatory design adopt Schallmo et al.'s (2020) interview/workshop-driven approach.

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RQ4: Which of the reviewed maturity models provides SMEs with the most feasible, actionable and results-oriented path toward digital transformation?

Blatz et al. (2018) emerge as the most immediately feasible: the 3-level, 6-dimension survey can be executed quickly, yields a clear scorecard and proposes targeted next steps—ideal when management capacity is tight. Tubis (2023) offers the most actionable process-specific roadmap: its organisational-vs-process split and PDCA-style guidance let a firm prioritise concrete improvements in the weakest department and track them over time. Schallmo et al. (2020) appear in the middle: workshop facilitation makes actions tangible and culturally embedded, but it needs coordination effort. Medina (2024) and Aras & Büyüközkan (2023) deliver the deepest, research-grounded advice; however, their breadth and granularity mean they are best reserved for SMEs that can commit greater time and analytical resources or that have already mastered a baseline model and want a more rigorous second stage.

Consequently, for a typical resource-constrained SME starting out, Blatz et al. (2018) is the most pragmatic single-model choice; Tubis (2023) is the best when departmental imbalance is a critical issue; Schallmo et al. (2020) provide a collaborative path when staff engagement is paramount. SMEs with the capacity for a more elaborate exercise can layer the holistic Medina et al. (2024) or Aras and Büyüközkan (2023) frameworks on top of an initial quick scan. The analysis of several models resulted in creating a six-step framework (see Figure 1). The purpose of this framework is to enable SMEs to make a systematic choice of the digital maturity model and to implement it, with the model in question being one that matches both the company's internal capacity and its strategic transformation goals. The result is a targeted, realistic digital transformation roadmap rather than an overly complex or insufficiently robust approach.

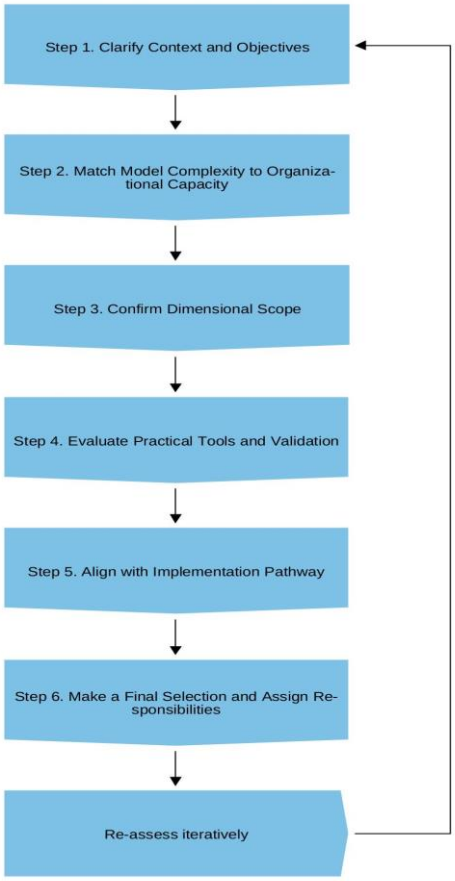


Figure 1. Six step framework

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1. Clarify Context and Objectives
   - Identify Digital Goal - Determine whether the main impetus is a rapid baseline assessment or a deep dive into multiple departments. Also, establish immediate vs. long-term objectives: cost savings, process reengineering, new market entry, etc.
   - Map Constraints - List major constraints (limited budgets, minimal transformation expertise, or time-pressed managers). Note any strategic or cultural barriers (resistance to technology, staff skill gaps, etc.).
2. Match Model Complexity to Organisational Capacity
   - Gauge Resource Availability - Assess how much managerial time is available for surveys/workshops and the level of internal expertise in data analysis or facilitation. If resources are sparse, leaner approaches (e.g., Blatz's simpler 3-level scale) might be preferable.
   - Depth vs. Simplicity Trade-off - Decide if you need a quick, high-level maturity snapshot (Blatz et al., 2018), a moderate-level approach with structured co-creation (Schallmo et al.), or a deeply holistic one (Aras & Büyüközkan (2023), Tubis (2023), or Medina et al. (2024)). Consider departmental analysis (Tubis (2023)) if uneven readiness across departments is a core issue.
3. Confirm Dimensional Scope
   - Organisational vs Process Dimension - If your SME's operations vary widely in maturity (e.g., advanced production but under-digitised logistics), a two-tier model like Tubis (2023) will better expose departmental disparities. Alternatively, if the entire organisation (people, culture, governance) needs uniform digitisation, frameworks like Aras & Büyüközkan (2023) or Medina et al. (2024) capture broad transformations.
   - Focus on People and Culture - If staff buy-in or cultural change is the biggest blocker, prefer a model that weighs these factors heavily (Aras & Büyüközkan (2023), Tubis (2023), or Schallmo (2020), which all emphasise employee engagement).
4. Evaluate Practical Tools and Validation
   - Review Self-Assessment Instruments - For minimal overhead, look at models with concise surveys (Blatz et al., 2018) or moderate question sets (Schallmo (2020)). If you can handle extensive questionnaires and deeper reporting (Medina (2024), Aras & Büyüközkan (2023), or Tubis (2023)), you'll gain richer, more granular results.
   - Check Empirical Support - Ensure the model's track record aligns with your enterprise's sector or scale. Consider whether partial or full validation (e.g., pilot tests, published case studies) increases confidence.
5. Align with Implementation Pathway
   - Phased Roadmap - All chosen models provide a multistage approach (e.g., Blatz's dimension-based improvements or Aras & Büyüközkan's 4-phase transformation). Ensure the steps are feasible for your timeline. If departmental-level improvement is key, confirm the model easily decomposes improvements among distinct units (Tubis's process dimension or Schallmo's workshop approach).
   - Incremental vs. Comprehensive Rollout - If you aim to pilot in just one area (say, logistics) before scaling up, confirm the model is flexible enough to handle partial deployments. Confirm that the model provides broader synergy strategies for more integrated transformations (culture, data, technology, etc.).
6. Make a Final Selection and Assign Responsibilities
   - Pick the Model - Synthesise context, resource fit, scope, and tool preference to finalise which maturity model best meets your SME's priorities. If no single model fits perfectly, adapt the dimension sets from multiple references (e.g., combine a simpler scale with a more robust departmental assessment).
   - Define the Self-Assessment Team - Establish an internal cross-functional group (managers, department heads, possibly external experts). Train them on the model's rating scales, data collection needs, and outcome interpretation.

The digital strategy under review should be subject to regular re-assessment, with follow-up maturity evaluations to be conducted at regular intervals (e.g. every 6–12 months). These evaluations aim to track progress, measure improvement, and refine the strategy based on lessons learned.

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If an SME has limited prior experience with transformation and a constrained schedule, Blatz et al. (2018) may represent the most pragmatic initial option because of its uncomplicated 3-tier scale and direct scoring methodology. Those seeking a more process-specific diagnosis — particularly if they run advanced production lines but less sophisticated logistics — may benefit from Tubis (2023), which distinctly addresses organisational- versus process-level maturity and can highlight departmental gaps. Schallmo et al. (2020) adopt an SME-oriented approach, yet the necessity for more workshop-style engagements remains a requirement that can be met by SMEs that prefer collaborative design sessions. Meanwhile, Medina et al. (2024) and Aras & Büyüközkan (2023) may offer stronger theoretical rigour and broader cross-sector adaptability, but they can be more resource-intensive. The optimal choice is ultimately contingent on the objectives of the SME in question, the prevailing digital culture, and the entity's capacity to engage in a comprehensive, multi-phase evaluation. SMEs can chart a realistic yet impactful path to digital maturity by selectively blending the clarity of simpler models with the thoroughness of multi-layer ones. The proposed assessment framework is intended to assist in identifying the most appropriate digital maturity model for SME companies, thereby serving as a guideline for selecting the optimal model.

Conclusions

This study aimed to help small and medium-sized enterprises (SMEs) cut through the crowded field of digital maturity models and choose an assessment that fits their strategic intent and day-to-day constraints. A PRISMA-guided review distilled 450 scholarly and practitioner records into five rigorously documented maturity models. Despite different labels, all converge on six core dimensions—strategy, processes, technology, data, people-culture and customer/value—organised in tiered levels that link diagnosis to improvement planning.

To make those differences actionable, we applied a transparent multi-criteria decision analysis (MCDA) using four equally weighted factors: scope, complexity, validation evidence and actionability. The scoring (0–5 Likert × 20 %) highlighted a clear complexity–benefit trade-off. The three-level Blatz model scored highest on feasibility/actionability (90 % and 84 %) and thus suits “quick-scan” baselines. Tubis also excelled in actionability (81 %) thanks to its process-specific roadmap, while Medina achieved the broadest scope (88 %) and strongest diagnostic depth, albeit with the highest assessment burden. These quantitative insights feed directly into the proposed six-step selection framework, which guides SMEs to map resources, maturity gaps and cultural readiness before choosing or sequencing models along a phased digital transformation journey.

Academically, the work synthesises fragmented literature into an evidence-based decision logic; managerially, it offers resource-constrained firms a pragmatic path toward digital mastery that balances ambition with feasibility. Limitations remain. The open-access search protocol may have missed pay-walled models, MCDA weights were set heuristically rather than through a formal Delphi, and some reviewed frameworks have been validated only in single-region pilots—leaving cross-industry generalisability uncertain. Future research should stress-test alternative weighting schemes, expand empirical validation across sectors and geographies, and track performance outcomes as firms progress through maturity levels. By iteratively grounding theory in practice, scholars and practitioners can ensure that digital maturity assessments remain living, actionable tools rather than academic artefacts.

Research Limitations and Future Research

It is important to acknowledge the limitations inherent in the literature search process. Specifically, the study employed designated key phrases and an "open access" criterion across the Google Scholar, Web of Science, Scopus, and ScienceDirect databases. Consequently, the search results were confined to sources in which the specified key phrases appeared in the title, abstract, or indexed keywords, as databases such as Web of Science and Scopus do not provide access to the complete texts of indexed articles. This approach may have inadvertently excluded relevant studies in which the key phrases were present solely within the full text. Furthermore, it was determined that certain digital maturity models (DMM) for SMEs may have been underrepresented due to the constraints imposed by the search process.

Although the multi-criteria decision analysis brings structure and transparency, its results rest on several assumptions constraining generalisability. First, the scoring is based on a small sample of five models, so correlations and rank orders should be interpreted as indicative rather than definitive. Second, the equal weighting (0.25 each) and 0–5 Likert ratings reflect weights set heuristically rather than through the quantitative method; different weighting schemes could alter the aggregate rankings. Third, some sub-scores (e.g., "actionability") had to be inferred from qualitative descriptions in the source papers rather than field testing, introducing subjective bias. Therefore, readers should view the MCDA outcomes as a decision-support aid, not a prescriptive league table, and perform sensitivity checks before applying the scores to their contexts.

Subsequent research endeavours will concentrate on evaluating the proposed assessment framework through its practical implementation in various SME settings. This will enable iterative refinements based on empirical evidence and stakeholder feedback. The process has been designed to guarantee that the framework is adaptable to different SMEs' unique operational constraints and strategic priorities. The ultimate objective of this process is to enhance the framework's effectiveness as a tool for guiding digital transformation initiatives in resource-constrained environments.

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MARKET MOVES PREDICTIONS USING RETRIEVAL-AUGMENTED GENERATION (RAG) ANALYSIS OF CAPITAL MARKET EXPERT OPINIONS IN SOCIAL MEDIA

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This study explores the predictive value of expert opinions from financial market media using Artificial Intelligence (AI), specifically, Retrieval-Augmented Generation (RAG) framework integrated with a Large Language Model (LLM). By analysing 3,877 YouTube videos spanning 12 months, the research categorised 4,808 expert opinions—either explicit or inferred—into directional market predictions (up, down, flat) for seven diversified financial assets. Results indicate that aggregated expert opinions correlate significantly with short-term market movements but lose predictive power for longer horizons. Explicit opinions demonstrated similar accuracy to inferred judgments, suggesting that LLMs effectively extract latent insights from unstructured data, enhancing accessibility and utility for retail investors. The study highlights the democratising potential of LLMs, providing timely and scalable analysis of vast datasets. However, challenges remain, such as understanding domain-specific nuances and speaker attribution within multimedia content. Statistical analysis reveals that expert opinions, particularly when aggregated, identify exploitable inefficiencies, thereby challenging the Efficient Market Hypothesis's assumption of perfect information dissemination. Short-term market anomalies observed align with behavioural finance theories of cognitive bias and delayed information diffusion. By bridging qualitative sentiment with quantitative modelling, this research underscores the transformative role of AI-driven tools in financial analysis, offering new avenues for individual and institutional investors. Further development of LLMs tailored to domain-specific complexities may revolutionise investment practices and advance research on market behaviour.

Keywords: AI; RAG; LLM; market movement prediction; investment; social media; financial markets

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JEL Classifications: G11, G14, C45

Additional disciplines: information and communication

1. Introduction

Financial markets are increasingly shaped by the dynamics of expert commentary disseminated via digital platforms, particularly social media and video-based channels. Retail investors, in particular, rely on these expert opinions to form judgments under uncertainty, often perceiving them as more timely and accessible than institutional reports (Chaitanya & Nordin, 2021; Gaikwad et al., 2023). The proliferation of financial commentary across platforms like YouTube has significantly increased the visibility of analysts and independent experts, transforming the traditional flow of information and its role in market reactions (Vamossy, 2024).

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Previous studies have confirmed that sentiment extracted from financial texts, such as news headlines or earnings reports, can predict short-term market fluctuations, suggesting a measurable influence of media narratives on investor behaviour (Tetlock, 2007; Blasco, Corredor & Ferreruela, 2012). This predictive potential is grounded in behavioural finance, which highlights cognitive biases, social influence, and information cascades as mechanisms that cause market participants to respond in patterned, often irrational ways (Barberis, Shleifer & Vishny, 1998; Shiller, 2003). LLMs, particularly when integrated into RAG frameworks, offer new methodological possibilities for capturing these latent expert sentiments. Unlike traditional sentiment tools, LLMs can infer meaning from context-rich, unstructured data such as video transcripts, where expert judgments may be implied rather than explicitly stated (Gao et al., 2024; Zhao et al., 2024). This capability extends beyond text classification, enabling semantic extraction, contextual interpretation, and scalable analysis—making such tools increasingly relevant in real-time financial analytics (Delgadillo, Kinyua & Mutigwe, 2024). This study investigates whether expert opinions retrieved from YouTube financial channels—either directly stated or inferred using a custom RAG-LLM pipeline—can predict short-term movements in key financial assets.

2. Literature Review and Research Gap

Expert opinions disseminated via financial news media and social platforms significantly influence investor behaviour, particularly among retail investors. These platforms act as informal channels of financial education and information sharing, shaping perceptions of market trends and risks (Chaitanya & Nordin, 2021). Research indicates that retail investors perceive social media content as timely and, in many cases, more trustworthy than formal financial reports, particularly when authored by influential analysts or known professionals (Gaikwad et al., 2023). These dynamics are intensified by emotional contagion and group reinforcement mechanisms common to digital platforms (Vamossy, 2024). Seminal work by Tetlock (2007) showed that textual sentiment in financial news correlates with short-term stock returns, laying the foundation for computational sentiment analysis in finance. Similarly, Blasco et al. (2012) demonstrated that perceived expert consensus often drives market imitative behaviour.

Furthermore, previous work on crowd-sourced or panel-based expert forecasting indicates that diversity of opinion can improve predictive performance, particularly when aggregating across heterogeneous sources (Chandra & Kumar, 2011; Baltakienė, Kanniainen & Baltakys, 2021; Bender et al., 2022). Such findings align with behavioural finance, emphasising bounded rationality, overreaction, and delayed information assimilation in driving asset price fluctuations (Barberis, Shleifer & Vishny, 1998; Shiller, 2003). The Efficient Market Hypothesis (Fama, 1970) postulates that all publicly available information is reflected in prices. However, short-term inefficiencies — such as post-earnings drift or delayed reaction to the news — have been documented (Jegadeesh & Titman, 1993; Barberis, Shleifer & Vishny, 1998). These transient inefficiencies may be exploitable by real-time sentiment or expert opinion aggregation, especially using advanced AI tools.

Despite advances in natural language processing, most sentiment analysis applications in finance remain confined to structured textual data such as headlines, tweets, or earnings calls (Gu et al., 2024; Heydarian, Bifet, & Corbet, 2025). The unstructured and conversational nature of long-form video interview content, which is similar to earnings conference calls —where judgments may be implicit or context-dependent —poses a greater analytical challenge (Cao et al., 2024). Conventional models like FinBERT or VADER are ill-equipped to infer nuanced sentiment from such data (Yang, UY & Huang, 2020). Recent developments in LLMs, particularly when embedded in RAG systems, enable deeper contextual understanding and knowledge-grounded reasoning (Gao et al., 2024; Yu et al., 2024). These models can retrieve, interpret, and synthesise expert opinions from extensive multimedia datasets, offering new possibilities for market signal extraction (Delgadillo, Kinyua & Mutigwe, 2024).

Despite growing interest in AI-driven financial analysis, three major gaps persist: first, few studies focus on qualitative expert opinion in unstructured video formats, despite their popularity and influence; second, LLMs and RAG systems have not been extensively tested for inferential prediction based on expert sentiment — going beyond merely stated forecasts to interpret implicit views; third, there is limited empirical evidence on whether these LLM-extracted insights outperform or complement explicit expert predictions in the context of real-time market behaviour. This represents a significant omission, as LLMs may uncover latent sentiment and enhance the accessibility of advanced financial analysis for non-professionals. This study addresses this gap by applying

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a custom RAG-LLM pipeline to extract and classify 4,808 expert opinions from financial YouTube videos. It tests their alignment with short-term asset price movements across seven diversified instruments. The research contributes to behavioural finance by quantifying expert opinion accuracy and evaluating the predictive validity of inferred versus direct sentiment across a multimedia corpus.

3. Theoretical background

EMH assumes that financial markets fully reflect all available information, making it impossible to consistently achieve returns that outperform the market through analysis or prediction (Fama, 1970). While the EMH is seen as a cornerstone of modern financial theory, its universal applicability has been questioned, particularly in light of reported market anomalies and the evolving role of technological tools in financial analysis. The anomalies contradicting the EMH include, for example, the momentum effect, the calendar, such as "January" effects, or value-growth disparities (Fama & French, 1992; Jegadeesh & Titman, 1993; Cheema, Ding & Wang, 2023). The persistence of specific inefficiencies, such as overreaction and underreaction to earnings announcements (De Bondt & Thaler, 1985) and price drifts following news events (Barberis, Shleifer & Vishny, 1998) and identifying psychological biases and irrational behaviour as key drivers of short-term inefficiencies (Shiller, 2003) was also reported. These anomalies may suggest systematic departures from efficiency, creating opportunities for investors to exploit (Jegadeesh & Titman, 1993). The Grossman-Stiglitz Paradox (Grossman & Stiglitz, 1980) asserts that markets cannot be perfectly efficient, as the incentive to gather costly information diminishes in such a state. Active portfolio management leveraging segmented market information has been shown to yield superior results under specific conditions (Kacperczyk, Sialm & Zheng, 2005; Zhou et al., 2025), further contradicting key assumptions of the EMH.

4. Research objective and methodology

The integration of LLMs and RAG systems into financial opinions analysis introduces a new dimension to the process, supporting the processing of large amounts of unstructured data such as expert opinions. Tetlock (2007) demonstrated the predictive value of textual sentiment analysis, which aligns with the enhanced capabilities of LLMs in uncovering actionable signals. These tools challenge the EMH's implicit assumption of equal accessibility and interpretability of public information by extracting latent insights from qualitative data (Zhao et al., 2024).

This research aims to explore whether expert opinions from media sources are predictive of subsequent market movements. The study seeks to answer the two research questions: (1) Are diverse expert opinions pulled from recordings of industry-paid professionals and independent financial journalists predictive of actual market movements? (2) Are explicit opinions, directly stated by experts, more predictive of asset price movements than inferential judgments made by LLMs based on the broader context of the discussions and their internal knowledge? By comparing explicit expert opinions expressed in the YouTube (YT) videos with inferential judgments made by LLM, the study aims to assess whether the latter provides additional predictive value beyond direct expert commentary and whether LLM can be used to enhance the interpretation of financial market opinions when direct signals are not readily available.

In this study, qualitative predictions of the market movements expressed in YT videos were converted into 3 categorical variables reflecting the direction of the prediction (up, down or flat). Statistical analysis was employed to assess the association between the predicted and actual market movements. The BLINDED LLM-based tool developed by the research team to support evidence synthesis and analysis was used to support the analysis of the video scripts and assign one of the pre-defined categories. The accuracy of the analysis was manually confirmed on 10% of the analysed sources, demonstrating a high level of accuracy. Any discrepancies in the judgment were resolved in a discussion between DG, AB and MG.

To address these questions 3877 YouTube (YT) videos covering 7 financial assets (tickers) over the 12 months from October 2023 to September 2024 were analysed. A database of 17953 YouTube videos as the primary data source was assembled (Those video transcripts were downloaded using YouTube API, integrated into BLINDED tool. At the dates of uploading minor number of videos did not have the text transcripts. We

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considered this fact as insignificant for the size and quality of final dataset). 78 relevant channels were selected, discussing the capital and financial market issues. This selection ensured representation of the mainstream financial media (Bloomberg, Yahoo Finance, CNBC, etc.), smaller organisations, independent experts, and financial journalists. The former sources are assumed to host highly ranked financial experts, and the latter cater to niche audiences, potentially offering alternative or contrarian viewpoints to the consensus often found in mainstream coverage. Selected videos feature a diverse range of financial experts discussing market trends and predictions for Gold (Gold, or Gold CFD (ticker XAUUSD), or Gold ETFs (ticker GLD)), Bitcoin (Bitcoin (ticker BTCUSD) or Bitcoin ETFs), the S&P 500 (S&P500 index (ticker SPX) or S&P500 ETF (ticker SPY) US Treasury Bonds, Crude Oil, Tesla Inc. and Alphabet Inc. Some of the sources contained multiple opinions. LLM was allowed to identify no more than 2 opinions per source, resulting in 4808 opinions analysed (see Table 1). The correctness of this extraction was verified by the extra prompt aimed at detecting the number of experts.

Table 1. Breakdown of the opinions included in the analysis.

Asset	Number of YT videos	Number of Opinions	Direct Opinions	Inferred Opinions
Gold	724	704	411	293
Bitcoin	738	826	333	493
S&P 500	883	986	349	637
US Treasuries	392	383	152	231
Oil	685	618	299	319
Tesla Inc.	830	841	217	624
Alphabet Inc.	487	450	90	360
	4739*	**4808**	**1851**	**2957**

Note. The total number of YT videos was 3877, which is less than the sum of the second column because some videos contained recommendations for several tickers.

The assets selection criteria included: 1) diversification; 2) reasonable coverage in the selected YT videos; 3) high level of capitalisation (assets under management) and trading volumes. Research supports the assumption that portfolio diversification reduces idiosyncratic risks and enhances stability by spreading investments across different asset classes and regions, as it shows that diversification can mitigate specific asset risks and improve portfolio stability (Upson, Jessup & Matsumoto, 1975). Studies also indicate that holding a variety of assets can offset losses in one area with gains in another, thereby reducing overall portfolio volatility (Zaimovic, Omanovic & Arnaut-Berilo, 2021). This strategy is effective in achieving a more stable return profile (Woerheide & Persson, 1992). Goetzmann and Kumar, 2001 found that diversification reduces idiosyncratic risk, which is crucial during volatile periods. Furthermore, Clare et al. (2016) highlight that incorporating various asset classes, such as bonds, can improve risk-adjusted returns. A well-diversified portfolio can improve risk-adjusted returns, particularly for retail investors who may lack extensive resources for asset analysis, reducing unsystematic risk specific to individual investments (Zaimovic, Omanovic & Arnaut-Berilo, 2021).

Literature supports the importance of measuring asset correlation for diversification effectiveness. Low or negative correlations between assets can enhance diversification by ensuring that assets respond differently to market changes (Koumou, 2020). However, factors such as transaction costs, limited access to diverse assets, and biases like home bias can hinder true diversification (Nguyen et al., 2023). These impediments can lead to suboptimal portfolio construction, reducing the potential benefits of diversification (Zaimovic, Omanovic & Arnaut-Berilo, 2021). Assets selected for this study have low or negative correlations, as shown in Table 2. Moreover, all correlations are insignificant, except for TLT and USO, which is negative.

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Table 2. Correlation matrix for selected assets (tickers). Monthly returns.

		TLT return	GOOG return	TSLA return	GLD return	GBTC return	USO return	SPY return
TLT return	Pearson's r	—						
	df	—						
	p-value	—						
GOOG return	Pearson's r	-.141	—					
	df	11	—					
	p-value	.645	—					
TSLA return	Pearson's r	.192	.165	—				
	df	11	11	—				
	p-value	.529	.591	—				
GLD return	Pearson's r	-.045	.036	-.243	—			
	df	11	11	11	—			
	p-value	.883	.907	.424	—			
GBTC return	Pearson's r	-.085	-.092	-.150	.201	—		
	df	11	11	11	11	—		
	p-value	.783	.766	.625	.510	—		
USO return	Pearson's r	-.587*	.347	.090	-.300	.085	—	
	df	11	11	11	11	11	—	
	p-value	.035	.246	.771	.320	.783	—	
SPY return	Pearson's r	.447	.225	.296	-.140	.437	.185	—
	df	11	11	11	11	11	11	—
	p-value	.126	.459	.326	.649	.135	.546	—

Note. Correlation tests performed for the monthly returns computed as closing prices for the first day of the respective months divided by the respective value of the previous month. Source of data: https://www.tradingview.com/. Jamovi 2.3.28 was used for computations.
* $p < .05$

The analytical approach centres on using a RAG system empowered by an LLM (described below) to extract and synthesise expert opinions from the transcripts of these videos. The opinions extracted were categorised into either explicit or inferential. Explicit opinions are those directly stated by the experts in the recordings, reflecting a clear expectation of price movement. In cases where no explicit opinion was presented, the LLM drew inferential conclusions from the text, identifying the likely sentiment based on the broader context of the discussion.

RAG is a framework designed to enhance the capabilities of language models by integrating external knowledge sources into the generation process (Yu, 2022; Yu et al., 2024). The primary purpose of RAG is to improve the accuracy and relevance of generated content by retrieving pertinent information from a vast corpus of documents, which is then used to inform the generation process (Gao et al., 2024; P. Zhao et al., 2024). This approach allows RAG to overcome the limitations of traditional language models that rely solely on pre-trained data, which may not be up-to-date or comprehensive (Yu, 2022; Gao et al., 2024). The RAG framework consists of two main components: a document retriever and a text generator (Zhao et al., 2024; Yu et al., 2024). The document retriever is responsible for identifying and retrieving relevant documents from a large dataset based on the input query (Yu, 2022; Gao et al., 2024). RAG's ability to incorporate external knowledge dynamically makes it particularly useful for tasks that require up-to-date information, such as question answering and fact verification (Gao et al., 2024; P. Zhao et al., 2024). By leveraging both structured and unstructured data sources, RAG can provide more accurate and diverse responses compared to models that rely solely on pre-trained data (Gao et al., 2024; Yu et al., 2024). This integration of retrieval and generation processes not only enhances the model's performance but also improves its interpretability, as the generated content can be traced back to specific data sources (Zhao et al., 2024; Yu et al., 2024).

A RAG approach was implemented in three steps. First, textual content (transcripts for videos) was converted into dense embeddings using the 'text-embedding-3-large' model (https://openai.com/index/new-embedding-models-and-api-updates/). The 'text-embedding-3-large' model is specifically designed to create high-dimensional vector representations of text, encapsulating semantic meaning. This capability is crucial as it allows for efficiently transforming text into embeddings, facilitating various natural language processing tasks

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(Petukhova, Matos-Carvalho & Fachada, 2024). By leveraging LLMs, these embeddings enhance the semantic understanding of text. They achieve this by capturing the context and relationships between words. (Cao, 2024). The efficiency in transforming text data into embeddings is a significant advantage of using LLMs. This efficiency is realised through the model's ability to process large corpora and generate embeddings that reflect a comprehensive understanding of language variations (Harris, Butani & Hashmy, 2024). In the second step the similarity search was conducted using cosine similarity algorithm (https://www.pinecone.io/learn/vector-similarity/) offered by Pinecone.io. This step involved applying the user's query to the text chunks identified as most relevant in the previous stage. For this task, the ChatGPT-4o-mini was used. In the third step, the ChatGPT-4o model was used to extract and analyse information from the selected text chunks, utilising its advanced capabilities in language understanding and generation.

The exponential moving average (EMA) is an effective method for measuring medium-term tendencies in stock price analysis due to its ability to give more weight to recent prices, allowing it to respond more quickly to price changes than a simple moving average (Lorig, Zhou & Zou, 2019; Billah et al., 2024). It makes it suitable for capturing medium-term trends in stock prices, as it can quickly adjust to changes in market conditions (Droke, 2001; Arisoma & Narulita, 2019). The EMA is often used in financial markets to smooth out price data and identify trends, making it a valuable tool for validating expert predictions (Droke, 2001; Raudys & Pabarškaitė, 2018).

For assets included in the analysis, EMA can help validate predictions by highlighting the underlying trend and filtering out short-term volatility (Droke, 2001; Arisoma & Narulita, 2019). The EMA's responsiveness to recent price changes makes it particularly useful in volatile markets, where quick adjustments to new information are crucial (Raudys & Pabarškaitė, 2018; Arisoma & Narulita, 2019). Applying the EMA to these assets makes it possible to gain insights into the medium-term direction of prices, aiding in the assessment of expert forecasts (Droke, 2001; Raudys & Pabarškaitė, 2018). Our research used 4 weeks EMA (All indicators were calculated using www.tradingview.com).

The ATR is a well-established measure of market volatility, introduced in "New Concepts in Technical Trading Systems" (Wilder, 1978). It is widely used as a volatility indicator in technical analysis and trading systems (Edwards, Magee & Bassetti, 2018). The ATR's ability to measure volatility makes it a versatile tool in both long and short-trading systems (Gayed, 2015). It is now used in various trading systems and strategies, including trend-following systems like the parabolic stop and reverse (SAR) (Yamanaka, 2012). Additionally, ATR is used in conjunction with other indicators to improve trading systems. The ATR's effectiveness in capturing market volatility is supported by its inclusion in numerous studies and its application in different market conditions (Edwards, Magee & Bassetti, 2018). The widespread use of ATR in various trading systems and its inclusion in technical analysis literature further support its acceptance in the finance community.

We are using a fraction of ATR to establish if the underlying asset's month-over-month price movement is different from the typical volatility for this asset. The selection of a fractional threshold should support the purpose of research and is heavily affecting the hit rate. We opted for 5% (500 basic points) intervals across the range spanning from 5% to 50% threshold. For each of the 7 assets the 4 months ATRs were calculated (All indicators were calculated using www.tradingview.com), followed by applying 12 months simple moving average to arrive to a single smoothed ATR value per asset.

Extracted opinions are assigned to one of two groups as assessed by the LLM (direct or inferred). Each opinion was categorised as either Up, Flat or Down, reflecting the experts' prediction of the expected price movements in the next few weeks. The opinions were counted for each month, and a weighted average for each month was calculated using the formula:

(Up-Down) / (Up + Flat + Down)

to assess the general price movement prediction for each asset in each month. If the module of weighted score was smaller than .1 then the price movement was categorised as ‘Flat’ and assigned 0. The ‘Up’ price movement was assigned 1 when the weighted score was larger or equal to .1, and ‘Down’ price movement was assigned -1 if the weighted score was less or equal to -.1.

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These values were then compared to factual price dynamics by calculating the annualised monthly returns. For the month of opinions observation (current month), this month's last week 4-weeks exponential moving price average (4W-EMA) was divided by the respective value of the previous month, minus 1, and multiplied by 12 for the convenience of the price dynamics perception (current month annualised return). For the month following the current month (next month), the next month's last week 4W-EMA was divided by the respective value of the current month, minus 1, and multiplied by 12 (next month annualised return).

In addition, the month-to-month EMA change values were transformed into the categorical price move assessment by comparison with various thresholds established as fractions of ATR: -1 for negative price moves, 0 for sideways dynamics, and +1 for positive moves. The rationale for using different ATR fractions is that assigning a 'flat' label to a certain range of price volatility is a discretionary decision influenced by the purpose of analysis, target returns and risk profile.

Finally, 'Hit' scores reflected the comparison result, where 1 was assigned to matching values and 0 to mismatches, considering matching of 'flat' prediction with a sideways market move computed using ATR fraction values sampled at 5% intervals across the range spanning from 5% to 50%, and "up" and "down" by matching with positive or negative market move beyond the sideways range in each ATR threshold case.

The Hit Rates were calculated to assess the proportion of correct predictions in each of the analysed groups. Different thresholds were applied for the flat trend in the assets included (see Table 3). The correlation analysis between weighted scores with the current and next month's returns was used to see whether the predictions and actual market movements were associated. Wilcoxon signed-rank test was employed to explore differences between the accuracy of direct and inferred opinions.

5. Results and discussion

Considering a 0.5 hit rate as indicating a 50/50 chance of predicting the market movement, applying narrower volatility ranges for the sideways dynamics returns better hit-rates. Table 3 represents average hit-rates for all seven tickers, and the ticker-by-ticker grouping is provided in Appendix A. While 'flat' thresholds from 5% to 30%, applied to the current market move, return chances to predict exceeding 50/50, the same approach for next market move does not show such accuracy. In the best option - 5% ATR - only one direct prediction (USO) and three inferred predictions (TLT, USO and GOOG) for the current month's end-of-month (EoM) EMA meet the .5 threshold, while the remaining values exceed it. Meanwhile, the combined total hit rate (direct plus inferred) for each ticker falls within the range [0.67, 0.83], indicating that the chances of the blended expert panel predicting the market movement are better than 50/50, if the sideways dynamics is defined as equal or less than 5% of ATR. In contrast, the same combined measure for the market movement of next month's EoM EMA within this ATR range is below 0.5 for four out of seven assets, indicating that the expert panel fails to predict the market movement over the longer-term horizon.

Both explicit and inferred expert opinions correlated significantly with current-month price movements ($p < 0.001$), demonstrating their ability to predict market trends within the same month. Diversity of perspectives seems to enhance the reliability of predictions over shorter timeframes by incorporating varied methodologies and viewpoints. However, the predictive power of these opinions does not extend to longer-term horizons, as no significant correlations with next month's price movements were observed.

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Table 3. Average hit-rates for seven tickers

Fraction of ATR assigned for 'Flat'	Average hit rate (opinions are equal to current EoM price move) direct	Average hit rate (opinions are equal to current EoM price move) inferred	Average hit rate (opinions are equal to current EoM price move) total	Average hit rate (opinions are equal to next EoM price move) direct	Average hit rate (opinions are equal to next EoM price move) inferred	Average hit rate (opinions are equal to next EoM price move) total
5.00%	0.67	0.63	0.71	0.51	0.5	0.51
10.00%	0.62	0.6	0.69	0.46	0.5	0.49
15.00%	0.6	0.6	0.67	0.45	0.49	0.48
20.00%	0.58	0.58	0.63	0.4	0.44	0.46
25.00%	0.55	0.58	0.61	0.38	0.45	0.45
30.00%	0.54	0.51	0.56	0.37	0.46	0.43
35.00%	0.54	0.5	0.55	0.36	0.48	0.44
40.00%	0.54	0.49	0.52	0.35	0.44	0.4
45.00%	0.46	0.48	0.48	0.36	0.43	0.38
50.00%	0.45	0.44	0.44	0.31	0.4	0.33

All the correlations of weighted scores (either direct or inferred) with the current month's return were statistically significant ($p < .001$), which shows the positive significant association between the expert panel opinion and actual market moves for the short-term perspective (see Table 3). Moreover, direct ($M = 0.281$, $SD = 0.495$) and inferred ($M = 0.292$, $SD = 0.379$) weighted scores also correlate with each other ($r = .576$, $p < .001$), which indicates that LLM's inference on expected market moves derived from the conversations and wider context may be associated with the explicitly expressed expert opinions.

To test the difference between the direct and inferred opinions, a paired-sample t-test was conducted. The data were normally distributed, as assessed by the Shapiro-Wilk test ($W = 0.974$, $p = 0.088$). The results indicated no significant difference between the two groups, $t(83) = -0.247$, $p = 0.805$, $d = -0.027$. This finding answers the second research question: For the current months' time horizon, explicitly stated expert opinions do not differ from inferences made by the LLM from non-explicit recommendations. None of the correlations of weighted scores (whether direct or inferred) with the next month's return was statistically significant. Thus, the data does not provide enough evidence to support an association between weighted opinion scores and market movement on a time horizon longer than a month.

Explicit opinions were found to be no more predictive than inferential judgments. Both types of predictions demonstrated similar levels of correlation with current-month price movements, indicating that LLMs can effectively infer market expectations from broader contextual cues and implicit sentiments in the discussions.

Both explicit and inferred predictions were found to be associated with the market movement in the short term (within the same month the predictions were made) and performed similarly in terms of their predictive accuracy. The longer-term predictive accuracy was not confirmed. These findings suggest that the diversified set of opinions shared through YT channels may provide support for investors in making short-term decisions with a large volume of information needed to be analysed in a very short time. LLM based tools such as BLINDED tool, can offer this ability, offering speed of processing data exceeding ability of human analyst and providing quick 'as you need' support for individual investors.

The similar accuracy of direct and inferred opinions shows the potential of LLM based tools to interpret and summarise a wide range of non-direct data. This could potentially offer a high-level specialist opinion to different groups of investors, improving the accessibility of the industry (Yang, Tang & Tam, 2023). In the longer term this could lead to a change in market dynamics resulting from democratisation of investment practices (H. Zhao et al., 2024).

Using the RAG framework provided an effective solution for extracting and synthesising expert opinions from video transcripts in the financial markets' domain. By combining the document retrieval capabilities of RAG with an LLM, we could efficiently capture nuanced opinions on the selected asset price movements, producing

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robust results. RAG's source selection process generally performed well, consistently retrieving relevant content and enabling effective data extraction.

This research also highlighted a few challenges in using an LLM based tool in the analysis process. The BLINDED tool dealt well with information related to all types of analysed assets, however the TLT analysis required a change in the prompt due to the inverse character of prices and yields for fixed income instruments: when the yield goes higher ('long' movement as the price rise for equities), the prices of bonds go down. Lack of understanding of this directional relationship initially led to some inaccuracies in interpreting recommendations. This demonstrates the need for careful formulation of prompts, fitting with the characteristics of the specific data, rather than using 'one fit all' approach (Krause, 2023). This may be particularly important when LLM based tools are introduced to the users, especially those less familiar with this technology (Zamfirescu-Pereira et al., 2023). Especially as an increasing amount of research highlights the multiple misconceptions users may have regarding the capabilities of LLMs, expecting them to 'think' and 'know things' (Bowman, 2023; Birhane & McGann, 2024; Wang et al., 2024). Additionally, the LLM occasionally failed to distinguish between different speakers within a single video, causing minor issues in attributing expert opinions accurately. These limitations underscore the importance of refining LLM capabilities, especially in areas requiring a clear understanding of financial instruments and speaker identification within complex multimedia sources.

The comparable predictive accuracy of inferred and explicitly stated expert opinions demonstrates the utility of latent information embedded in textual data. This finding aligns with prior research emphasising the value of sentiment analysis in financial contexts. For instance, Tetlock (2007) demonstrated that qualitative analysis of financial texts could predict stock price movements by capturing underlying sentiment and market expectations. Inferred insights reflect a combination of explicit signals and contextual nuances thus potentially enhancing traditional analysis (Gu et al., 2024). This underlines the importance of advanced analytical tools in extracting actionable information from large, unstructured datasets.

The predictive power of aggregated opinions may also complement existing factor-based models of asset pricing. For instance, the Five-Factor Model accounts for much of the variation in returns between diversified portfolios by integrating independent risk factors (Fama & French, 2015). However, the ability of inferred opinions to predict price movements suggests that latent information, not explicitly modelled, may act as a supplementary risk factor. This finding encourages further research into the intersection of qualitative sentiment analysis and quantitative risk modelling.

In the study, we examined the predictive capacity of expert opinions within the framework of market efficiency. Our findings indicate that aggregated expert opinions, particularly when interpreted through advanced tools like LLMs, can uncover exploitable inefficiencies. This suggests that while aggregated expert opinions exhibit short-term predictive power, their accuracy diminishes over longer horizons. While the long-term efficiency of markets is supported, our findings reveal statistically significant short-term predictive power in expert opinions. These results suggest that short-term inefficiencies exist, likely arising from delays in the dissemination or interpretation of information by market participants (Jegadeesh & Titman, 1993).

This supports a dynamic interpretation of EMH, wherein market efficiency is temporally bounded and contingent upon the speed of information dissemination and integration (Chordia, Roll & Subrahmanyam, 2005). The theory of delayed information diffusion further explains such anomalies, positing that inefficiencies arise temporarily as markets adjust to new data (Hong & Stein, 1999). Behavioural finance literature provides another explanation for such inefficiencies, highlighting cognitive biases, such as overreaction or underreaction to news, as drivers of these transient anomalies (Barberis, Shleifer & Vishny, 1998). These biases create temporary windows of opportunity where informed actors or advanced analytical systems can exploit market dislocations before prices fully adjust.

The findings also intersect with the Joint Hypothesis Theorem, which highlights the inseparability of tests of market efficiency from the models of market equilibrium employed (Fama, 1970). Observed short-term

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inefficiencies could result from limitations in existing equilibrium models rather than a failure of market efficiency itself. For example, the Fama-French Five-Factor Model extended the traditional Capital Asset Pricing Model (CAPM) by incorporating factors such as size, value, profitability, and investment intensity (Fama & French, 2015). However, new factors—such as the rapid dissemination of information via social media or the influence of algorithmic trading—may represent emerging dimensions of market behaviour that are not fully captured by existing models.

A selection of YT videos published in English was selected for analysis using the available resources. Although the sample characteristics seem to reflect the opinions on the topic well in the selected timeframe, the narrower selection could introduce bias or skew data in one direction or another. For practical reasons, seven different assets were selected for analysis. This limits the conclusions to these assets only.

Conclusions

This study demonstrates that aggregated expert opinions extracted from YouTube media using LLM-enhanced RAG frameworks can predict short-term market movements significantly. The novel contribution lies in showing that inferred opinions generated by LLMs from unstructured expert discourse are just as predictive as explicitly stated ones—an insight not previously documented in the financial AI literature. This expands the analytical toolkit available for interpreting informal financial commentary and challenges the assumption that only formal, explicitly declared views are of value.

The research contributes to behavioural finance and AI-driven market forecasting by evidencing that aggregated media sentiment—when processed via state-of-the-art neural models—captures transient inefficiencies in asset pricing. These inefficiencies are short-lived and suggest that market participants do not always incorporate qualitative insights immediately, providing a potential edge for retail investors using LLM tools.

There are several limitations. The dataset is restricted to English-language YouTube videos and seven financial assets, limiting the generalisability of the results. Attribution errors in speaker identification and the inverse nature of bond yield-price relationships posed challenges for LLM interpretation. Furthermore, the study's predictive power diminishes over longer horizons, indicating that while LLMs can summarise market mood effectively, they cannot fully anticipate delayed reactions or structural shifts.

The results underscore the potential of generative AI in synthesising decentralised and noisy expert discourse, offering a scalable means to support investor decision-making in the face of overwhelming information volumes.

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ONLINE REPUTATION OF HOTELS: AN EMPIRICAL STUDY ON THE CZECH MARKET

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Abstract. The online reputation of hotels plays a crucial role in customer decision-making when selecting accommodation. Review portals are currently an invaluable source of information for potential guests. This research evaluates the reputation of six renowned hotels in the Czech Republic and identifies the factors that most significantly influence this reputation. The main objective of the paper is to evaluate the reputation of the selected hotels in the online environment and identify the key factors influencing their reputation. Content, descriptive, and variance analyses were employed to achieve the research objective. Data for the period 2021-2023 were obtained from the online review portal Booking.com. Key factors for each hotel were identified using content analysis. The analysis revealed that the most frequently mentioned factors were the staff, food, amenities, location, wellness, cleanliness, and price. The comparison of the hotels showed differences in their market popularity. The results of the variance analysis indicated the changes in hotel reviews within the period 2021-2023, showing that evaluations varied depending on the pandemic situation and current conditions. The findings are beneficial for strategic planning and the improvement of hotel services, staff development, and management practices, as well as for future customers, as they provide a better understanding of the factors influencing customer satisfaction and loyalty. A limitation of the research could be false or modified customer reviews. Future research could focus on a broader range of hotels and include other review platforms to provide a more comprehensive view of hotels' online reputations.

Keywords: online environment; reputation; hotel; reviews; key factors

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JEL Classifications: M14, M21, M31

1. Introduction

Online reviews and social media play a significant role in shaping customer perceptions of hotel quality and reputation. They provide crucial information to potential guests, aiding in booking decisions and shaping their opinions of hotels. This underscores the importance of actively managing online reputation (Dorčák, Markovič & Pollák, 2017; Világi, Konečný & Ruschak, 2022; Gabbard, 2023; Straková & Kostiuk, 2023; Konečný et al., 2024). Social media marketing is essential for modern hospitality brands to adapt and innovate. It helps shape and enhance customer perceptions, thereby enabling hotels to gain a competitive advantage in the industry

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(Dorčák, Štrach & Pollák, 2015; Malik, 2023; Dušek, 2023). Research indicates that ratings and reviews from renowned individuals connect the quality of online booking sites and customers' booking intentions, highlighting the significance of customer feedback in influencing booking decisions and hotel reputation (Kareem & Venugopal, 2023). Social media also facilitates collaboration with customers, enhances brand awareness, and impacts purchase decisions through online interactions (Kapoor, 2018). Understanding and leveraging online reviews and social media platforms, such as Airbnb and Booking, are crucial for building and improving brand reputation in the hospitality sector (Hamdan, Darós & Guijarro, 2022; Pártlová, Dušek & Sagapova, 2022). This paper aims to assess the reputation of six selected hotels in the Czech Republic in the online environment and identify the key factors influencing their reputation. The selected hotels include BoHo Hotel Prague – Small Luxury Hotels, Chateau Herálec Boutique Hotel and Spa by L'Occitane, Carlsbad Plaza Medical Spa and Wellness, Four Seasons Hotel Prague, Mandarin Oriental, Prague, and Augustine, a Luxury Collection Hotel, Prague. To achieve the objective, the following research questions were formulated: What key factors drive customers to visit the selected hotels? What is the online reputation of the selected hotels in the Czech market? Do the average ratings of the selected hotels differ in 2021, 2022, and 2023, i.e., from the period of the COVID-19 pandemic to the present?

2. Theoretical background

Online reviews are crucial in selecting hotels as they significantly influence customer decision-making and hotel ratings (Guo & Yan, 2023; Liu & Li, 2024; Han & Mikhailova, 2024). However, the sheer volume of online reviews can lead to information overload, affecting consumers' cognitive fluency and decision-making processes (Guo & Yan, 2023). To address the problem of fake reviews, machine learning algorithms such as Multinomial Naive Bayes, Support Vector Machine, and Logistic Regression are employed to detect fraudulent reviews, thereby increasing the credibility of online platforms (Jadhav et al., 2024). Additionally, combining consumer-generated and retailer-induced reviews through the propensity score adjustment technique aims to create a more reliable and representative environment of online reviews that positively influences hotel selection (Han & Mikhailova, 2024). Furthermore, the direct and mediated effects of reviews and ratings from celebrities on the quality of booking websites and online booking intentions underscore the significant influence of online reviews on hotel selection decision-making (Kareem & Venugopal, 2023). Various key factors identified in research studies influence customers' decisions to visit specific hotels. Factors such as ethical brand values and trust are very important in shaping customers' interest in hotels, as a high level of trust can contribute to positive perceptions of service quality, safety, privacy, and overall satisfaction (Karina & Pratomo, 2023). Aspects of service quality, such as tangibility and empathy, are vital for shaping customers' perceptions and decision-making processes when selecting a hotel. To enhance service quality and gain a competitive advantage, hotel operators and managers should focus on improving these factors (Khanna & Sharma, 2023). Service quality, cleanliness, amenities, and staff behaviour are key factors influencing customer satisfaction in the hospitality sector. These aspects should be understood and prioritised to facilitate informed decision-making and improve business performance (Mohanty, Mohapatra & Mohanty, 2023). Trust, word-of-mouth recommendations, and customer satisfaction directly impact guests' decision-making about hotels. This points to the need for regular staff training and a caring approach to customers in order to increase their satisfaction and loyalty (Abdelhamid & Fawzy, 2023). Additionally, corporate social responsibility (CSR) initiatives, particularly those focused on environmental protection and philanthropy, have a greater impact on customer satisfaction and their willingness to return than service quality or brand attitude. This underscores the importance of implementing CSR strategies to improve customer experience and increase hotel loyalty (Simarmata et al., 2023; Ruschak et al., 2023). The average ratings of the selected hotels varied in the years 2021, 2022, and 2023, being influenced by various factors. The research showed that the COVID-19 pandemic significantly impacted customer satisfaction during their stays at the hotels. Although ratings improved after the most severe pandemic periods, they still did not reach the pre-pandemic levels. This highlights the significance of quality hotel services for overall customer satisfaction (Straková et al., 2021; Kostiuk et al., 2021; Markovič et al., 2022; Pollák et al., 2022; Straková, Talíř & Váchal, 2022; Pollák et al., 2021; Alfaro-Navarro & Andrés-Martínez, 2024). Moreover, increasing online ratings are associated with higher hotel quality. Each increase in rating by one standard deviation leads to a 27% increase in demand, which is particularly important for hotels with a lower number of stars (Santos, 2020). In the future, it is assumed that combining traditional rating systems with customer online reviews will

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improve transparency for customers and enable innovative hotels to better position themselves in the market. Conversely, hotels that do not adapt might face lower interest and risk of obsolescence (Hensens, 2015). The COVID-19 pandemic has significantly impacted the hotel sector, resulting in changes in customer satisfaction and average ratings during their stays (Alfaro-Navarro & Andrés-Martínez, 2024). Studies indicate that hotels faced considerable financial problems, leading to partial or complete closures, job losses, and reduced working hours for employees (Shrestha et al., 2023). To adapt to the post-pandemic period, hotels need to become more flexible, improve their cleaning practices, and introduce contactless services to maintain customer loyalty (Wu, 2023). Hotels in areas such as the Opatija Riviera are focusing on improving service quality and customer satisfaction to remain competitive and support their long-term growth and development (Alkier, Milojica & Roblek, 2023). The impact of COVID-19 on stock returns in the hotel sector varied depending on the pre-pandemic characteristics, with stock resilience influenced by factors such as size, leverage, cash flow, and internationalisation (Rathore et al., 2023; Bečica et al., 2024). Overall, the pandemic forced hotels to focus on service improvements, increased flexibility, and crisis management strategies to cope with the challenges and changes caused by COVID-19. The key indicators to measure the hotel industry's recovery in average ratings after the pandemic include the adoption of contactless services through technology, a shift towards domestic tourism and staycations, sustainability practices leading to higher occupancy rates and customer satisfaction, flexibility in booking and cancellation policies to restore traveller confidence, and the implementation of workplace health measures (WHM) to improve performance, service recovery, and financial performance (Ernawati et al., 2022; Chissom, 2024; Vavrová et al., 2024). Maintaining high-quality standards, implementing meticulous cleanliness protocols, informing customers through online platforms, adjusting rates to accommodate weaker purchasing power, implementing flexible booking conditions, and redesigning human resource policies are key operational adjustments that can impact hotel brand resilience and their recovery after the pandemic (Ernawati et al., 2022). In addition, analysing customer expectations of hotels, identifying new service environment attributes during health crises, and designing improvements for responsible service recovery can also contribute to measuring industry recovery (Serrano-Baena et al., 2023).

3. Research objective and methodology

This paper aims to assess the reputation of six selected hotels in the Czech Republic in the online environment and identify the key factors influencing their reputation. The selected hotels include BoHo Hotel Prague – Small Luxury Hotels, Chateau Herálec Boutique Hotel and Spa by L'Occitane, Carlsbad Plaza Medical Spa and Wellness, Four Seasons Hotel Prague, Mandarin Oriental, Prague, and Augustine, a Luxury Collection Hotel, Prague. The selection of hotels for this study was based on the publicly available ranking of the most luxurious hotels in the Czech Republic, as published by Němcová (2022). These hotels were chosen because they represent high-end establishments with a strong brand presence and a high volume of customer reviews on Booking.com. While they are not identical in size or capacity, they share comparable price ranges and target similar customer segments – mainly affluent international travellers and high-income domestic clients. Although slight differences in services and locations exist, all selected hotels belong to the luxury category and operate within the same market expectations for premium service, allowing for relevant comparative analysis. The key factors will be evaluated based on online customer reviews from Booking.com for the period from January 2023 to December 2023. Furthermore, the position and popularity of these hotels in the Czech market will be analysed, and the question of whether customer reviews of the hotels changed between 2021 and 2023, i.e., during and after the COVID-19 pandemic, will be examined. Data used for the analysis of the reputation of the six selected hotels (BoHo Hotel Prague – Small Luxury Hotels, Chateau Herálec Boutique Hotel and Spa by L'Occitane, Carlsbad Plaza Medical Spa and Wellness, Four Seasons Hotel Prague, Mandarin Oriental, Prague, and Augustine, a Luxury Collection Hotel, Prague) were sourced from the review portal Booking.com. This portal includes reviews from both Czech and international customers; for the purposes of this paper, it is not necessary to group these data, as the focus is on the overall online reputation of the hotels. The research questions will be addressed using content analysis, descriptive analysis, analysis of variance, and subsequent data comparison. The reviews included in the analysis were published in the period from January 2023 to December 2023 and the results will be compiled into graphs using MS Excel. Content analysis will be employed to answer the first research question, which involves identifying important factors in customer reviews. This analysis enables us to identify and categorise the most frequent factors mentioned in the reviews. The second research question, concerning the position and popularity of the hotels in the Czech market, will be addressed using descriptive

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analysis and the star ratings from Booking.com. These ratings will be compared across the individual hotels to determine their overall market position. Analysis of variance (ANOVA) will be conducted to answer the third research question, which examines changes in hotel ratings during and after the COVID-19 pandemic. The analysis will compare star ratings from the pandemic and post-pandemic periods. A p-value will be calculated to test the hypothesis against a 5% significance level. If the p-value is less than 0.05, the alternative hypothesis will be accepted, indicating that the ratings have changed. If the p-value is greater than 0.05, the null hypothesis is accepted, stating that the ratings have not changed.

4. Results

In the first part of the research, a content analysis of reviews published from January 2023 to December 2023 on Bookings.com for the selected hotels was conducted. Using content analysis, the key factors that influenced visitors to choose these hotels were identified. The frequency of these key factors mentioned in the reviews was plotted in graphs using MS Excel. The second part of the research focused on determining the overall popularity of the hotels. This involved comparing the selected hotels and other popular hotels in the Czech Republic available on Booking.com. Moreover, the main key factors identified in the first part of the research were compared across the six selected hotels. The final part of the research analyses whether hotel ratings changed between 2021 and 2023. This question was answered using analysis of variance (ANOVA) in MS Excel. The analysis helped to determine whether and how the ratings changed during the monitored period.

4.1. Content analysis of reviews of selected hotels

A content analysis of the reviews for the six selected hotels (BoHo Hotel Prague – Small Luxury Hotels, Chateau Herálec Boutique Hotel and Spa by L'Occitane, Carlsbad Plaza Medical Spa and Wellness, Four Seasons Hotel Prague, Mandarin Oriental, Prague, and Augustine, a Luxury Collection Hotel, Prague) identified the key factor most frequently mentioned by customers on Booking.com. These key factors were recorded in absolute numbers, as many reviews continued multiple key factors. The analysis enabled the identification of the main key factors with the highest frequency of occurrence. Based on the data from Booking.com, it was possible to categorise these key factors according to different times of the year and determine which factor was preferred by customers in that period for each hotel.

4.1.1 Content analysis of reviews of selected hotels

The first hotel analysed was BoHo Prague, which had 513 reviews on Booking.com during the study period. Of this number, 190 reviews contained verbal ratings, allowing for the analysis of the key factors most frequently mentioned by customers. It shall be noted that the reviews of BoHo Prague were predominantly positive, with very few negative comments. The majority of the hotel's customers were international guests, with reviews from Czech visitors being very rare. The analysis identified a total of seven key factors, namely staff, wellness, food, amenities, location, cleanliness, and price.

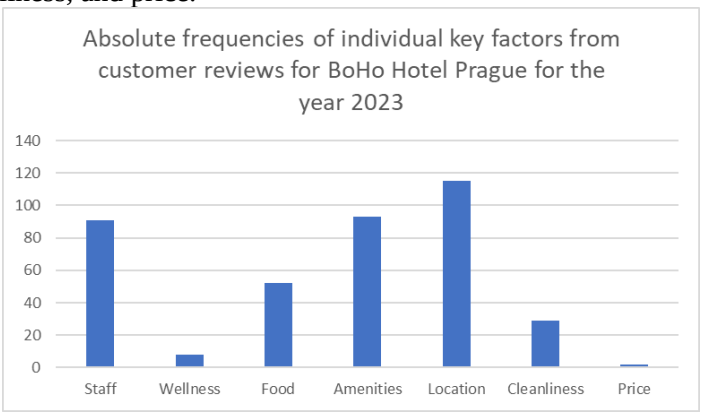


Figure 1. Absolute frequencies of key factors for BoHo Hotel Prague in 2023

Source: Authors based on data from Booking.com.

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A graphical representation of the results (see Figure 1) shows the key factors with the highest frequency of occurrence in the reviews. These factors were divided into categories that encompass the services offered by the hotels. The "Staff" category includes all hotel employees (receptionists, chauffeurs, cooks, hostesses, waiters, or cleaners). This factor was mentioned 91 times in customer reviews. "Wellness" includes all spa services offered by the hotel, such as saunas, massages, spa access, or the possibility to use a swimming pool and gym. This factor was mentioned eight times in the reviews. "Food" includes all meals and refreshments offered to customers, breakfast, lunch, dinner, bar services, and room service, mentioned 52 times in the reviews. "Amenities" refers to the room amenities, the comfort of the furniture, and the architecture of the hotel. This factor was mentioned 93 times. The location of the hotel was mentioned 115 times, making it a major key factor for BoHo Prague, located close to Wenceslas Square, tourist attractions, the train station, and the metro station. The "Cleanliness" category, which includes the overall cleanliness of the hotel, rooms, and housekeeping services, was mentioned 29 times. The "Price" category was only mentioned twice.

A detailed analysis of the content identified the changes in the frequencies of these key factors throughout the year. The "Staff" factor consistently showed a very high frequency, being mentioned 20 times in the spring, 28 times in the summer, 16 times in the autumn, and 27 times in the winter. "Wellness" was mentioned less frequently, with two mentions in the spring, one in the summer and autumn, and four in the winter. The "Food" factor was mentioned more frequently, with 12 mentions in the spring, 19 in the summer, 11 in the autumn, and 10 in the winter. The "Amenities" factor appeared 19 times in the spring, 30 times in the summer, 19 times in the autumn, and 25 times in the winter. The "Location" factor showed a higher frequency, being mentioned 31 times in the spring, 33 times in the summer, 24 times in the autumn, and 27 times in the winter. The "Cleanliness" factor was mentioned 6 times in the spring, 8 times in the summer, 6 times in the autumn, and 8 times in the winter, while "Price" was mentioned twice in the reviews, once in the spring and once in the winter (see Figure 2).

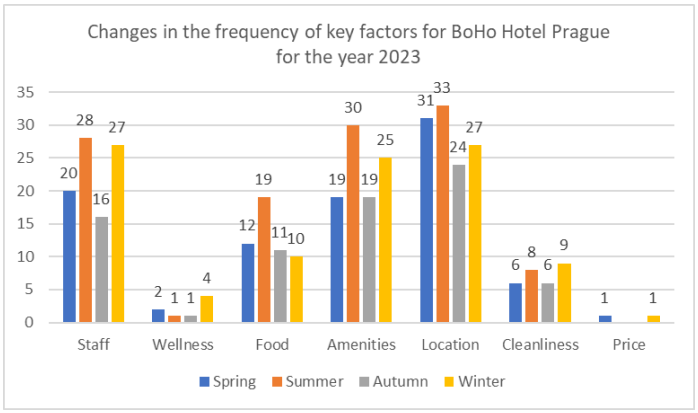


Figure 2. Changes in the frequency of key factors for BoHo Hotel Prague for the year 2023

Source: Authors based on data from Booking.com.

4.1.2. Chateau Herálec Boutique Hotel and Spa by L'Occitane

Another hotel whose reviews were analysed in this study is Chateau Herálec Boutique Hotel and Spa by L'Occitane. During the specified period, the hotel received 149 reviews on Booking.com in the given period was 149, of which 101 included verbal ratings that were used to identify key factors. These factors and their absolute frequencies were graphically recorded. The vast majority of the reviews were from Czech customers, with fewer reviews from international guests, primarily from Austria and Germany. Negative reviews were infrequent and often lacked verbal ratings to pinpoint the reasons for customer dissatisfaction. Unlike BoHo Hotel Prague, Chateau Herálec responded proactively to many customer reviews.

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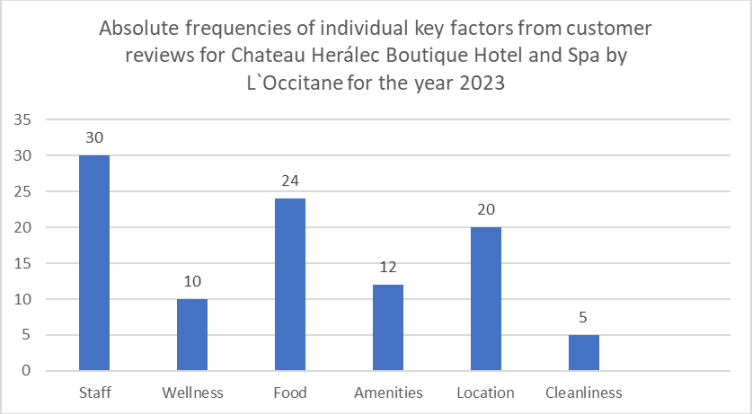


Figure 3. Absolute frequencies of key factors for Chateau Herálec Boutique Hotel and Spa by L'Occitane for the year 2023

Source: Authors based on data from Booking.com.

Based on the graphical representation of the frequencies (see Figure 3), it can be stated that the primary key factor influencing customers' choice of this hotel is the staff. This category includes all hotel staff that may interact with hotel guests. This key factor was mentioned 30 times in the reviews. The "Wellness" factor, encompassing all spa-related services, was mentioned 10 times. The "Food" factor was cited 24 times, "Amenities" 12 times, and "Cleanliness" five times. The content analysis identified the absolute frequencies of individual key factors by season, providing a detailed view of the development of these frequencies. The graph in Figure 4 illustrates the changes in the frequencies of the selected key factors throughout the year 2023. The "Staff" factor varied considerably, being mentioned ten times in the spring, eleven times in the summer, five times in the autumn, and four times in the winter. The "Wellness" factor was less frequently mentioned, with the highest frequency of five mentions in the spring, twice in the summer and autumn, and only once in the winter. The "Food" factor was mentioned eleven times in the spring, eight times in the summer, three times in the autumn, and twice in the winter. "Amenities" was mentioned less frequently, with three mentions in the spring, four in the summer and autumn, and one in the winter. The "Location" factor was mentioned nine times in the spring, eight times in the summer, and three times in the autumn. The factor was not mentioned at all in the winter. The least frequently mentioned factor was "Cleanliness" with two mentions in the summer and autumn and one mention in the winter.

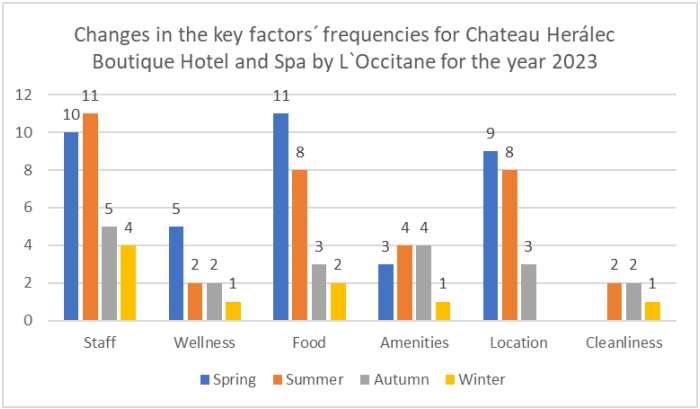


Figure 4. Changes in the key factors' frequencies for Chateau Herálec Boutique Hotel and Spa by L'Occitane for the year 2023

Source: Authors based on data from Booking.com.

4.1.3. Carlsbad Plaza Medical Spa a Wellness

Another hotel analysed is Carlsbad Plaza Medical Spa and Wellness, located in Karlovy Vary near Vřídelní kolonáda. The hotel received a total of 440 reviews on Booking.com. Among these, 152 reviews included verbal ratings that enable the identification of key factors through content analysis. The identified key factors

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included staff, wellness, food, amenities, location, cleanliness, and price, as those identified for BoHo Hotel Prague.

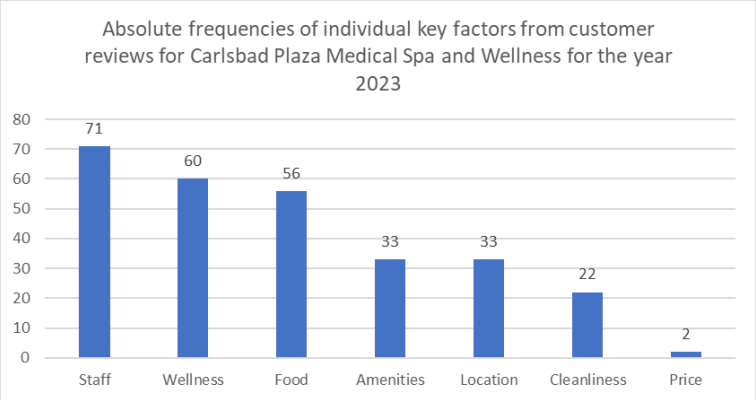


Figure 5. Absolute frequencies of key factors for Carlsbad Plaza Medical Spa and Wellness for the year 2023

Source: Authors based on data from Booking.com.

As illustrated in Figure 5, the primary key factor for this hotel was staff. This factor includes all hotel employees, being mentioned 71 times in the reviews. The "Wellness" factor, which encompasses all spa-related services and the gym, was mentioned 60 times. The "Food" factor, referring to the hotel restaurant and room service, was mentioned 56 times. "Amenities", which include furniture and hotel architecture, was mentioned 33 times, the same as the "Location" factor. "Price" was mentioned twice in the reviews. The application of content analysis allowed for the identification of changes in the absolute frequency throughout the individual periods of the year. Figure 6 shows that the "Staff" factor was mentioned 9 times in the spring, 6 times in the summer, 14 times in the autumn, and 22 times in the winter. The "Wellness" factor was mentioned 24 times in the spring, four times in the summer, 13 times in the autumn, and 19 times in the winter. The "Food" key factor showed relatively stable frequencies throughout the year, except for the summer, when it was mentioned four times. In the spring, the factor was mentioned 19 times, 16 times in the autumn, and 17 times in the winter. The "Amenities" factor was mentioned 10 times in the spring, 4 times in the summer, 11 times in the autumn, and 8 times in the winter. The "Cleanliness" factor was mentioned 7 times in the spring, once in the summer, 4 times in the autumn, and 10 times in the winter. The "Price" factor was mentioned once in the spring and twice in the winter.

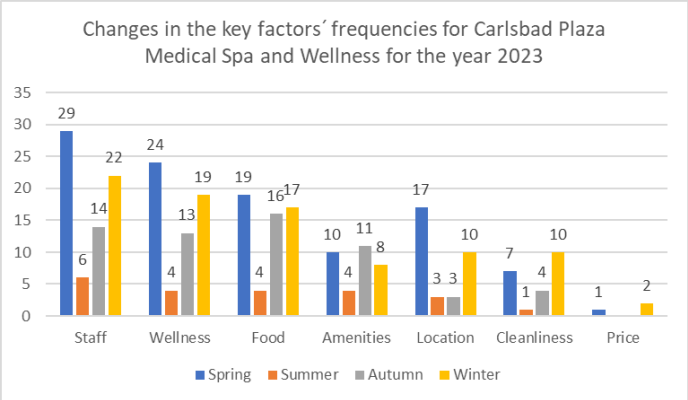


Figure 6. Changes in the key factors' frequencies for Carlsbad Plaza Medical Spa and Wellness for the year 2023

Source: Authors based on data from Booking.com.

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4.1.4. Four Seasons Hotel Prague

In 2023, Four Seasons Hotel Prague received a total of 167 reviews on Booking.com. Of this number, 23 reviews were with detailed verbal ratings. The key factors mentioned in the reviews include staff, wellness, food, amenities, location, and cleanliness.

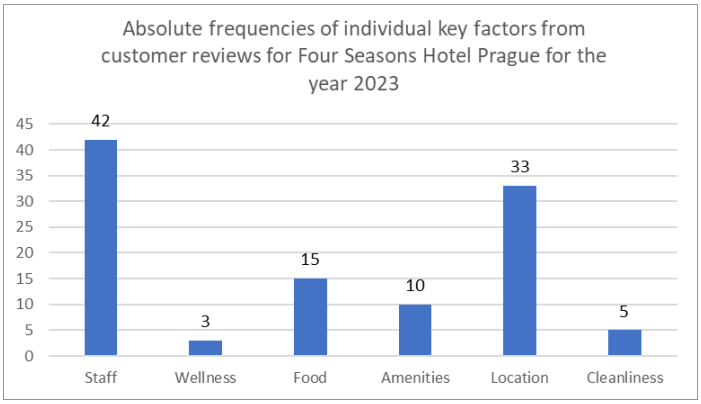


Figure 7. Absolute frequencies of key factors for Four Seasons Hotel Prague for the year 2023

Source: Authors based on data from Booking.com.

Figure 7 illustrates that the most frequently mentioned key factor in the reviews is the staff. This includes all hotel employees, with receptionists being the most commonly referenced, appearing 42 times in the reviews. The "Wellness" factor (including the pool and saunas) was only mentioned three times. "Food", encompassing the evaluation of all served meals and bar offerings, was mentioned 15 times in the reviews, while "Amenities", including furniture and architecture, were mentioned 10 times. Location, an important factor in choosing the hotel, was mentioned 33 times. The hotel is centrally located in Prague, close to major landmarks. Hotel cleanliness was mentioned five times across all seasons as a key factor. Figure 8 shows the development of these factors throughout the year 2023. The "Staff" factor was mentioned 11 times in the spring, 7 times in the summer, 13 times in the autumn, and 11 times in the winter. The "Wellness" factor was not mentioned in the spring, mentioned once in the summer, and twice in the autumn and winter. "Food" was mentioned three times in the spring and summer, six times in the autumn, and three times in the winter. The "Amenities" factor was mentioned three times in the spring and summer, six times in the autumn, and three times in the winter. "Location" was mentioned 11 times in the spring, 5 times in the summer, 7 times in the autumn, and 10 times in the winter. The "Cleanliness" factor was mentioned twice in the spring, once in the autumn, and twice in the winter. This factor was not mentioned in the summer.

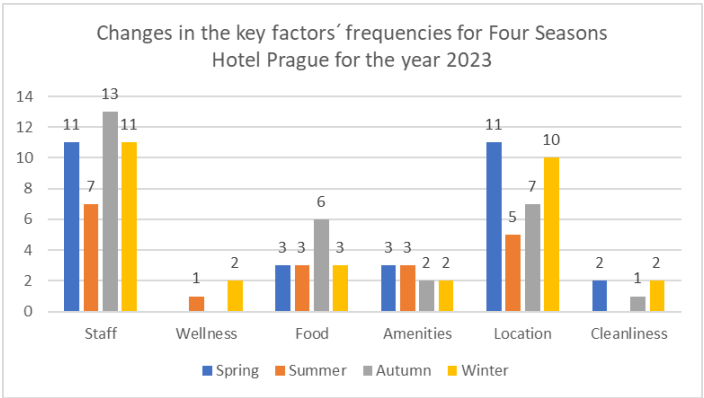


Figure 8. Changes in the key factors' frequencies for Four Seasons Hotel Prague for the year 2023

Source: Authors based on data from Booking.com.

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4.1.5. Mandarin Oriental, Prague

Another hotel analysed was Mandarin Oriental, Prague, which received 52 reviews on Booking.com for the year 2023. Of this number, only 14 reviews included verbal ratings based on which the key factors were identified. These factors included staff, amenities, and location.

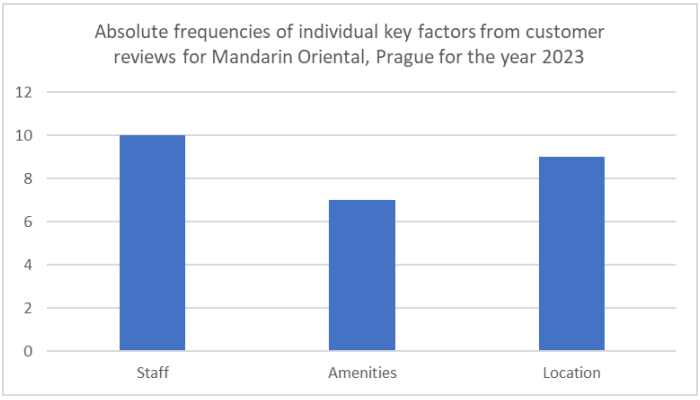


Figure 9. Absolute frequencies of key factors for Mandarin Oriental, Prague for the year 2023

Source: Authors based on data from Booking.com.

The above graph (see Figure 9) illustrates that the primary key factor in choosing the hotel was the staff. This factor included all hotel employees, with receptionists and masseurs being mentioned most often by hotel guests, appearing 10 times in the reviews. The "Amenities" factor (furniture, indoor and outdoor architecture, and spa amenities) was mentioned 7 times. Customers most frequently commented on the overall architecture of the hotel. The "Location" factor was mentioned nine times. The analysed data enabled observing how the frequencies of these key factors changed throughout the monitored period. As seen in Figure 10, the "Staff" factor was most frequently mentioned in the spring months, specifically 5 times. In the summer months, this factor appeared in the reviews three times and once in the autumn and winter months. The "Amenities" key factor was mentioned in the reviews 3 times in the spring, twice in the summer, and twice in the winter. In the autumn months, the factor was not mentioned. The "Location" key factor was mentioned 4 times in the spring, twice in the summer, and once in the autumn. The factor showed a slight increase in the winter months, as mentioned twice in the reviews.

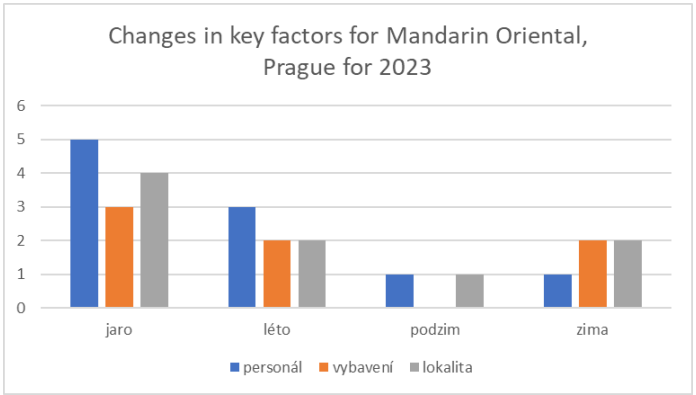


Figure 10. Changes in key factors for Mandarin Oriental, Prague for 2023

Source: Authors based on data from Booking.com.

4.1.6. Augustine, a Luxury Collection Hotel, Prague

In 2023, this hotel received a total of 30 reviews on Booking.com, 11 of which included detailed verbal ratings. This allowed for an analysis of the key factors influencing guests' choice of the hotel. The major factors identified were staff, amenities, food, and location. The hotel is situated in the centre of Prague near many

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historical monuments, what was frequently highlighted in the reviews. However, customers noted that one of the most intriguing aspects of the hotel is its amenities, which is due to the renovated historic buildings.

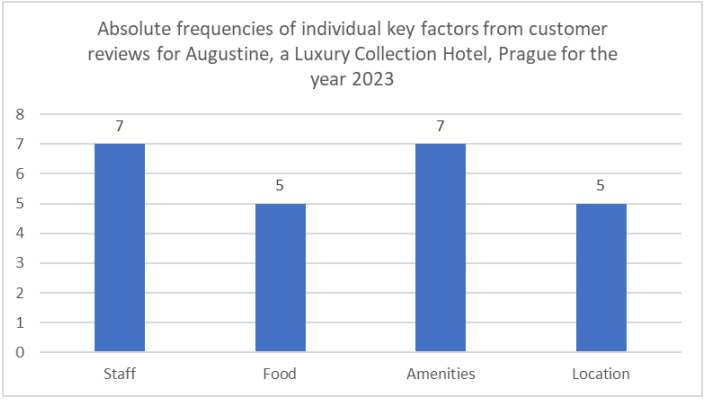


Figure 11. Absolute frequencies of key factors for Augustine, a Luxury Collection Hotel, Prague for the year 2023

Source: Authors based on data from Booking.com.

In this case, the main key factors were two aspects (see Figure 11). The first was the staff, who, according to customer reviews, were noted for their very friendly approach. The second key aspect was the amenities of the hotel, which impressed customers with their modern design. Both of these factors were mentioned a total of seven times in the reviews. The factors of "Food" and "Location" were mentioned five times each. Customers positively evaluated the food, particularly appreciating the hotel restaurant and breakfast. The location of the hotel, which is close to Prague Castle and other historical monuments, was also an important factor for customers. The data analysis revealed that the frequency of these factors varied across different seasons. Unlike other hotels, there were no reviews with detailed verbal ratings available for analysis during the spring months (see Figure 12). The "Staff" key factor was most frequently mentioned in the winter months, appearing five times in the reviews. The "Food" factor was not mentioned during the summer and autumn months but was noted five times in the winter. The "Amenities" factor was mentioned once in the summer and in the autumn, with the frequency increasing to 3 mentions in the winter. The "Location" key factor was mentioned only once in both the summer and autumn, but the frequency increased to 5 in the winter months.

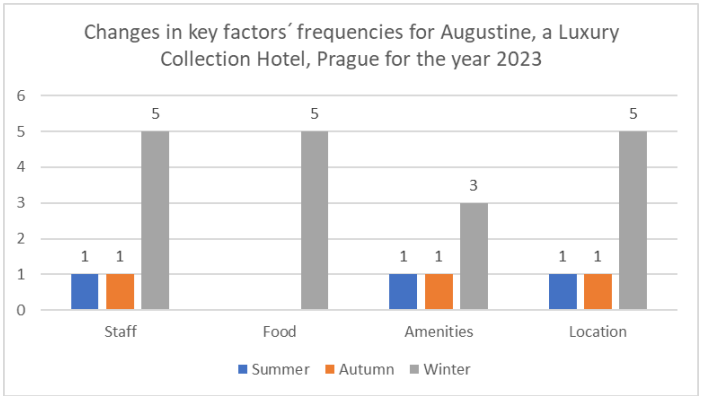


Figure 12. Changes in key factors' frequencies for Augustine, a Luxury Collection Hotel, Prague for the year 2023

Source: Authors based on data from Booking.com.

4.2. Comparison of selected hotels' ratings

To answer the second research question, it was necessary to compare the rating of the aforementioned luxury five-star hotels with other Czech hotels. Given that these hotels are highly rated on Booking.com, a comparison was made between them and another popular hotel with high ratings. The aim was to determine how popular these selected hotels are with customers and which of them is the best. The comparison considered the overall ratings of the hotels on Booking.com, which represent the average of customer reviews over the entire period

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of the hotels' profiles on the portal. In addition, key factors that help explain the position of each hotel on the Czech market, which included its facilities and quality of services, were also considered.

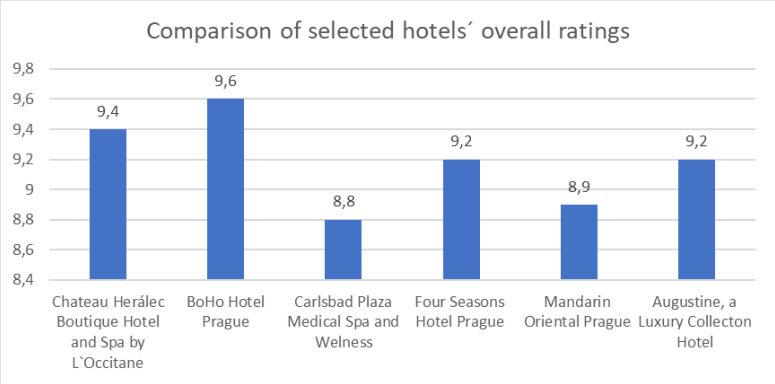


Figure 13. Comparison of selected hotels' overall ratings

Source: Authors based on data from Booking.com.

The graph of the overall ratings of the hotels (see Figure 13) indicates that the highest rating (9.6 out of 10 points) was awarded to Chateau Herálec. This hotel received mostly positive reviews on Booking.com; however, there were also negative reviews, similar to BoHo Prague, where a lack of responses to reviews was noted. The second highest rating of 9.4 points went to BoHo Hotel Prague, which also had the highest number of reviews among the selected hotels for the year 2023, both with and without verbal ratings. Unlike other hotels, there were no responses to negative reviews. Carlsbad Plaza Medical Spa & Wellness received the lowest rating of 8.8 out of 10. This hotel was actively engaged in discussions with reviewers, responding to both positive and negative reviews, including criticism related to reconstruction and parking. The Four Seasons Hotel Prague was awarded a rating of 9.2 points and actively responded to customer reviews. However, the presence of negative reviews indicates the difficulty of meeting the high standards typical of the Four Seasons chain. Mandarin Oriental, Prague received a rating of 8.9, with a relatively lower number of reviews on Booking.com. Most of the ratings were responded to by the hotel management, who made efforts to meet customer requirements. Augustine, a Luxury Collection Hotel, Prague received fewer ratings on Booking.com compared to other hotels. Most reviews were positive, although the hotel received a lower number of reviews in 2023 compared to the preceding years. Despite this, the hotel received a rating of 9.2 points. The comparison of luxury hotels in the Czech Republic showed that Chateau Herálec Boutique Hotel and Spa received the highest review score. An analysis of the key factors for those hotels revealed that for the majority, the main factor was the staff, which encompassed all hotel employees from receptionists to masseurs, cooks, and housekeepers. Thus, the success and high ratings of these hotels were predominantly due to positive customer reviews, which most often highlighted the human factor. BoHo Hotel Prague, the second highest-rated hotel, identified "Location" as a major key factor. The key factors and their relative frequencies are detailed in Table 1, which shows the percentage of main key factors for each hotel in comparison to other factors. Individual key factors showed a relative frequency between 20 % and 60 %.

Table 1. Relative frequencies of the main key factors of selected hotels

Hotel	BoHo Hotel Prague	Chateau Herálec Boutique Hotel and Spa by L'Occitane	Carlsbad Plaza Medical Spa and Wellness	Four Seasons Hotel Prague	Mandarin Oriental Prague	Augustine, a Luxury Collection Hotel
Key factor	Location	Staff	Staff	Staff	Staff	Staff and Amenities
Relative frequency of key factor	29,5%	29,7%	25,6%	38,5%	38,5%	60,8%

Source: Authors based on data from Booking.com.

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A further comparison with other popular hotels according to Booking.com, a website that ranks highly rated hotels, reveals that the six selected hotels maintained a high position in the Czech market and were popular among customers even compared to other well-rated hotels. The graphical representation in Fig. 14 shows that hotels whose key factors were analysed in this paper achieved higher ratings than most of the other selected hotels.

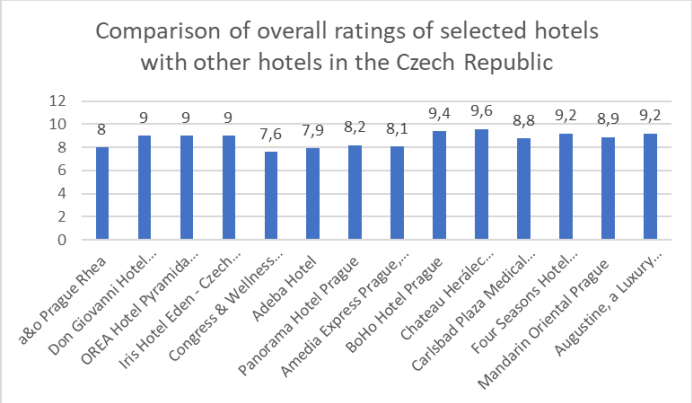


Figure 14. Comparison of overall ratings of selected hotels with other hotels in the CR

Source: Authors based on data from Booking.com.

Even though some hotels, such as OREA Hotel Pyramída and Iris Hotel Eden, received a rating of 9 on Booking.com, they still did not reach the level of the selected and previously analysed hotels, which were rated higher. This is because hotels like OREA Hotel Pyramída and Iris Hotel Eden are only four-star hotels. Other hotels, such as Adeba Hotel or Congress & Wellness Hotel Olsanka, which received an overall rating of less than 8 points, were rated with only three stars.

4.3. Analysis of variance of selected hotels' average ratings in 2021-2023

To answer the third research question, an analysis of variance was performed using the ANOVA function in MS Excel. The aim was to determine whether customer ratings changed in the years 2021-2023, i.e., during and after the COVID-19 pandemic. The data were obtained from Booking.com, where the hotel's overall ratings were analysed for the years studied. The portal displayed only the overall average rating from the year when the hotel profile was created, not individual yearly ratings. The analysed data included the number of points awarded by customers over the given period, which were then recorded in MS Excel. A one-factor analysis of variance determined a p-value, which was compared to a predetermined significance level of 5 %. If the p-value is greater than 0.05, the null hypothesis that the rating changed is accepted. If the p-value is less than 0.05, the alternative hypothesis that refuted the claims that the average rating of hotels changed over the period is accepted. This method allowed for the analysis of average ratings for each year to identify any changes.

4.3.1. BoHo Hotel Prague – Small Luxury Hotels

BoHo Hotel Prague – Small Luxury Hotels received a total of 1,735 reviews on Booking.com in the given period, including a hotel rating score. Using analysis of variance, it was possible to test the null and alternative hypotheses. According to the null hypothesis, the hotel's rating did not change between the COVID-19 pandemic and the present, while the alternative hypothesis suggests that the hotel's rating remained stable during the pandemic and the following years. The results in Table 2 show that the p-value was 0.8202788, which is approximately 82.02 %. This means that the p-value is greater than the determined significance level, indicating that the null hypothesis that the rating changed in the analysed years could be accepted. Based on this test, the alternative hypothesis was rejected.

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Table 2. Analysis of variance for BoHo Hotel Prague – Small Luxury Hotels

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0,376	2	0,187895760	0,19813365	0,820278797	3,000916788
Within Groups	1643,453056	1733	0,948328365			
Total	1643,828848	1735				

Source: Authors based on data from Booking.com.

Based on the results of the analysis of variance, it is possible to determine the average ratings of BoHo Hotel Prague for individual years. In 2021, the received rating was 9.39 out of 10.

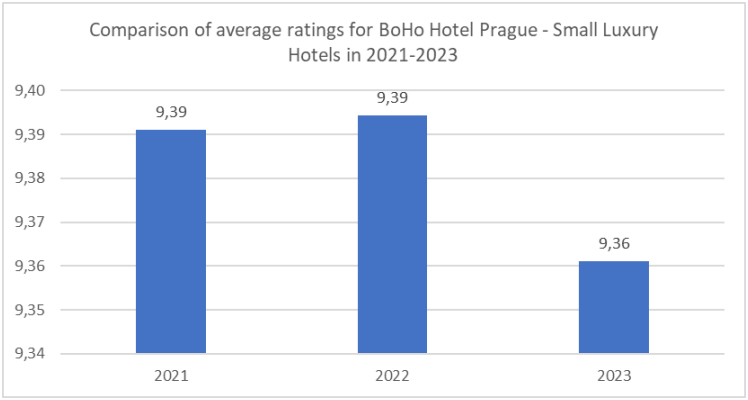


Figure 15. Comparison of overall ratings of selected hotels and other hotels in the CR

Source: Authors based on data from Booking.com.

The same rating was recorded in 2022, while in 2023, the rating decreased slightly to 9.36. This change indicates a slight decrease in the rating (see Figure 15 above).

4.3.2. Carlsbad Plaza Medical Spa and Wellness

Carlsbad Plaza Medical Spa and Wellness had a total of 943 reviews on Booking.com over the given period. According to the null hypothesis, the hotel's rating changed during the pandemic compared to the present situation, while the alternative hypothesis states the opposite. The results of the analysis indicate that the p-value is 0.91878501, which corresponds to 91.87 %. This value is greater than the significance level of 5%, which means that the null hypothesis can be accepted. This indicates that the average rating of the hotel changed in the indicated years. Therefore, the alternative hypothesis is rejected.

Table 3. Analysis of variance for Carlsbad Plaza Medical Spa and Wellness

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0,4	2	0,22465518	0,08471075	0,91878501	3,00528965
Within Groups	2495,5573	941	2,65202689			
Total	2496,0066	943				

Source: Authors based on data from Booking.com.

The analysis of variance enabled determining the average ratings of the hotel for the given years.

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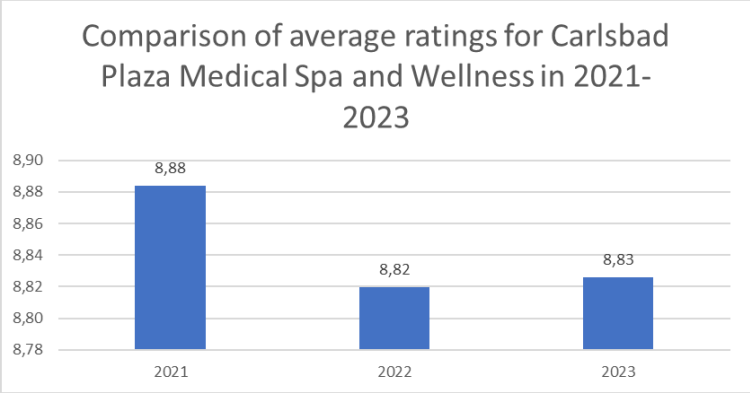


Figure 16. Comparison of average ratings for Carlsbad Plaza Medical Spa and Wellness in 2021-2023

Source: Authors based on data from Booking.com.

Similar to the previous example of BoHo Hotel Prague, the rating of this hotel during the COVID-19 pandemic and at present showed very slight changes (see Figure 16 above), often by only a hundredths. In 2021, the overall average rating was 8.88 out of 10. In 2022, the rating was 8.82, while in 2023, it increased slightly to 8.83.

4.3.3 Four Seasons Hotel Prague

Four Seasons Hotel Prague had 401 reviews on Booking.com over the given period. According to the null hypothesis, the hotel's rating changed during the pandemic compared to the current situation, while the alternative hypothesis states that the rating did not change. The p-value is 0.14108378 (see Table 4), which corresponds to 14.10 %. Since the p-value is greater than the significance level of 5 %, the null hypothesis that the average hotel rating changed in the years 2021-2023 can be accepted.

Table 4. Analysis of variance for Four Seasons Hotel Prague

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7,97503	2	3,987513547	1,968045248	0,141083785	3,018337541
Within Groups	808,4254704	399	2,026128999			
Total	816,4004975	401				

Source: Authors based on data from Booking.com.

Based on the analysis of variance, it was possible to determine the average rating of Four Seasons Hotel Prague for each year.

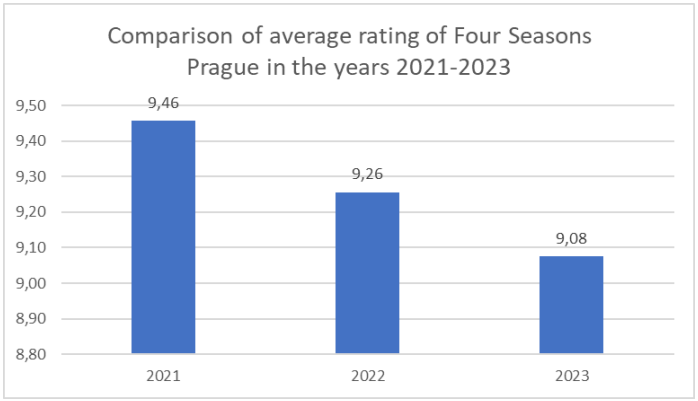


Figure 17. Comparison of average rating of Carlsbad Plaza Medical Spa and Wellness in the years 2021-2023

Source: Authors based on data from Booking.com.

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This rating is shown in the graph (see Figure 17 above), which indicates that in 2021, the hotel's average rating was 9.46 out of 10. In 2022, this rating dropped to 9.26, and in 2023, the rating showed another decrease to 9.08. This means that between 2021 and 2023, the average rating of Four Seasons Hotel Prague dropped by nearly four-tenths.

4.3.4. Chateau Herálec Boutique Hotel and Spa by L'Occitane

In the years 2021-2023, Chateau Herálec Boutique Hotel and Spa by L'Occitane received 252 reviews with overall ratings for the hotel. The null hypothesis states that the rating changed during the pandemic compared to the present situation; according to the alternative hypothesis, the rating did not change. As seen in Table 5, the p-value is 0.6102622, which corresponds to 61.02 %. The p-value supports the null hypothesis, stating that the average rating of the hotel changed over time.

Table 5. Analysis of variance for Chateu Herálec Boutique Hotel and Spa by L'Occitane

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0,9605	2	0,480252356	0,494843453	0,610262217	3,03191842
Within Groups	242,6284281	250	0,970513712			
Total	243,5889328	252				

Source: Authors based on data from Booking.com.

Based on the results of the analysis of variance, it was possible to determine individual mean values of the overall ratings within the given period.

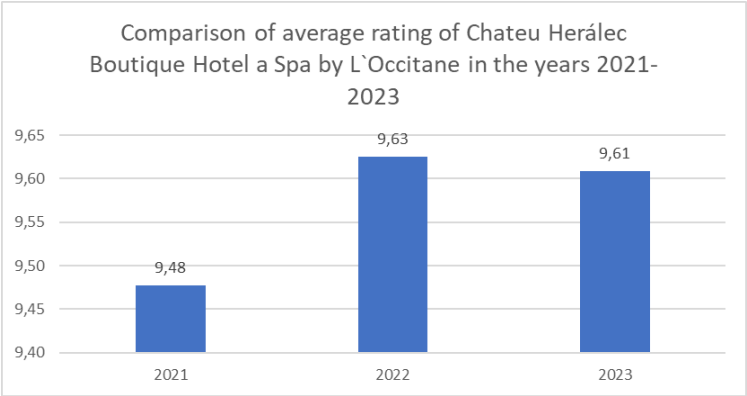


Figure 18. Comparison of average ratings of Carlsbad Plaza Medical Spa and Wellness in the years 2021-2023

Source: Authors based on data from Booking.com.

Figure 18 above shows that in 2021, Chateau Herálec Boutique Hotel and Spa by L'Occitane achieved an average total score of 9.48 out of 10. In the following year, the rating increased to 9.63. The overall average rating in 2023 is similar to the preceding year, reaching the value of 9.61.

4.3.5 Mandarin Oriental, Prague

Another hotel analysed is Mandarin Oriental in Prague. In the years 2021-2023, this hotel received 131 reviews with rating scores on Booking.com. The null hypothesis states that the hotel's rating changed during the pandemic compared to the present situation, while the alternative hypothesis states the opposite. Table 6 indicates that the p-value is 0.80474112, which corresponds to 80.47 %. This value is greater than the significance level of 5 %, which means that the null hypothesis is accepted, as the average hotel's rating changed in the years 2021-2023.

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Table 6. Analysis of variance for Mandarin Oriental, Prague

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1,2425	2	0,621263858	0,217600871	0,804741123	3,066391037
Within Groups	368,3029268	129	2,855061448			
Total	369,5454545	131				

Source: Authors based on data from Booking.com.

The analysis of variance enabled determining the hotel's overall rating for individual years. The rating is graphically illustrated below (see Figure 19).

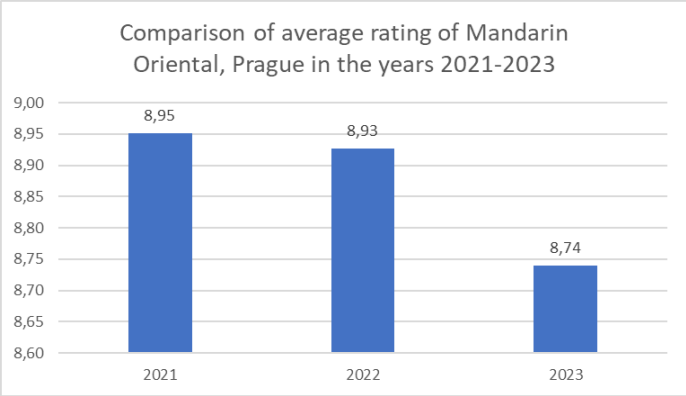


Figure 19. Comparison of average rating of Mandarin Oriental, Prague in the years 2021-2023

Source: Authors based on data from Booking.com.

In 2021, Mandarin Oriental Hotel achieved a rating of 8.95 out of 10. In 2022, the rating dropped slightly to 8.93, which was followed by another decrease of nearly two-tenths in the next year, reaching 8.74 out of 10.

4.3.6. Augustine, a Luxury Collection Hotel, Prague

This hotel received 138 reviews on Booking.com during the given period, each including a score. The null hypothesis states that the hotel's rating changed during the pandemic period compared to the present. Conversely, the alternative hypothesis states that the hotel's rating did not change between the global pandemic period and the present. As seen in Table 7, the p-value is 0.82073825, corresponding to 82.07 %., which is greater than the significance level of 5 %. The results of the analysis confirm the null hypothesis that the average ratings of the hotel in the given period between the pandemic and the present changed. Therefore, the alternative hypothesis is rejected.

Table 7. Analysis of variance for Augustine, a Luxury Collection Hotel, Prague

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0,66473	2	0,33236283	0,197893773	0,820738249	3,075852636
Within Groups	191,4631376	114	1,679501207			
Total	192,1278632	116				

Source: Authors based on data from Booking.com.

The application of analysis of variance enabled the determination of this hotel's average ratings of this hotel over the given period. The rating is graphically illustrated below (see Figure 20)

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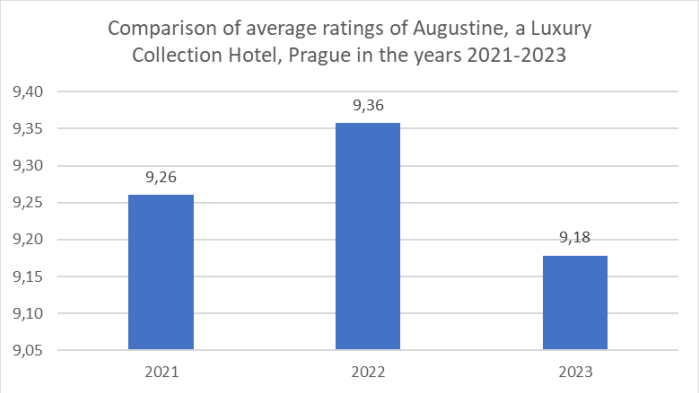


Figure 20. Comparison of average ratings of Augustine, a Luxury Collection Hotel, Prague in the years 2021-2023

Source: Authors based on data from Booking.com.

In 2021, the hotel achieved an overall average rating of 9.26 out of 10. In the next year, the rating increased to 9.36, which was followed by a drop by nearly two tenths in 2023, reaching the value of 9.18.

Discussion of answers to the research questions

Based on the results obtained, it was possible to answer all research questions concerning the selected high-rated Czech hotels, namely BoHo hotel Prague, Mandarin Oriental, Prague, and Augustine, a Luxury Collection Hotel, Prague. All information and reviews were obtained from the online portal Booking.com and included data for the year 2023.

Research question 1: What key factors drive customers to visit the selected hotels? The answer to the question was obtained through analysing reviews from the year 2023, i.e., the first year without the influence of COVID-19. The analysis helped to identify key factors, namely staff, wellness, food, amenities, location, cleanliness, and price. Each hotel had its own specific key factors, with staff being often the most frequently mentioned key factor.

Research question 2: What is the online reputation of the selected hotels in the Czech market? The descriptive analysis and comparison of the selected hotels with other highly rated Prague hotels showed that the selected hotels consistently achieved strong ratings on Booking.com, with average scores ranging from 8.0 to 9.6 out of 10. The highest rating was awarded to Chateau Herálec Boutique Hotel and Spa by L' Occitane, which received 9.6 points. Overall, the reputation of all the hotels analysed was very good.

Research question 3: Do the average ratings of the selected hotels differ in 2021, 2022, and 2023, i.e., from the period of the COVID-19 pandemic to the present? The analysis of variance using the ANOVA function in MS Excel demonstrated that the average ratings of the hotels changed between 2021 and 2023. The null hypothesis proposing that the average ratings varied during this period was confirmed. It was found that the average ratings fluctuated year by year, something not directly observable on Booking.com.

A research limitation is the reliance on data from only one review platform. Incorporating multiple sources would likely yield more accurate results. Another limitation is fake or edited reviews, which may skew the results. The findings of the research are valuable for the hotels themselves, particularly for strategic planning and service improvement, as well as for their staff, customers, and professionals in the field of online reputational management. The research provides a deeper understanding of the factors influencing customer satisfaction and loyalty.

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Conclusions

The objective of the paper was the analysis of reputation management and identification of key factors for a selection of hotels, including BoHo Hotel Prague - Small Luxury Hotels, Chateau Herálec Boutique Hotel and Spa L'Occitane, Carlsbad Plaza Medical Spa & Wellness, Four Seasons Hotel Prague, Mandarin Oriental, Prague, and Augustine, a Luxury Collection Hotel, Prague, on the basis of reviews from Booking.com for the year 2023. The objective was achieved, and all research questions were addressed. The analysis of customer reviews identified the key factors that attract customers, with the most frequently mentioned being staff, wellness, food, amenities, location, cleanliness, and price. For each hotel, the frequency of these factors was determined, and a primary key factor was selected. A subsequent comparison of the average ratings of the selected hotels offered a more detailed perspective on their popularity in the Czech market. The analysis revealed that these hotels are highly sought after and well-rated, with average scores ranging from 8.0 to 9.6 out of 10. The most popular hotel was Chateau Herálec Boutique Hotel and Spa by L'Occitane, with a rating of 9.6 out of 10, making it one of the top-rated hotels in the Czech Republic on Booking.com. The next part of the research focused on an analysis of variance to determine whether the ratings of the selected hotels changed between 2021 and 2023. A null hypothesis was formulated, suggesting that the average ratings of the hotels changed over this period, while the alternative hypothesis posited the opposite. The analysis confirmed the null hypothesis, indicating that average hotel ratings did indeed change during and after the pandemic period. This paper provides new insights into the selected hotels that may be valuable for customers, as well as for hotel owners and staff. These insights can be leveraged to improve and maintain the reputation of these establishments. One of the main limitations of this study is the reliance on a single data source – Booking.com. Although this platform is widely used and highly influential in the hospitality sector, an analysis of reviews from additional platforms (e.g., TripAdvisor, Google Reviews, Expedia) would increase the robustness of the findings. Future research should include data from both domestic and international review platforms to capture a broader and more representative picture of customer feedback. Another important limitation is the potential presence of fake or manipulated reviews, which may distort the results despite platform efforts to moderate content. In addition, the methodological approach focuses solely on numerical review scores without accounting for other influential factors identified in the literature – such as corporate social responsibility (CSR) initiatives, offline word-of-mouth, branding strategies, or customer loyalty programs. These aspects may significantly influence a hotel's reputation but were not examined in this study due to data accessibility and methodological scope. A more comprehensive model integrating these qualitative factors would be beneficial for future research.

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ASSET-LIGHT CONSTRUCTION OF TECHNOLOGY-DRIVEN STARTUPS: INSIGHTS FROM CASE STUDIES IN CHINA*

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Abstract. The resource-efficient allocation advantages of asset-light operations have garnered considerable attention from technology-driven startups in China. Clarifying the construction pathways of asset-light operations is crucial for guiding the development of such enterprises. This study examines two asset-light, technology-driven startups in China to identify key elements of the asset-light operation process and comparatively analyze their heterogeneous construction pathways using imprinting theory. The findings reveal that the alignment of open demand and connectivity conditions forms the foundation for establishing asset-light operation partnerships, while shared logic facilitates collaborations. Establishing symbiotic relationships is identified as a key factor in the sustainable development of asset-light operations. Regarding resource integration pathways, relationship-based entrepreneurial teams typically form asset-light resource networks in a $0 \rightarrow n$ diffusion pattern by engaging in acquisitive resource integration behavior, exhibiting the characteristic of expansive resource capability. Conversely, technology-based entrepreneurial teams form $0 \rightarrow 1 \rightarrow n$ bridging resource networks through accumulative resource integration, demonstrating exploratory resource capability. These findings contribute to the study of asset-light operations in independent entrepreneurship and offer differentiated asset-light construction pathway references for technology-driven startups

Keywords: asset-light operations; distinctive construction pathways; resource integration; symbiosis; technology-driven startups

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JEL Classifications: M31, M41, G32

1. Introduction

China's innovation and entrepreneurship policies have driven a surge in entrepreneurial activity. Many technicians have established technology-driven startups, transforming their proprietary technologies into technological products. By the end of 2023, China had 563 000 registered technology small- and medium-sized enterprises (SMEs), marking a year-on-year increase of 25% (Data source: National Database of Science and Technology-Based SMEs). The rapid growth of these enterprises is crucial for achieving sustained technological advancement and economic development. Hui et al. (2022) highlighted that the development of technology-driven startups is often constrained by limited internal resources and difficulty in securing external resources. Business model innovation enables technology-driven enterprises to address resource constraints by expanding external resource acquisition channels, thus meeting resource demands and fostering growth (Chesbrough, 2010; Afuah, 2014; Yi et al., 2024; Lin et al., 2024, Ji et al., 2024).

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Asset-light operation models involve resource allocation (Liang et al., 2023), characterized by their ability to focus limited resources on areas closely related to company development (Wang et al., 2020). Many technology enterprises in China, such as Xiaomi, NIO, and Digital China, have adopted asset-light operation, minimizing expenditures on fixed assets and outsourcing non-core functions such as manufacturing, after-sales, and logistics. This approach allows them to allocate more resources to research and development (R&D), enhancing their core competitiveness. Further, asset-light operations enable technology-driven startups to expand their resource networks and integrate external resources through strategic collaborations (Yi et al., 2024). The model demonstrates superior resource acquisition and operational efficiency, effectively aligning with the needs of technology-driven startups. On October 11, 2024, the Shanghai Stock Exchange officially released the "Guidance on the Application of Issuance and Listing Review Rules No. 6 - Criteria for Identifying Asset-Light and High R&D Investment (Trial)," guiding technology-driven startups to prioritize R&D investment through asset-light strategies.

How do technology-driven startups establish an asset-light operational model? Research has examined the generative elements and models of asset-light operations in spin-off technology startups, revealing that their development is considerably influenced by resources from their parent companies (Li et al., 2020). However, independent technology-driven startups receive no resource support from a parent company, making their approach to asset-light operations substantially different from that of spin-off technology startups. Additionally, scholars have examined the asset-light business models of established technology enterprises, analyzing how innovation ecosystems emerge and evolve under asset-light operation (Yi et al., 2024). Nonetheless, the resource constraints and strategic motivations of established firms differ greatly from those of startups, limiting the applicability of their asset-light models as a reference. The characteristics of technology-driven startups—particularly those lacking resources from a parent company and severely resource-constrained—have not addressed asset-light operation. Therefore, this study, using the case study approach, focuses on two technology-driven startups from China to analyze the construction process of asset-light operation. Our findings fill this gap in the literature on asset-light operation regarding independent entrepreneurship while providing a reference for technology-driven startups to construct their asset-light operations.

2. Theoretical Review of Asset-light Operation in Techno-entrepreneurial Enterprises

From the perspective of value chain theory, asset-light operations benefit technology-driven startups in two primary aspects. First, asset-light operations assist enterprises in identifying key activities within their internal value chains, allowing them to allocate resources to areas closely related to the company's value (Wang et al., 2020, Wang et al., 2024). By minimizing ownership of physical resources while maximizing the flexibility and conversion capacity of internal resources (Kang et al., 2024), asset-light operations enhance the operational efficiency of technology-driven startups (Liou, 2011). Second, asset-light operations emphasize the outsourcing of non-core business functions (Seo & Soh, 2019; Zhang & Zhang, 2024), which helps technology-driven startups gradually accumulate numerous partners, forming a vertical value chain (Yi et al., 2024). Technology-driven startups can integrate complementary resources and even create a symbiotic ecosystem from the vertical value chain (Hohberger et al., 2020; Liang et al., 2023). Despite existing research on the mechanism of asset-light operations for technology-driven startups, research is needed on "how to construct asset-light operations", such as the criteria for technology-driven startups to identify and position key elements of asset-light operation within their internal value chains, pathways for technology-driven startups with scarce resources to establish vertical value chains through asset-light operation, and strategies for maintaining asset-light operation to obtain more resource support. Therefore, our study employs a longitudinal case study approach based on value chain theory to analyze the construction mechanism of asset-light operation in technology-driven startups.

The key to constructing asset-light operation and harnessing its effect lies in resource integration (Shou & Li, 2024). Resource dependence theory emphasizes that external resources are crucial for the development of enterprises, focusing on external resource acquisition. Some scholars argue that newly established enterprises should enhance their visibility and reputation to attract stable external resources (Li et al., 2020). However, technology-driven startups whose core competencies are not yet widely recognized face challenges in securing resource support solely based on technological potential. Generally, these startups acquire external resources

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through two avenues. First, proactive external resource bricolage by the technology entrepreneurship team (Engel et al., 2017). Second, technology-driven startups rely on third-party platforms for resource acquisition, such as joining entrepreneurial platforms or business incubators (Grilli & Marzano, 2023). Research on resource integration has primarily focused on spin-off startups, with a lack of investigation into independent technology entrepreneurship. Compared with general technology entrepreneurship, spin-offs can use the resource network of the parent company, thereby effectively connecting multiple asset-light resource collaborations (Walter et al., 2014). Conversely, independent technology-driven startups lack the inherent advantages of a parent company's resources, necessitating distinct resource integration strategies for asset-light operations. Therefore, our study analyzes the resource integration pathways of asset-light operations in the context of independent entrepreneurship based on resource dependence theory.

Additionally, technology entrepreneurship heavily relies on the entrepreneurial team, with team characteristics such as entrepreneurial passion (Cardon et al., 2009; Ahsan et al., 2023), leadership abilities (Hensellek et al., 2023), influencing entrepreneurial opportunities (Li et al., 2022) and entrepreneurial performance (Wang et al., 2023). However, the application of imprinting theory in entrepreneurship primarily focuses on explaining the imprinting effects of initial conditions on newly established enterprises (Li et al., 2020), neglecting the imprinting effects of entrepreneurs' prior experiences and expertise. Consequently, there is no profound interpretation of the imprinting effects of entrepreneurial team characteristics during the asset-light operation process of technology-driven startups. Our study incorporates the prior work experience characteristics of entrepreneurial teams into the research, analyzing the differentiated paths of asset-light operation construction formed by teams with different characteristics.

3. Materials and Methods

Research has explored asset-light operation in technology entrepreneurship, but explanations of its construction mechanisms remain lacking. There is an urgent need to elucidate the research question of how independent technology-driven startups construct asset-light operations. A case study approach is well-suited for such research questions involving phenomenon explanation and theory building (Eisenhardt, 1989; Yin, 1981). Therefore, given the research context, we conduct a time-series analysis of the case data to comprehensively illustrate the asset-light operations process. Subsequently, we conduct a comparative analysis of the two cases to examine how asset-light operations emerge based on variations in entrepreneurial team characteristics.

3.1. Case Selection Based on Theoretical Sampling

Theoretical sampling is performed to identify individuals, events, locations, or entities that are likely to exhibit variations among concepts, increasing the density of conceptual attributes and dimensions. Unlike statistical sampling, which prioritizes representativeness and breadth, theoretical sampling focuses on the informativeness of the selected cases (Corbin & Strauss, 2014). Theoretical sampling emphasizes conceptual relevance and depth in the sampling process, requiring the selection of research subjects that can provide the maximum amount of information pertinent to the research question, guided by the research objective. This study analyzes the construction of asset-light operation in independent technology-driven startups. The selected cases must meet the following criteria:

1. Establishment: The selected enterprises must originate from technology transformation and be independently founded. According to Zahra's (1996) definition of young enterprises, the selected case enterprises must have been established for no more than five to eight years. Additionally, these enterprises should be founded and operated primarily by local entrepreneurs to represent the management style of traditional Asian enterprises.

2. Capital operation model: The selected cases must have undergone both the decision-making and implementation stages of asset-light operations.

3. Operation status: After establishing the asset-light operation, the enterprises must maintain operation efficiency and increase competitiveness. This can be evaluated using indicators such as R&D performance, product market share, and sales revenue.

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Based on the outlined theoretical sampling criteria, this study first selects WH as a research case. The rationale for this choice is that the technology-driven startups discussed in this study are initiated by technicians who commercialize proprietary technologies. WH is a typical example of a company founded by technicians to implement technological entrepreneurship, and its entrepreneurial teams are more likely to exhibit technical characteristics. To avoid potential research bias from a focus on technology-based entrepreneurial teams, a second case, GJ, was selected. GJ was founded by technicians with diverse prior occupational backgrounds and has a relationship-based entrepreneurial team. This selection broadens the scope of asset-light research in a normal environment, enhancing theoretical validity and maximizing the saturation of theoretical sampling.

This study adheres to confidentiality agreements by using the abbreviations GJ and WH to represent the two technology-driven startups examined. GJ, established in 2018, specializes in technology products addressing sand-casting issues in glass mold cavities. GJ began planning asset-light operations in May 2018, achieving a relatively complete asset-light operation cooperation framework by the end of 2020. WH, established in 2019, focuses on addressing the high-cost problem of imported steel rings in the textile industry. It began preparing for asset-light operations in March 2019 and completed its asset-light operation transformation by the beginning of 2021. Both companies have been operating asset-light for three to four years, steadily developing their asset-light value chain. Table 1 presents key events in their asset-light operations.

Table 1. Key events for the selected cases

Firm name	Phase	Date	Event	Number of meetings the research team attended
GJ	Pre-decision stage	2018.05	Identify the resource gaps in technology entrepreneurship	2
		2018.06	Prepare for asset-light technology entrepreneurship	3
		2018.10	Initiate contact with mold manufacturers	1
		2018.12	Present the technological product's prospects to potential partners	1
	Implementation phase	2019.05	Establish material supply cooperation with upstream enterprises	2
		2019.10	Sign cooperation intentions with nearby machining enterprises	2
		2020.03	Sign a contract with the production laboratory of an upstream enterprise to set up a product performance testing base	1
		2020.05	Join the research institute	1
WH	Pre-decision stage	2019.03	Conduct preparatory meetings for asset-light technology entrepreneurship	1
		2019.04	Perform preliminary research to determine the required resources for the product	3
		2019.10	Apply for government funding support	1
	Implementation phase	2019.12	Engage with the research institute and join their facilities	1
		2020.03	Approach textile enterprises, present the product's cost advantages, and secure cooperation for pilot production lines	3

Additionally, we consider the principle of data availability when selecting cases, as timely and adequate acquisition of case data is essential for ensuring the robustness and reliability of case study conclusions. The first author of this paper is a minority shareholder in WH and a member of GJ's entrepreneurial team, primarily responsible for accounting tasks. These positions enable direct involvement in the early planning stages of asset-light technology entrepreneurship for both companies, facilitating the continuous observation of their operations.

3.2. Data Collection

To ensure research reliability and validity, triangulation verification was adopted during data collection (Yin, 2009). Secondary data, interview data, and participant observation data were combined to form multi-channel data sources. The secondary data were mainly obtained from the official websites of GJ and WH, corporate

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system documents, and relevant meeting documents of asset-light operation partners. First-hand case data were collected through participatory observation, longitudinal research, and semi-structured interviews. During data collection, we fully respected the informed consent and autonomy of all participants. Prior to the commencement of data collection, we provided each potential participant with detailed research instructions, including the research objectives, methodologies, potential risks, and participant rights, ensuring their voluntary participation based on a thorough understanding of the research content. Participants were entitled to withdraw from the study at any time without any negative consequences, and written informed consent was obtained from all participants. To safeguard participants' privacy and data security, we implemented stringent confidentiality measures. All collected data were stored in an encrypted database, accessible only to authorized research team members. Our research team underwent rigorous confidentiality training to ensure their understanding and adherence to relevant confidentiality regulations. We only collected information necessary for the study and disposed of or destroyed it upon study completion. The collection of first-hand data was conducted in three stages, as illustrated in Figure 1.

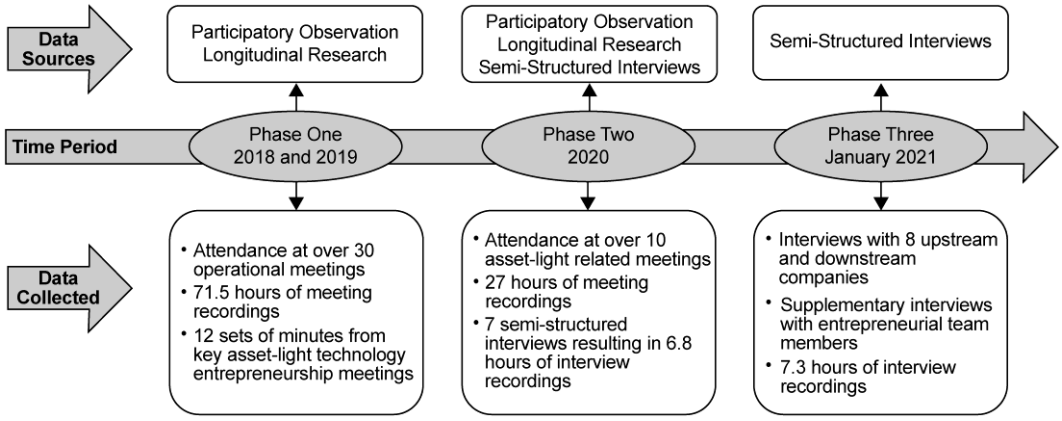


Figure 1. First-hand data collection process

3.2.1. Participatory Observation and Longitudinal Research

In the first phase of data collection, the authors conducted participatory observation and longitudinal research primarily by attending the operational meetings of the case study firms. The author team directly observed and recorded data related to the construction of asset-light operations during the meetings. The team members did not give any guidance or suggestions during discussions and decisions on asset-light operations, ensuring the authenticity and reliability of the case data. While collecting the primary data, the team attended over 40 operational meetings across two enterprises, including 22 meetings focused on asset-light operations. Table 1 summarizes the meeting schedule and relevant events of the attended meetings.

3.2.2. Semi-structured Interviews

Semi-structured interviews were conducted through face-to-face and online meetings. The interviews focused on open-ended questions related to asset-light operations. As the first author is responsible for accounting tasks and is a minority shareholder of WH, she was involved in designing the semi-structured interview guide but did not conduct interviews. The purpose of this approach is to minimize external interference and ensure the authenticity and objectivity of the case data.

The interviews were divided into two parts. The first part introduced the study, clarified the anonymity of the interviews, and gathered relevant information about the interviewees. The second part addressed questions about asset-light operations, such as the understanding of asset-light concepts, reasons for choosing this model, factors considered in constructing the operations, whether the asset-light operations achieved the expected outcomes, and how resources were pooled and integrated during the process.

During the second phase of data collection, we interviewed seven entrepreneurial team members. In the third phase, we interviewed nine upstream and downstream companies' representatives and conducted supplementary

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interviews with four new entrepreneurial team members. The selected interviewees had to be deeply involved in the development of asset-light operations. This criterion enabled the provision of detailed and comprehensive data for the research. In the selection of interviewees, diversification regarding profession, position, and prior work experience was required to ensure the generality and applicability of the research results. Moreover, to enable richer and more comprehensive case data, representatives from upstream and downstream companies were included in the selection process. Additionally, we ensured that interviewees participated willingly and cooperatively, facilitating a smooth interview process. No new information or concepts emerged during the final interviews with two upstream/downstream company representatives and three entrepreneurial team members, indicating theoretical saturation (Flick, 2022). Table 2 provides detailed information about the interviewees.

Table 2. Interviewee summary

No.	Sex	Age (years)	Major	Education	Position	Previous employment experience
1	Male	34	Engineering	Master	Core entrepreneurial team member	Technical engineer assistant
2	Male	42	Management	MBA	Core entrepreneurial team member	Entrepreneurial manager
3	Male	28	Engineering	College	Entrepreneurial team member	Production supervisor
4	Female	27	Financial	Graduate	Entrepreneurial team members	Administrative
5	Male	38	Engineering	Master	Core entrepreneurial team members	Technical engineer
6	Male	40	Engineering	PhD	Core entrepreneurial team members	Technical researcher
7	Male	35	Engineering	Master	Entrepreneurial team members	Entrepreneurial manager
8	Female	45	Management	Graduate	Financial team of an upstream company	-
9	Male	49	Engineering	Graduate	Production employee in an upstream company	-
10	Male	43	Management	Graduate	Marketing executive of an upstream company	-
11	Male	39	Engineering	Master	Technical staff of an upstream company	-
12	Female	45	Management	Master	Financial employee of a downstream company	-
13	Male	37	Management	Graduate	Sales Executive of a downstream company	-
14	Male	35	Engineering	Master	Technical staff of a downstream company	-
15	Male	47	Management	Master	Operations Supervisor of a downstream company	-
16	Male	39	Engineering	Graduate	Production supervisor of an upstream company	-
17	Male	41	Engineering and Management	Master	Entrepreneurial team member	Entrepreneurial Manager
18	Female	33	Engineering	PhD	Core entrepreneurial team member	Technical Researcher
19	Male	24	Engineering	Master	Entrepreneurial team member	Technical Researcher
20	Male	34	Engineering	PhD	Entrepreneurial team member	Technical Researcher

To ensure the reliability and validity of the study, necessary measures were taken during the research process (Table 3), particularly during data collection and analysis.

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Table 3. Guarantee strategies for reliability and validity

Reliability and validity indicators	Research phases	Guarantee strategies
Reliability	Research design	Theoretically guided research design. Extensive literature review to establish a reasonable theoretical framework. Develop a detailed research plan. Conduct multiple discussions and revisions until consensus is reached.
	Data collection	Establish a database and categorize the data while ensuring confidentiality.
Internal validity	Data collection	Avoidance of dual roles. The first author, who is both a researcher and a member of the entrepreneurial team, only participates in the design of the interview outline and is not involved in any data collection processes.
	Data analysis	Three groups independently conduct data coding, and expert discussions are organized to resolve disagreements until a consensus is reached.
External validity	Case selection	Case selection is based on theoretical sampling, with multiple cases chosen for comparison.
	Data collection	Multiple data collection methods based on triangulation. Validation and supplementation of primary and secondary data, using participatory observation, longitudinal research, and semi-structured interviews in the process of primary data collection.
Construct validity	Data analysis	Five experts independently review the data analysis report, and face-to-face discussions are held between the researchers and experts until consensus is reached.

3.3 Data Analysis

NVivo software (Nvivo QSR, Chadstone, Victoria, Australia) was used to analyze the case data. The case coding followed a three-stage process: open coding, axial coding, and selective coding (Glaser et al., 1968). During axial coding, the construction process of asset-light operations in technology-driven startups became evident, leading to the formation of a storyline in selective coding.

3.3.1 Open Coding

Open coding primarily identified emerging phenomena within the case data and classified them into preliminary categories. Twenty-three categories were extracted. Table 4 presents some open coding examples from our cases.

Table 4. Open coding examples

Data	Phenomenon	Category
(GJ): "...whether it's machining equipment or raw materials, substantial financial support is required. However, the funds available in the early stages of the venture are insufficient to meet these needs..." (a1) (WH): "The funds we have are really limited. We can't simultaneously cover R&D expenses and equipment costs. Solving the issue of tight funding is something we constantly face..." (a2)	a1 Initial Funding Deficiency a2 Funding Shortage	A1 Funding Gap
(GJ): "...all these require various large-scale pieces of equipment. Purchasing such large equipment would tie up valuable funds in heavy assets, which is too risky for us..." (a3) (WH): "... investing the funds in building the textile experimental workshop wouldn't be feasible. The funds are limited, and once invested, their liquidity decreases. If the product trial were to fail, we would face the risk of having no funds for improvements..." (a4)	a3 Capital Immobilization Risk in Equipment a4 Liquidity Risk	A2 Risk Avoidance
(GJ): "...there are many companies around the glass mold producers involved in glass blowing, forming an upstream and downstream industry chain from mold production to mold usage..." (a5) (WH): "...the Wuxi area has many textile companies. Through government introductions, it is relatively easy to find upstream and downstream partners..." (a6)	a5 Complete Industrial Chain a6 Upstream and Downstream Cooperation	A3 Industry Environment
(GJ): "...my technology product targets the current process updates for glass molds (a7). The current process no longer benefits from labor advantages, and the country is very strict on environmental protection..." (WH): "...imported steel collars last longer, but the individual price is too high. If we can reduce this part of the cost, the overall cost for	a7 Resolution of Process Challenges a8 Resolution of Cost Challenges	A4 Technological Interdependence

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textile companies will decrease. We solve this technical problem through coating technology...” (a8)		
(GJ): “...these all require various large-scale pieces of equipment, which is almost unaffordable in the early stages of entrepreneurship. We can only collaborate with companies that have such equipment and conditions...” (a9) (WH): “In the early stages of entrepreneurship, with limited funds and resources, what do we do? (a10) We have to obtain resources externally, continuously seek partners, and get the resources we need. For equipment requiring significant investment, especially general-purpose equipment, we prefer to collaborate rather than purchase, to avoid tying up our funds...” (a9)	a9 Insufficient Equipment a10 Limited Resources	A5 Resource Deficiency
(GJ): “...the production process for glass mold profiles requires a profile production line to be in sync (a11). Continuous improvement of material composition is also needed. A processing center must create mold samples, which are then tested for performance on the production line (a12). All of this requires various large-scale equipment...” (WH): “...our funds are very limited, but the equipment needed for pilot testing (a11) and the production-related workshop environment (a13) require substantial investment...”	a11 Equipment Demand a12 Product Testing Requirements a13 Pilot-Testing Environment Requirements	A6 Open Demand
GJ): “The sand-casting technology we use now requires significant investment in environmental protection. Some large companies import profiles and process them into molds, but the cost is too high (a14)… “...our entrepreneurial product just happens to address the current environmental issues with sand-casting technology (a15). They are willing to give it a try, and with pilot testing in their workshops, they can directly see the real application effects of the product...” (WH): “...steel collars are consumables in the textile industry. Long-term dependence on imported materials leads to high prices, which directly impacts product costs (a14) “…	a14 Low-Cost Demand from Downstream Enterprises a15 Environmental Demand from Downstream Enterprises	A7 Connectivity Conditions
(GJ): “...some of our technology products are still in testing, so it’s currently challenging to provide technical services to partner companies. However, we found that entrepreneurs often have some degree of willingness to contribute to economic development and industry chain upgrades (a16) ...”	a16 Entrepreneurial Contribution Willingness	A8 Shared Logic
(GJ): “During the pilot testing of our technology products, we faced two issues. One was adjusting the internal structure of iron profiles, which required finding a supplier that could meet our specifications. Our team discovered that JB Group was interested in starting an iron project and had an experimental production line that could offer us the chance to adjust the profile composition (a17) ... The other issue was that the pilot products needed to undergo several tests on the glassware production line to ensure mold quality. However, setting up such a production line was unrealistic for us. Our team’s technical leader used their academic connections to reach out to a mold manufacturer, which was also working on improving iron profile mold processes and had a suitable testing environment (a18) ...”	a17 Identification of Special Material Suppliers a18 Identification of Product Testing Manufacturers	A9 Resource Bricolage
(GJ): “Our asset-light technology venture is the result of support from many partners, including those providing raw materials (a19). The industry partnerships our team built in the early stages provided us with more options (a20) ...”	a19 Support from Multiple Partners a20 Network of Initial Collaborative Resources	A10 Diffusive Resource Network
(WH): “By applying for government funding, we gradually learned about many entrepreneurial platforms through government introductions (a21). These platforms can provide office equipment and other resources for businesses...” “...we primarily focus on technology and have some contacts with external companies. However, finding genuine partners is quite challenging. Government support helps us access other resources. For instance, we needed to test our product on textile production lines. The government assisted us in connecting with textile companies, facilitating access to pilot-testing equipment and environments (a22).”	a21 Government Bridging to Startup Platforms a22 Government Bridging to Downstream Resources	A11 Bridging Resource Network
(GJ): “During the startup phase, resources are extremely scarce. To get the necessary support—technology, funding, equipment, etc.—team members reached out to many previous partners (a23).”	a23 Acquisition of Resources from Initial Partners	A12 Acquisitive Resource Integration

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(GJ): "...we continuously searched for and sought out partnerships. We didn't limit ourselves to a single resource provider, as that wouldn't be sufficient (a24). We always focused on collaborative needs, striving for mutual resource support with any partner we chose. This approach ensures long-term stability (a25)." (WH): "...of course, team members also made efforts to find resources independently. For example, we frequently presented our products at various seminars hosted by research institutes, aiming to impress resource holders with our technological prospects (a26) …."	a24 Non-Dependence on a Single Partner a25 Exploration of New Partners Based on Existing Network a26 Team Members' Expansion of Resource Suppliers	A13 Exploratory Resource Capability
(WH): "Technology is crucial, and it's something our team has continually researched. The advanced nature and development prospects of our technology are key factors in attracting external resources (a27). We keep accumulating technological advancements and applicability to secure resource partners (a28)."	a27 Attraction of External Resources Based on Technological Advancement a28 Accumulation of Technology to Attract Resource Partners	A14 Accumulative Resource Integration
(WH): "Initially, the company's operational funds came from team members. Later, we applied for government funding and joined a research institute, laying the groundwork for acquiring additional resources. The research institute is well-acquainted with local companies and was willing to introduce us to potential upstream and downstream partners, using existing partners to connect with new ones (a29)."	a29 Government Bridging Resource Utilization Capability	A15 Expansive Resource Capability
(GJ): "To get the resources we need, we first need to understand what we can offer them. If our needs align perfectly, a stable partnership is likely (a30). Technology and talent are essential resources for tech entrepreneurship. We have two ways to acquire them (a31): First, we use technology development outsourcing, which is a common approach. Second, we offer equity to young tech professionals to join us in starting the business (a31). Outsourcing technology development meets the performance needs of R&D staff (a32). Starting a business together provides a shortcut for young people to achieve their entrepreneurial dreams..."	a30 Alignment of Mutual Resource Needs a31 Meeting Entrepreneurial Requirements a32 Meeting Performance Needs	A16 Resource Reciprocity
(WH): "...applying for government startup funds to fill our funding gap (a33) is a good option. Since our technology product is in the early stages, we can't offer much to partners in terms of benefits or resources. They have to wait, so they are unlikely to help us for free, except for the government (a34)."	a33 Obtaining Startup Fund Support a34 Government Grant	A17 Parasitism
(GJ): "...Downstream companies are willing to provide us with product testing environments and access to some equipment (a35), as our technology products could bring them tangible benefits in the future. Even though we can't offer them immediate benefits, we can provide them with technical information (a36). While this doesn't bring them direct benefits, our presence doesn't harm their interests either (a37) …" (WH): "...With government mediation, we established partnerships with downstream companies. Currently, we only use their equipment during their idle times (a35), which doesn't affect their production (a37), and we haven't yet been able to provide them with direct benefits (a38)."	a35 Support for Testing Environment and Equipment a36 Provision of Technical Information a37 No Interest Harm a38 No Revenue Generation	A18 Commensalism
(WH): "...As we develop, our low-cost steel collars reduce the costs for downstream companies, and they become our market (a39)." (GJ): "...We are customers of upstream companies, which provide us with low-cost materials, reducing our costs (a39). Downstream companies are our customers. Our technology products address their long-standing issues with labor and environmental costs (a40). We've created jobs and generated tax revenue..."	a39 Mutual Benefit of Low-Cost and Market Resources a40 Mutual Benefit of Market and Technical Resources	A19 Mutualism
(GJ): "...During the process of refining our technology product, we encounter some challenging issues. At these times, we seek out specialized technical teams in the field to resolve them. We sign technical contracts (a41), where they help us determine technical data, and we pay them accordingly. We generally avoid deeper technical cooperation due to core technology protection (a42) ..."	a41 Technical Commissioning a42 No In-Depth Cooperation	A20 Cooperative Symbiosis
(WH): "...As our program improves, it gradually meets the needs of textile companies and significantly reduces their costs (a43). We are	a43 Cost Reduction	A21 Value Symbiosis

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also beginning to see returns from the textile program's technology products (a44)." (GJ): "...With the development of our technology products, we've achieved some revenue (a43). The increasing demand for raw materials provides JB with a stable market for iron sales (a45) and alleviates the environmental funding pressure on downstream companies (a44) ..."	a43 Product Revenue Generation a44 Alleviation of Environmental Funding Pressure a45 Market Expansion for Upstream Enterprises	
(GJ): "...At the start, we didn't have any revenue to offer to upstream and downstream partners. However, we established communication channels to provide them with the latest technical information (a47)." (WH): "Before collaborating with us, they didn't know that surface coating treatment could enhance the durability of the program. Our collaboration not only facilitates resource exchange but also information sharing. In the information age, our partners need to be more sensitive to information (a48)."	a47 Technical Information Exchange a48 Enhancement of Information Sensitivity	A22 Opportunity Symbiosis
(GJ): "JB provides us with reasonably priced raw materials, and we supply molds and mold profiles to glass mold companies. The upstream companies support us with raw material resources (a49), and we provide them with market resources (a50), as well as technical resources to the mold companies (a51), which in turn are part of our market resources..." (WH): "For downstream textile companies, we mainly provide them with technological products (a51). They are our largest market (a50) ..."	a49 Raw Material Resources a50 Market Resources a51 Technical Resources	A23 Resource Empowerment

3.3.2 Axial Coding

After identifying the categories through open coding, we employed axial coding to analyze the logical relationships between the categories. We adopted the classic analysis model of causal conditions → action strategies → outcomes (Table 5).

Table 5. Axial coding process

Main category	Causal conditions	Action strategies	Outcomes
Perceiving asset-light technology entrepreneurship	Funding resource gap and risk mitigation	Exploration of low-cost operation models based on industry chain	Opportunities for asset-light operations through heavy asset transfer
Defining asset-light operations content	Enterprise technology alignment with industry chain needs, industry chain resources meeting entrepreneurial requirements	Identifying asset-light operation partners and engaging in resource bootstrapping	Identifying feasible directions for asset-light operations
Building an asset-light technology entrepreneurship resource network	Asset-light entrepreneurship resource integration and capability	Integrative and accumulative resource integration Expansive and extended resource capability	Establishing a resource network for asset-light technology entrepreneurship
Forming integration and symbiosis in asset-light operations	Systematic operation of asset-light technology entrepreneurship resource network	Symbiosis of resources	Integration and symbiosis in asset-light operations

We identified four main categories by comparing and analyzing 23 categories: the perception of asset-light technology entrepreneurship the definition of asset-light operation content the construction of an asset-light technology entrepreneurship resource network and the formation of integrated, symbiotic asset-light operations. These categories define the key elements of asset-light operation construction for technology-driven startups. Table 6 presents the results and interpretations of the axial coding categories.

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Table 6. Axial coding results and explanations

Main category	Sub-category	Definition
AA1 Perceiving Asset-Light Technology Entrepreneurship	A1 Funding Gap	Insufficient funding faced at various stages
	A2 Risk Avoidance	Liquidity risks due to the materialization of funds
	A3 Industry Environment	The industry chain of technology-driven startups, including the completeness and resource endowment of the chain
	A4 Technological interdependence	The close connection between the technology gaps of partner firms and the technology products of technology-driven startups in specific business relationships
	A5 Resource Deficiency	Various resources required by technology-driven startups besides funding
AA2 Defining Asset-Light Operations Content	A6 Open Demand	Resources that technology-driven startups find difficult to internalize and need to obtain externally
	A7 Connectivity Conditions	The need for technology products from technology-driven startups by industry chain firms, and their ability to provide specific resources to technology-driven startups
	A8 Shared Logic	The willingness of participants in asset-light technology entrepreneurship to enable technology products and upgrade industries, along with their actions in resource provision and integration
AA3 Building an Asset-Light Technology Entrepreneurship Resource Network	A9 Resource Bricolage	Actions to maximize resource exploration and acquisition channels based on open demand
	A10 Diffusive Resource Network	The formation of a diffusion characteristic resource network in asset-light technology entrepreneurship through reliance on self-networked multi-party cooperation
	A11 Bridging Resource Network	The formation of a bridging characteristic resource network in asset-light technology entrepreneurship through the reliance on early entrants' bridging capabilities
	A12 Acquisitive Resource Integration	The resource acquisition model in asset-light technology entrepreneurship involving the use of relationship resources to develop new resource providers
	A13 Exploratory Resource Capability	Integration of existing and new resources based on an acquisition model, and expansion of the asset-light technology entrepreneurship resource network through new resource channels
	A14 Accumulative Resource Integration	Attracting and cultivating resource acquisition channels based on technological advancement, characterized by technology and resource accumulation
	A15 Expansive Resource Capability	Expanding new resource acquisition channels based on existing resources, demonstrating the extension of existing resource potential
AA4 Forming Integration and Symbiosis in Asset-Light Operations	A16 Resource Reciprocity	Technology-driven startups provide technical resources to asset-light partners, while partners provide specific startup resources
	A17 Parasitism	Technology-driven startups benefit from asset-light operation partners, while partners experience some loss of benefits
	A18 Commensalism	Technology-driven startups benefit from asset-light operation partners, with no loss or minimal loss of benefits for partners
	A19 Mutualism	Mutual benefit for both technology-driven startups and partners in asset-light operations
	A20 Cooperative Symbiosis	A formal coexistence relationship emphasizing cooperation and support, without forming close resource ties
	A21 Value Symbiosis	Cost reduction for individual operational entities achieved through coordination between technology-driven startups and asset-light technology partners
	A22 Opportunity Symbiosis	Irreplaceable resource connections are built gradually between technology-driven startups and asset-light technology partners, creating joint development opportunities
	A23 Resource Empowerment	Resource support provided by the asset-light technology entrepreneurship ecosystem to all participating entities

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3.3.3 Selective Coding

By analyzing the logical relationships between the four main categories, we identified that the core category "asset-light operations in technology entrepreneurship" can integrate all case data, and the following storyline emerged.

Technology-driven startups, driven by resource and capital shortages, seek operational models that facilitate resource bricolage and cost control. A complete industry chain and strong technological interdependencies trigger the awareness of asset-light operations. When open demands align with connectivity conditions, companies cultivate shared logic to identify asset-light partnerships. Technology-driven startups engage in resource integration through direct resource bricolage, expansion of new resources, or extension of existing resources. During the building of an asset-light operational resource network, technology-driven startups focus on establishing symbiotic relationships to facilitate the integration and sustainability of these operations.

4. Case Study

4.1. A Longitudinal Case Study: The Construction Process of Asset-light Operations

A longitudinal analysis of the two case enterprises is conducted to reveal the construction process of technology-driven startups' asset-light operation (Figure 2).

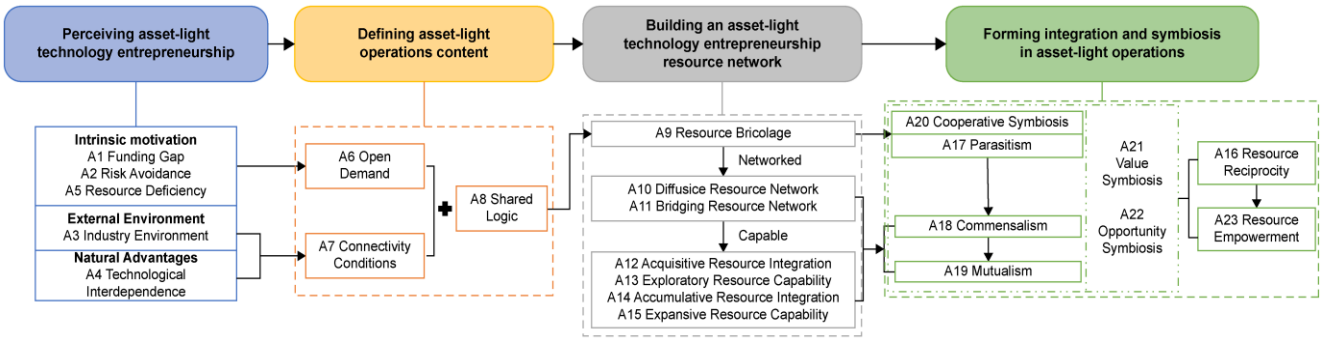


Figure 2. The construction process of technology-driven startups' asset-light operation

4.1.1 Stage 1: Perceiving Asset-light Technology Entrepreneurship

Based on the value chain theory, a series of related activities and tasks collectively constitute the value construction process of an enterprise (Jacobides, Winter 2012). Enterprises need to identify and concentrate resources on activities with higher added value in their internal value chain to enhance the competitive advantage. Technological R&D is an internal high-value chain link, serving as the foundation of core competitiveness for technology-driven startups. However, respondents from GJ and WH indicated that the purchase of large equipment imposes enormous financial pressure, especially during the initial stage, resulting in funding constraints that hinder technological R&D. Resource dependence theory posits that maintaining organizational operations requires a variety of different resources (Pfeffer, Salancik 1978), as self-sufficiency in all resource provisions is infeasible (Ulrich, Barney 1984). Therefore, reducing heavy asset investments, seeking external resource support, and focusing limited resources on high-value-added technological R&D links within the value chain are critical strategic priorities for technology-driven startups. Asset-light operation emphasizes shifting heavy asset investments to the external environment, enhancing resource use efficiency and flexibility. This approach aligns with the needs of technology-driven startups, leading to its gradual adoption.

In addition, external environmental factors also influence technology-driven startups' perception of asset-light operation. China boasts a relatively complete manufacturing industry chain, providing an ideal environment for technology-driven startups to develop asset-light operations based on upstream and downstream enterprises. Further, technology-driven startups are often established to incubate products with specific technical challenges in certain links of the industry chain. This characteristic directly fosters a collaborative asset-light operation

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model based on technological interdependence. For example, GJ corresponds to the environmental protection mold production process, while WH corresponds to the steel guide bushing production line. Both companies exhibit strong technological interdependence with upstream or downstream enterprises, enabling the externalization of heavy asset investments related to production environments.

4.1.2. Stage 2: Defining Asset-light Operations Content

Technology-driven startups exhibit high technological interdependence within the industrial chain, guiding them to gradually define asset-light operations by using the vertical value chain to identify potential partners for collaboration. Case analysis reveals that during the transitional process of perceiving asset-light operations, technology-driven startups gradually clarify their required resources based on internal value chain analysis, a process known as open demand. Subsequently, based on technological interdependence, technology-driven startups further conduct vertical value chain analysis, focusing on excavating potential collaborators within the relevant value chain who exhibit technological dependence and resource complementarity, thereby creating connection conditions for asset-light operation cooperation. Technology-driven startups continuously match their open demand with connectivity conditions, and when both reach a state of resource complementarity and goal alignment, asset-light operation cooperation is formed, completing the definition of asset-light operation content.

However, if the potential of technological products has not yet been recognized, it is difficult for technology-driven startups to establish asset-light operation partnerships directly with upstream or downstream companies. Case analysis shows that in the absence of a technology spillover effect, technology-driven startups foster asset-light partnerships by cultivating shared logic among potential collaborators. Based on resource dependence theory, a shared logic suggests that transforming originally idle resources into valuable assets aligns with optimizing resource allocation and improving resource use efficiency (Hillman et al. 2009). For example, GJ continuously emphasizes the importance of environmental protection for industry development to stimulate resonance among target partner enterprises, and assists in asset-light operation cooperation by establishing shared logic. Through asset-light operations, GJ obtained external resource support, while partners expanded their resource boundaries, representing a valuable use of idle resources.

As shown in Figure 2, technology-driven startups conduct vertical industrial chain analysis based on their open demand, identify potential asset-light operation cooperation partners who meet the connectivity conditions, and define asset-light operations by cultivating shared logic.

4.1.3. Stage 3: Building an Asset-light Technology Entrepreneurship Resource Network

Resource dependence theory posits that no organization can independently produce or satisfy all the resources necessary for its survival, necessitating reliance on external resources from its environment (Pfeffer, Salancik 1978). Consequently, resource bricolage persists throughout the stages of entrepreneurial firm development. Whenever new open resource demand arises, resource bricolage behavior occurs. Data coding reveals that resource bricolage activities are particularly active after the identification of asset-light operation partners, especially in assembling existing resources, including general heavy assets, production environments, and social resources related to asset-light operation partners.

However, direct resource bricolage behavior cannot guarantee the stability of external resource acquisition for technology-driven startups. Resource dependence theory emphasizes that organizations need to establish interactive dependence relationships with other entities in their specific survival environments, thereby forming a resource network (Ulrich, Barney 1984), and reducing the uncertainty of external resource dependence (Drees, Heugens 2013). Technology-driven startups primarily construct an asset-light operational resource network through the following two stages:

First, by continuously expanding the asset-light resource network, technology-driven startups can alleviate their dependence on existing resource-holding entities and enhance the stability of resource acquisition.

Second, the diverse relational resources and expansion capabilities of technology-driven startups are key to this approach. By establishing new resource cooperation relationships, they can reduce dependence on existing

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resource-holding entities and capitalize on resources, which is beneficial for technology-driven startups to construct a stable resource network.

Overall, aligning with the emphasis of resource dependence theory on external resource acquisition, interaction with resource-holding entities, and strategic resource behavior, the construction of an asset-light operation resource network for technology-driven startups progresses through three phases: (1) resource bricolage (external resource acquisition), (2) resource network establishment (interaction with resource-holding entities), and (3) resource capitalization (strategic behavior Figure 2). In the process of constructing an asset-light operation resource network, differentiated resource integration paths are formed due to differences in resource endowments among entrepreneurial teams. Subsequent case comparisons will further analyze these strategies in conjunction with imprinting theory.

4.1.4. Stage 4: Forming Integration and Symbiosis in Asset-light Operations

Maintaining effective asset-light operation cooperation is crucial for the stability of asset-light operations. Shared logic is insufficient to maintain long-term asset-light operation partnerships due to the lack of tangible benefits. From symbiosis theory, interdependent and interactive symbiotic relationships among organizations form the foundation for long-term cooperation, where mutual benefits determine the type of symbiotic relationship and the degree of its maintenance. Analysis of case enterprises reveals that by combining the characteristics of their technology products with the needs of their partners, startups strategically use their resource advantages at different developmental stages to establish various symbiotic relationships. For example, during the resource bricolage stage, the resource advantages of technology-driven startups are yet to be developed. However, by providing resources such as technical guidance and technical information, they maintain asset-light operation cooperation based on cooperative symbiosis or parasitism relationships. As technology products continuously evolve, partners can obtain symbiotic benefits such as small-scale process improvements and small-scale new markets through participation in asset-light operations, gradually transitioning the relationship into a commensalism symbiosis. When technology products gradually gain market recognition and the vertical value chain based on asset-light operations becomes increasingly active, both technology-driven startups and their partners can acquire necessary resources from the value chain, forming a mutualistic symbiosis. During integration and symbiosis, the symbiotic relationship exhibits an evolutionary process from cooperative/parasitic symbiosis to commensalism symbiosis, and finally to mutualistic symbiosis (Figure 2). The gradual emergence of the original advantages of technology products is a key driver in promoting the development of symbiotic relationships.

During the evolutionary process of the symbiotic relationship types, the connotation of symbiosis has also undergone changes from value symbiosis to value symbiosis coexisting with opportunity symbiosis. During the resource integration phase of asset-light operations, collaboration reduces operating costs for startups and grants them access to their partners' resources. Additionally, the innovative technical information provided by technology-driven startups lowers information acquisition costs for partners. A value symbiosis is formed that reduces costs for both parties. As technological products address specific industry chain challenges, irreplaceable resource linkages between technology-driven startups and their asset-light operational partners are established. This creates opportunities for mutual development, resulting in the coexistence of value and opportunity symbiosis.

4.2. Comparative Case Study

4.2.1. Comparison of the Asset-light Formation Paths Based on the Characteristics of Entrepreneurial Teams: From Asset-light Resource Network Construction

Axial coding analysis reveals that the two case enterprises have different characteristics of resource endowment due to the early careers of the entrepreneurial team and show different resource integration paths in the construction of a technology entrepreneurship asset-light resource network. This aligns with the imprinting theory. The GJ team accumulated extensive cooperative relationships, indicating the relationship-based characteristics of the entrepreneurial team. By contrast, the WH team, primarily composed of technical developers, had abundant technical resources, indicating a technology-based entrepreneurial team. The

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differences in the characteristics of entrepreneurial teams have led to two technology-driven startups exhibiting distinct paths in constructing asset-light operation.

1. Relationship-based entrepreneurial team: diffusion-oriented asset-light operations construction path

GJ has a typical relationship-based entrepreneurial team, and social resources play a crucial role in the development of asset-light operations. Throughout this process, viable connections were explored by the GJ team's social networks to meet current resource needs and foster asset-light operational partnerships. Consequently, they continually added new, independent partners to their network, resulting in a $0 \rightarrow n$ diffusion pattern in their asset-light operation construction path (Figure 3).

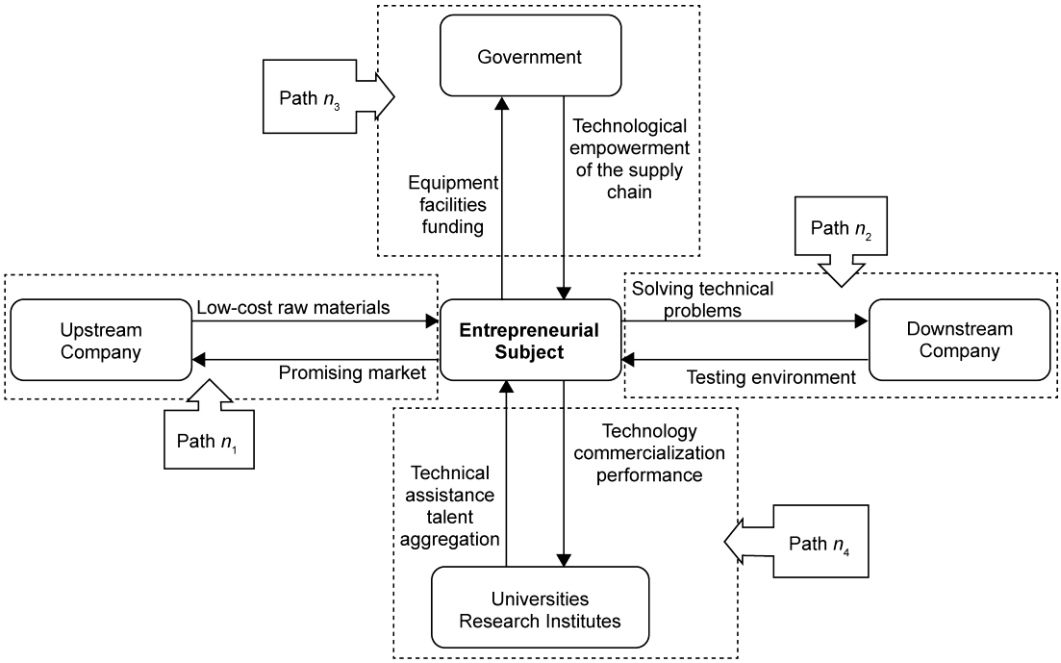


Figure 3. Diffusion-oriented asset-light operations construction path of relationship-based entrepreneurial team

Path n_1: To reduce the capital tied up in raw materials, low-cost raw material sourcing and inventory management have become open demands for GJ. During the building of an asset-light operation, the long-standing technical consulting relationships of team members with raw material holders are used to identify low-cost and flexible suppliers. Targeted raw material suppliers that have recently initiated a molten iron casting project require extensive market outlets for iron. This created a connectivity condition between GJ and upstream suppliers and led to an asset-light operational partnership in the raw materials sector.

Path n_2: During market research, the GJ entrepreneurial team visited multiple downstream enterprises to establish a foundation for borrowing heavy assets and testing facilities. GJ's technical products effectively address the environmental pressures caused by the current processes of downstream enterprises. Product testing by GJ did not disrupt the normal production activities of these enterprises and significantly reduced the integration costs of adopting new technologies. This arrangement led to asset-light cooperation between GJ and downstream enterprises.

Path n_3: In the early stages, essential facilities, such as office spaces, equipment, and factory buildings, require substantial financial investment. Fortunately, government policies supporting innovation and entrepreneurship provide opportunities to meet technology-driven startups' capital shortfalls. GJ joined a government-supported startup incubator to temporarily access office spaces, equipment, and factory facilities at no cost. Additionally, the incubator facilitates access to government funding, avoiding the collateral and interest burdens associated with external financing.

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Path n_4: Solving technical problems requires significant human, financial, and time resources. Non-core technical issues can be resolved through technological outsourcing. While updating their technological products, GJ opted to outsource non-core technical problems to universities, research institutes, or other relevant technical research teams. This approach efficiently and cost-effectively resolves technical issues while contributing to the partners' technology-transfer achievements. Additionally, through this technical assistance process, GJ gained access to young and creative professionals with specialized technical knowledge, providing a channel for recruiting high-level talent.

Relationship-based entrepreneurial teams tend to use their extensive network to facilitate resource bricolage by establishing new resource partnerships. During the resource networking phase, a diffusive resource network is likely to be formed, leading to acquisitive resource integration and ultimately demonstrating expansive resource capabilities (Figure 4).

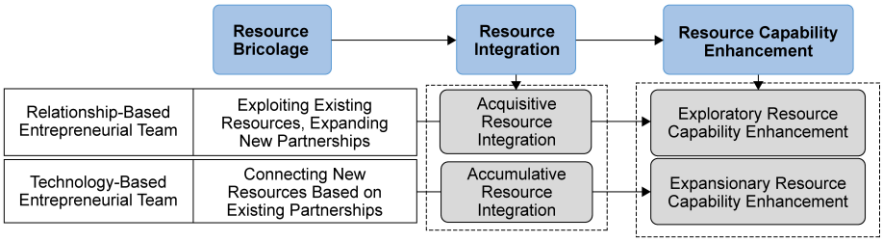


Figure 4. Contrast of resource integration evolution between relationship-based entrepreneurial teams and technology-based entrepreneurial teams

2. Technology-based entrepreneurial teams: bridging-type asset-light operation construction path

Technology-based entrepreneurial teams are often composed of specialized technical personnel who possess technical development capabilities but lack extensive relational networks. They therefore rely more on the advanced nature of their technology to attract partners and are further dependent on the bridging role of existing asset-light operation collaborators. Thus, the path for constructing asset-light operations exhibits a $0 \rightarrow 1 \rightarrow n$ bridging characteristic (Figure 5).

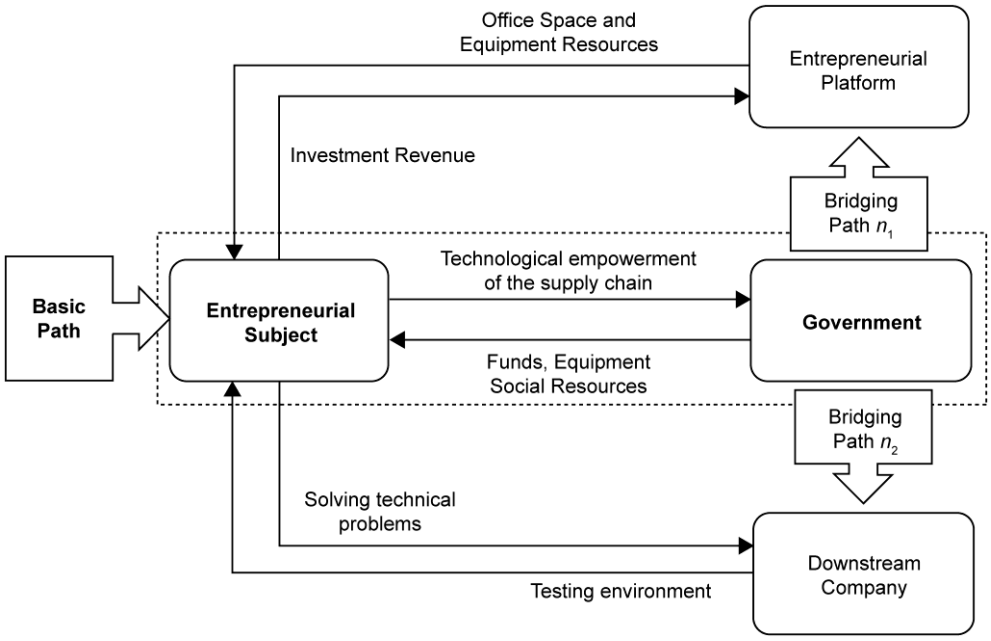


Figure 5. Bridging-type asset-light operation construction path of technology-based entrepreneurial teams

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Basic Path: Owing to a lack of relational resources, technology-based entrepreneurial teams face challenges in achieving diversified asset-light operational partnerships independently. However, government policies such as startup funding and support offer opportunities for these technology-based ventures to implement asset-light operations. WH alleviated its funding gap by applying for government startup funds and constructing a bridge to engage with upstream and downstream companies.

Bridge Pathn_1: The government introduced WH to local incubation platforms specializing in metal materials. WH established asset-light operational partnerships with incubation platforms, which provided access to office spaces, equipment, and factory facilities. Owing to the advanced nature of technology products and the high potential returns from their commercialization, WH could offer future investment returns to platforms.

Bridge Pathn_2: Asset-light operation partnerships for product testing environments and equipment with downstream companies are established through government facilitation. The production costs of downstream companies can be significantly reduced using WH technology products. However, information asymmetry and a lack of trust exist between WH and downstream entities. Government intervention can facilitate information channels and enhance mutual trust. Without affecting their production capacity, downstream companies adjust their production lines to test WH technology products.

In conclusion, technology-based entrepreneurial teams depend on collaborators, such as the government—accessible due to their technological advantages—to establish connections with more resource partners and engage in resource bricolage, ultimately forming a bridging resource network. The resource integration behavior of technology-based entrepreneurial teams demonstrates the feature of accumulative resource integration and eventually leads to the formation of exploratory resource capability (Figure 4).

4.2.2. Comparison of Paths for the Maintenance of Asset-light Operations: From the evolution of Symbiotic Relationships

The formation of symbiotic relationships among resource collaborations is the core factor in maintaining and stimulating the efficacy of asset-light operation. Moreover, due to the distinct interest points of the collaborating parties, differentiated evolution paths of symbiotic relationships have emerged (Figure 6).

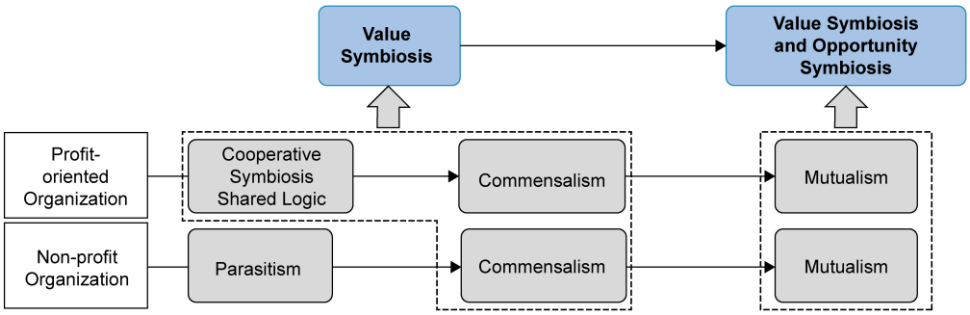


Figure 6. The evolution of symbiotic relationships

4.2.3. Evolutionary Path of Symbiosis with Non-profit Organizations

The evolution of symbiotic relationships between technology-driven startups and the government as well as incubators follows a similar pattern, transitioning from parasitism to commensalism and ultimately to mutualism. Initially, technology-driven startups derive benefits without providing immediate returns, resulting in a parasitic relationship. However, government and incubators, owing to their service-oriented and non-profit nature, accept this dynamic. With the generation of revenue from technology-driven startups, the government receives tax benefits, and incubators can secure investment returns. However, the symbiotic benefits generated in the early stages of revenue remain lower than those provided by the government and the incubators, leading to commensalism. As asset-light operations integrate and cycle, symbiotic benefits continue to grow, and the relationship gradually evolves from commensalism to mutualism.

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4.2.4. The Evolutionary Path of Symbiosis with Profit-oriented Organizations

The essence of enterprises is to pursue maximum profits, making it difficult for profit-oriented enterprises to form a parasitic relationship with technology-driven startups. Thus, in technology entrepreneurship, a pattern of evolution from shared logic → strong commensalism → weak commensalism → mutualism is observed in the relationships with upstream and downstream companies. Initially, asset-light partnerships are formed through shared logic, constructing a formal symbiotic relationship with constructive collaboration but limited resource integration. Upstream and downstream companies benefit from access to the latest technical information and improve certain production processes by improving technological products. However, the benefits to technology-driven startups outweigh those to their partners, leading to strong commensalism. With further technological product development, this dynamic shifts toward weak commensalism. Once the product gains market acceptance, it provides a large market for upstream companies and reduces production costs for downstream firms. At this stage, these upstream and downstream companies become stable suppliers and market resources for technology-driven startups, establishing mutualism.

5. Discussion and Conclusion

5.1. Summary of Findings

This study employs a longitudinal case analysis and horizontal case comparison of two technology-driven startups from China to examine the construction path of asset-light operations. The main research findings are as follows:

First, the resource gap and limited funding drive technology-driven startups to adopt asset-light operation modes that use industrial chain resources. The high technological integration between technological products and industrial chains facilitates connectivity, shaping the perception and definition of asset-light operations. Through the development of an asset-light technology entrepreneurship resource network, these startups gradually achieve the integration and coexistence of asset-light operation with cooperative enterprises.

Second, based on imprinting theory, the heterogeneous asset-light resource integration path caused by the difference in entrepreneurial team resource endowment was analyzed through case comparison. Relationship-based entrepreneurial teams accumulate diverse relationship resources owing to their members' diverse prior careers. Their asset-light operation paths exhibit diffusion characteristics, focusing on expanding new resource partnerships as the main channel for resource integration, and finally demonstrate the expansive resource capability. By contrast, technology-based entrepreneurial teams are characterized by a bridging approach to constructing asset-light operations as they possess strong technical expertise but lack relationship resources. Their resource integration is based on using existing resource partnerships and forming extended channels for resource acquisition, eventually leading to the formation of exploratory resource capability.

Third, establishing symbiotic relationships is a key path to maintaining cooperation in asset-light operations. Our analysis reveals that in the initial stages of asset-light operations, technology-driven startups establish symbiotic relationships through shared logic to promote cooperation in asset-light operations. Both parties exhibit a spiraling symbiotic relationship, progressing from shared logic/parasitism to commensalism and ultimately to mutualism. However, the symbiotic relationships differ owing to the varying operational objectives of the cooperating parties. For government and non-profit incubators, the symbiotic relationship evolves from parasitism to commensalism and then to mutualism. Conversely, for upstream and downstream enterprises seeking profits or resources, the relationship evolves from shared logic to strong commensalism, weak commensalism, and ultimately mutualism. Regardless of partner type, these symbiotic relationships generally transition from single-value symbiosis to coexistence of value symbiosis and opportunity symbiosis.

5.2. Theoretical Implications

First, current research predominantly focuses on asset-light operation pathways in spin-off entrepreneurship (Li et al., 2020) or established enterprises (Yi et al., 2024). Our findings address the research gap in the mechanisms

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of asset-light operations in independent entrepreneurship and complement the theory of asset-light operations in the entrepreneurship field.

Second, unlike current research on entrepreneurial resource integration, which primarily examines influencing factors (Engel et al., 2017) or acquisition channels (Grilli & Marzano, 2023), this study integrates the resource dependency theory framework of external resource acquisition → resource subject interaction → resource strategic behavior. This research contributes to a deeper understanding of the resource integration behavior and evolutionary process of technology-driven startups in asset-light operations, enhancing the theoretical diversity of research on resource integration within the independent techno-entrepreneurial sector.

Finally, this study emphasizes the maintenance process of asset-light operations in technology-driven startups, which further expands the research content on asset-light entrepreneurship. Existing research primarily focuses on the generation of asset-light operations in entrepreneurial enterprises (Yi et al., 2024) and lacks an in-depth analysis of how to maintain asset-light operation cooperation. Based on symbiosis theory, our study analyzes the role of symbiotic relationships in maintaining asset-light operations and the evolutionary process of symbiotic relationships. This represents an application and extension of symbiosis theory and provides a new perspective for research on asset-light operations.

5.3. Practical Implications

This study presents several effective approaches for establishing asset-light operations.

First, the advancement of technological products is a sufficient condition for asset-light operations, and technological adhesion of these products within the industry chain is a necessary condition. Strong technological integration facilitates initial asset-light operational partnerships during the positioning stage. Therefore, identifying key technological integration points within the industry chain is crucial during the preparation phase, as it significantly enhances the efficiency of asset-light operational partnerships.

Second, fostering a shared logic in the initial stages of asset-light operations helps these firms address the lack of technological advancement and complementary resources. This approach facilitates the formation of preliminary formal operational collaborations.

Additionally, participating in asset-light operations offers traditional manufacturing firms a pathway to enhance their technological innovation capabilities. Traditional manufacturers often struggle with inadequate R&D performance owing to a shortage of technical personnel and limited access to cutting-edge innovations. By offering equipment or specialized production environments to technology-driven startups, traditional manufacturers can acquire technological products aligned with their development, facilitating technological updates and process improvements.

5.4. Limitations and Future Research Directions

The cases selected for this study focused on the manufacturing sector; however, its applicability to sectors such as pharmaceuticals, telecommunications, tourism, and finance remains unverified. Future research could expand the selection of firms to include a broader range of industries, enhancing the generalizability of the findings.

Moreover, as asset-light operations evolve, firms' partnerships become increasingly complex. A critical future research direction involves exploring how firms can establish an ecosystem for asset-light technology entrepreneurship during resource capability development. Further investigation is needed to understand the operation, structure, functioning, and potential benefits of such an ecosystem.

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COURSE CONTENTS FOCUSING ON CLIMATE, ENVIRONMENT AND SUSTAINABILITY: AN ANALYSIS OF COMMUNICATION FACULTIES IN TIMES 500 LIST*

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Abstract. As the problem of climate change has become a global issue due to global warming, addressing environmental and climate problems at the local or national level is necessary but not enough to tackle the issue. It is crucial to make and implement policies on a supranational level. Climate change is an issue that needs to be addressed with an interdisciplinary approach to ensure accurate and fluent communication among different realms. Therefore, professionals must specialise in this field, not only in science but also in other disciplines. In this context, where a balance is sought between sustainable life and climate change, communication is one of the areas that gains importance. Communication faculties should add climate-oriented courses to their curricula to achieve better implementation of local and global policies. This study aims to analyse the courses that already serve this purpose and to provide a roadmap for future ones. The course content of the communication faculties of the universities ranked in the top 500 in the Times Higher Education 2024 list was scanned using the keywords climate, environment, and sustainability. 123 courses, including the keywords in their names, were analysed sequentially using curriculum and content analysis methods. It has been concluded that climate-oriented courses are handled with an interdisciplinary approach designed to direct students to think analytically and focus on implementation. The curricula on this issue should include a comprehensive, action-oriented framework that encourages critical thinking.

Keywords: climate change communication; environment; communication faculties, sustainability

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JEL Classifications: I21, I23

Additional disciplines: educology, information and communication, ecology and environment

1. Introduction

Today, environmental problems related to climate change/crisis and failure to ensure sustainable production and consumption are among modern society's most pressing global challenges. Disciplines like communication, media, arts, and the culture industry are important in understanding these issues and addressing them effectively in educational institutions. Communication professionals are key in raising awareness through climate literacy. Therefore, it has become necessary to reshape the content of courses offered in communication faculties that will directly contribute to combating the climate crisis in a way that provides theoretical and practical

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knowledge. Courses offered in fields such as journalism, cinema and TV, communication studies, new/social media, public relations and advertising, focusing on climate, environment, and sustainability, can equip future communication professionals with the necessary skills to effectively understand and tackle these complex issues. For instance, a documentary film, a news series, or even a public service announcement can influence many people, raise their awareness of climate change, and motivate them to act in their communities. Similarly, through public relations, social media, communication, and advertising campaigns, individuals can be encouraged to change their behaviour and adopt sustainable lifestyles.

For this reason, this study aims to reveal how this issue is handled in communication faculties ranked in the top 500 in 2024 according to the Times Higher Education World University Rankings by analysing the undergraduate course content that includes the keywords climate, sustainability, and environment and contribute to the new course contents in different regions of the world in this direction.

2. Theoretical background

2.1. An overview of climate change and its impacts

Climate change is a process affected mainly by human activities, causing increased greenhouse gases in the atmosphere and leading to rising global temperatures. The main drives of these changes are the burning of fossil fuels, deforestation, unsustainable production approaches, and industrial activities, which increase with human-induced production and consumption (Cook, 2016). According to the United Nations Framework Convention Climate Change (UNFCCC), climate change is "a change in the compositions of the global atmosphere resulting directly or indirectly from human activities and leading to changes in the composition of the global atmosphere outside the natural variability of the atmosphere (UNFCCC, 1992). The climate crisis, a concept that triggers global warming because of anthropogenic processes such as the uncontrolled expansion of industrialisation, agricultural activities, and urbanisation, clearly reveals the impact of both economic and social structures on climate.

Climate change is a global phenomenon with profound social, economic, and environmental impacts on ecosystems and human societies. This includes the long-term consequences of environmental changes that directly affect species' habitats, reproductive strategies, and adaptation processes, the long-term warming trend caused by imbalances in atmospheric energy, and environmental changes such as rising temperatures, sea level rise, and biodiversity loss that have major effects on ecosystems (Somogyi & Nagy, 2022; Gqalindaba et al, 2024).

It also encompasses a prolonged time frame in which social structures and cultural norms are reshaped, altering the relationship between humans and the environment and posing a threat to sustainable development goals. Accordingly, the challenge of referring to a single cause is revealed. An interdisciplinary and solution-oriented approach is necessary at local, national, and international levels against this crisis and its consequences. The communication strategies that feed this approach should be prepared interdisciplinary and planned (Carone et al., 2025).

2.2. Climate, environment and sustainability communication education

Historically and mostly, educational institutions have handled climate issues, focusing on climate change science education. In recent years, there has been considerable progress in climate and climate change education at universities, particularly in response to the provisions of the Paris Agreement (UNFCC, 2015). Climate change education has been attracting increasing attention in scientific research, as evidenced by nearly 1,000 related references currently listed in the Web of Science, particularly within geographic and natural sciences education. Nevertheless, only a few of these sources explicitly highlight the significance of maps and geoinformation as key instructional tools for teaching and learning about climate change (Gonzalez et al., 2025).

Cano-Ortiz et al. (2024) show the importance of bioclimatology in land management among the inevitable applications for sustainable development that reduce climate change. The authors see bioclimatology as a new

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world economic model based on sustainable development and reasonable use of natural resources. However, the authors argue that scientific developments should be reinforced with applications and that future managers should receive sustainable development training.

Hindley (2022) sees the condition for adapting educational programs to climate change content in forming organisational culture, personal values, and positional identity factors. In other words, curriculum changes in organisational culture should be addressed in an institutional context, and climate communication education should be included in institutional decisions. Another issue the author draws attention to is the need for educators to provide students with knowledge and skills related to climate change education. The author, who sees students as future leaders, argues that green thinking and environmental awareness should be among the control points in their strategic decisions.

Li and Liu (2022) describe the results of their study on university students' knowledge and opinions about climate change as "worrying". The students were sure that global warming was occurring but knew little about the anthropogenic cause. Although they were less exposed to the effects of global warming than the previous generation, they did not know its causes. Although the education they received on climate education brought their knowledge level on the subject to a certain level, it was observed that they could not develop at a conceptual level. In addition, it was observed that they continued to feel unmotivated to take action after the education they received. They equated climate change action with decreased quality of life and even largely futile results.

However, universities worldwide have allocated limited time and resources to educational activities to prevent and reverse climate change. For this reason, climate education is a separate field from STEM education. Besides that, climate education has mostly been embedded in courses with different names in the context of sustainable development or various certificate programs offered outside the classroom.

According to the Global Education Monitoring Report published by UNESCO in 2020, which reveals the extent to which climate and climate change are included in national curricula, the issue of sustainable development was included in three-quarters of national curriculum frameworks, while the problems of climate change were included in only one-third (Moltan-Hill & Blaj-Ward, 2022). Thus, all students will contribute to increasing the impact and applicability of national and international policies by adapting this knowledge to their field (Moltan-Hill & Blaj-Ward, 2022).

On the other hand, climate change communication aims to raise personal and public awareness about the impacts of the crisis by strategically communicating scientific information to large audiences via different channels (van Eck et al., 2025). Effective communication strategies can create personal meanings that motivate individuals to act on climate change (Hurajova et al., 2022; Ben Romdhane et al., 2023; Sippel, 2023; Abuzeinab et al., 2024).

Aslam et al. (2024) draw attention to the fact that the consequences of climate change are felt more intensely in developing countries such as Pakistan. They emphasise the importance of creating awareness about climate change and the necessity of using conventional and new media tools. The point highlighted by the study is that university graduates use Information and Communication Technologies (ICT) more and that, thanks to this use, climate change awareness is more easily achieved.

Environmental communication is not limited to climate change, but in a broader perspective, it also addresses issues such as environmental pollution, biodiversity loss, environmental campaigns, and depletion of natural resources. It provides a valuable resource for understanding environmental communication's theoretical and practical dimensions, which are involved in crisis management, public participation, and policy-making processes.

Huang et al. (2025) addressed green consumption's temporal and spatial evolution within social networks. In the study where social network analysis was determined as the research methodology, the levels of interpersonal relationships were addressed in the context of green consumption. With this method, the concept of green consumption was spread. The other dimension of the study is to see the evolution of green consumption in different geographies and compare it with others. Ali et al. (2025, p.16) draw attention to the complex dynamics

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of green communication. The study reveals that green communication strategies should be carried out by considering geographical and demographic variables. However, the study draws attention to the formation of sustainable communication when all variables of green communication carried out in the North American region are considered.

While online education initially gained prominence as a necessary response to the pandemic, it has since evolved into a transformative force in the broader education and training landscape—an innovation many countries have actively pursued in recent years. Across the globe, governments, international organisations, academic institutions, and private sector actors are exploring strategies to transition from conventional instructional models to more comprehensive digital education frameworks (Zhao et al., 2023). In this context, Turkiye's experience—particularly the leadership of Anadolu University's Open Education Faculty—illustrates the potential of online education as a vital component of climate change communication. Digital platforms and online educational resources offer meaningful opportunities to enhance climate literacy by fostering sustainable development and advancing educational innovation.

Moreover, the rapidly advancing field of artificial intelligence has become increasingly relevant to climate change research and education. Among its emerging applications, generative artificial intelligence (GenAI) is a technology university students across various disciplines actively use. GenAI, a branch of AI based on generative models, can produce text, images, videos, and other forms of data. When employed thoughtfully, particularly in creative and educational contexts, GenAI goes beyond content generation to function as an interactive tool that helps students articulate, develop, and refine their ideas. In this study, students iteratively engaged with GenAI—modifying their prompts and critically evaluating the outputs—to construct well-developed future scenarios. This engagement promoted active learning and deeper cognitive involvement rather than passive consumption of AI-generated content. (Liu & Chateau, 2025).

Considering all these processes, increasing the diversity of courses on climate, environment and sustainability in departments within faculties of communication will directly contribute to the combat against climate crisis.

2.3. Climate crisis and communication faculties

International organisations, governments, public institutions, local governments, non-governmental organisations, universities and activists need to contribute to the action against climate change in areas that require not only scientific and technical expertise but also skills in informing and engaging the public (Khumalo et al., 2025; Martín & Sánchez, 2025; Atkociuniene et al., 2025).

In this context, alumni of communication faculties can play a vital role in the success of these action plans by organising effective campaigns, designing projects, developing climate-based journalism, producing audiovisual and visual content, understandably presenting complex environmental issues and raising public awareness. In parallel with this necessity, there has been an increase in the number of courses focused on climate change, sustainability and environment in communication faculties in recent years. It has become more important that these courses not only provide theoretical knowledge. Still, it should also be strengthened with practical applications to support students' ability to transfer this knowledge to society and to develop creative solutions to climate-oriented problems.

All departments in communication faculties worldwide can potentially add value to climate-oriented activities. The contributions of climate crisis, sustainability, and environment-oriented courses that should be included in these departments can be analysed from different angles. Especially in environmental communication and carbon footprint reduction projects, strategic public relations approaches can provide effective communication and develop environmentally friendly habits. For example, adopting sustainable living practices such as recycling, zero-waste strategies, or energy conservation is possible through a well-designed public relations campaign. The powerful visual tools of cinema and television help present complex environmental and climate issues in a way that all groups can understand. Communication graduates can raise awareness by creating media products such as documentaries and public service announcements. The involvement of communication faculty graduates in the preparation of climate change action plans, which include policies and social education

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processes, directly supports the impact of action plans. Graduates of communication faculties can reach large audiences and popularise calls to action by designing social media campaigns, developing social media content and creating internet trends. Communication specialists, who are also suitable for working with different disciplines, can effectively share scientific and technical knowledge with society (Arribas et al., 2024; O'Callaghan et al., 2025).

This ability manifests itself in interdisciplinary studies and increases the impact of the studies. The speciality of communication faculty graduates is delivering the right messages to the right target audience. These graduates play a strategic role in designing campaigns that appeal to different age groups or social segments. In addition to all these processes, the increase in natural disasters caused by climate change also increases the need for crisis communication strategies. Communication graduates can prevent panic and direct action by informing the public correctly during a crisis (Trenberth, 2011; Bussoletti et al., 2025).

Considering all these stages, research to the present day shows that communication faculties play a key role in addressing the climate crisis (Gustafson, 2025). Based on the necessity for communication experts to take a more active role among the decision-makers, practitioners of different sectors and non-governmental organisations in the struggle against climate change worldwide, it is necessary to analyse the courses in communication faculties that prepare professionals in this field. Analysing these courses in communication faculties of universities in countries and cities that feel the effects of the climate crisis at different levels and take measures in various ways will contribute to the field.

3. Research objectives and methodology

Although there are studies on the course contents of different departments of universities, there is a scarcity of studies that deal with a comprehensive analysis of the content courses offered in communication faculties around the world. For this reason, the course catalogues of the universities ranked among the top 500 universities in the TIMES 2004 list were analysed in two main stages. Curriculum analysis (Posner, 1995) and content analysis (Krippendorf, 2018) methods were used respectively.

In the first stage of the study, the curriculum analysis method was used to identify the universities among the top 500 universities in the Times Higher Education (THE) ranking and have a faculty of communication. The official websites of these universities were scanned, and those that offer courses, including keywords "climate, sustainability and environment" and those that do not, were divided into two categories. Thus, the extent to which universities include these topics in their programs was determined, and classification was made based on the presence of relevant courses. According to Posner (2004), curriculum analysis is an effective way to systematically examine educational programs' content, organisation, and goals. In this context, program analysis was chosen as an appropriate method to understand the extent to which universities address climate, environmental and sustainability issues.

After selecting the courses in the programs, a detailed content analysis was conducted for the courses for which syllabuses were available using the content analysis method. Krippendorff (2018) defines content analysis as "a research technique for making replicable and valid inferences from text to the context of their use". During the content analysis, the course's main objectives, the content and topics covered, the methodology and expected outcomes were sought. The selected syllabuses were pre-screened to ensure that they contained sufficient data and were relevant to this study, and as a result, a total of 22 syllabuses were analysed.

The universities' websites identified in the research were designed in different languages and styles. Researchers excluded universities' websites that did not offer an English language option from the study's scope. Another limitation of the study was that most universities offering courses with keywords did not share the course syllabus with external contributors. This prevented researchers from accessing any information beyond a brief description of the courses.

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3.1. Content analysis procedure

In the research process, an iterative coding method was adopted to analyse the syllabuses' content systematically. The research team developed a comprehensive analysis framework on an electronic database in this direction. The framework created specific categories by considering the main components expected to be found in course syllabuses. These categories included university names, course names, subject headings, and thematic framework. All the data was categorised according to these, and the data table was systematically entered.

To ensure consistency and reliability in data analysis, the double coder method was used, and regular team meetings were held to resolve possible differences in interpretation and to ensure consensus in the coding process. This process ensured the conformity of the data obtained with the analytical framework, and the reliability of the research results was increased.

3.2. Sample of the study

The research sample consists of the universities ranked in the top 500 in the TIMES 2024 list, which have faculties of communication and courses that include at least one of the keywords “climate”, "sustainability," and "environment." In this context, courses in master's and doctoral departments at universities were not included in the study. In terms of a systematic process within the research sample's scope, universities with communication faculties were first identified. Then, the faculties with courses containing the keywords were listed to be examined. The identified universities were reached through their websites, and the courses in the curriculum were found by searching the keywords. Websites without an English option were excluded. To reveal the similarities and differences in the themes and topics determined in the course content, the most appropriate 22 of a total of 123 syllabi were selected as the research sample.

4. Results and discussions

4.1. Preliminary analysis

In this study, it has been found that 391 universities among the top 500 universities in the TIMES 2024 list offer undergraduate courses in communication faculties. Among these, 123 courses offered in English included the specified keywords: "climate," "sustainability," and "environment." However, just 22 of these courses offered detailed information and allowed open access to their syllabi. In terms of regional distribution, universities in the top 500 are generally located in the USA, the United Kingdom, Australia, and the European Union. Since the undergraduate courses at universities in China are mostly in Chinese and their websites are in Chinese, no further comments could be made about their place in this ranking. Of the 123 courses, 78 are located in the USA, and 17 are in the UK. Australia has 7 courses, Ireland 5, Singapore 4, and Canada 3. 2 courses each in Norway, Sweden, and the United Arab Emirates, and 1 course each in Iran, Italy, New Zealand, and Hong Kong were analysed. Of the 123 courses identified, 117 have course descriptions. Detailed syllabuses of these 117 courses could not be accessed for the reasons mentioned in the limitations.

Almost all the 391 universities analysed in the first phase of the research were ranked between 1-200. The communication faculties of the top-ranked universities play a leading role in adding courses on climate, sustainability, and environment to the curriculum compared to other universities.

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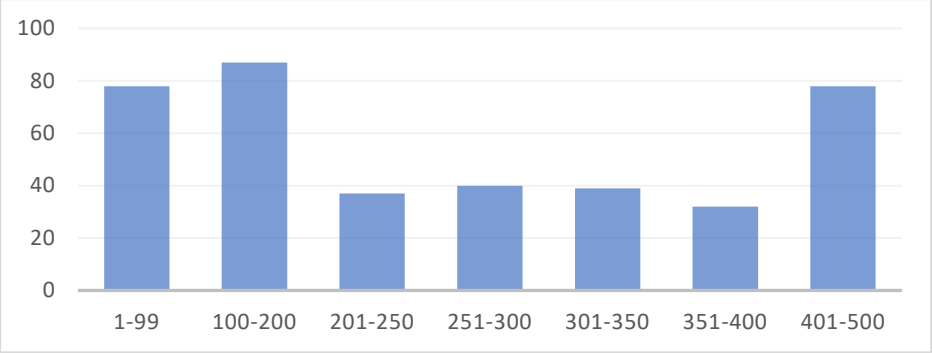


Figure 1. Distribution of the Rankings of Universities in the The 500 List
Source: The authors

As shown in Figure 2, the number of courses dealing with the environment and environmental issues is almost twice the total number of climate and sustainability-oriented courses.

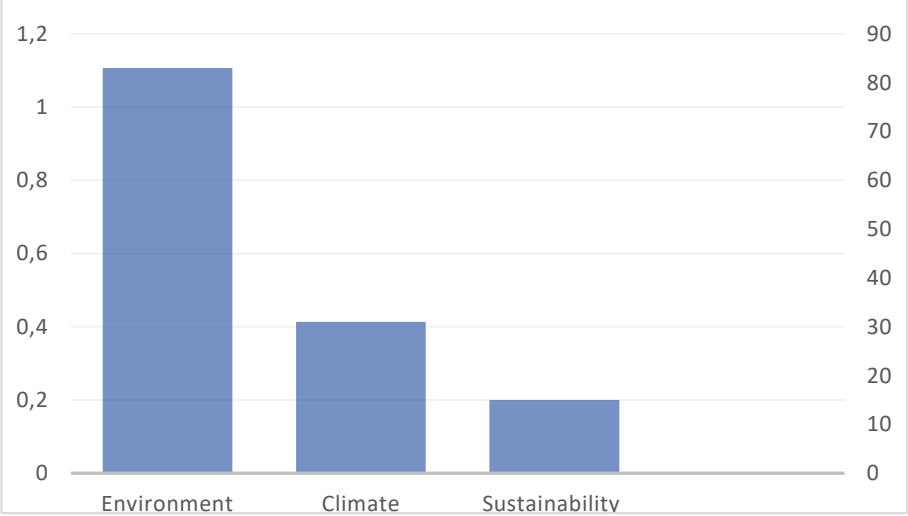


Figure 2. Distribution of the Key Words Included in the Course Titles
Source: The authors

Considering the broader scope of the word environment, the result is not surprising. Two of the keywords were used in common in 6 courses out of 123 total courses.

4.2. Content analysis

The course addresses the issue, starting with definitions of climate change. The courses offered in climate communication show significant diversity in terms of topics and how they approach the climate crisis. In this context, course descriptions and content were analysed to identify each course's main approach/focus and categorised under five main perspectives. This categorisation reveals what the courses teach and how and from which perspective they are approached.

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Table 1. The Perspective and the Approach of the Courses

Perspective	Description
Climate-Focused Science Communication	Dissemination of scientific knowledge to the public, climate science-focused communication
Social and Political Policy	Climate justice, public effect, inequalities
Media and Communication	Media narratives, news frameworks, popular culture and forms of communication
Activism Focused	Activism, social campaigns, public movement, student participation,
Critical and Alternative Approach	Critical media theories, capitalism, colonialism and petroculture

Source: The authors

With these frameworks, each course is coded according to the dominant approaches in its content. Courses covering more than one perspective were marked in more than one category. Table 2 systematically presents the perspective(s) under which each course is evaluated.

Table 2. Topics of the Analyzed Courses and the Way They Were Discussed

University	Course Name	Science Comm	Social/ Political	Media/ Comm	Activism	Critical
Monash University	Climate Change and Communication	x	x	x		
Southampton	Data Environmentalism	x	x	x		
Ohio State University	Communicating Science, Health, Environment & Risk	x	x	x		
Ohio State University	Principles of Environmental Campaigns		x	x	x	
University of Oslo	Communicating Climate Change		x	x	x	x
University of Oslo	Framing the Environment in Media & Communication		x	x	x	x
University of Leeds	Sociology and the Climate Crisis		x	x	x	x
University of Leeds	Climate Communication		x	x	x	x
University of Florida	Environmental Journalism	x		x		
University of Florida	Brand Sustainability Communication	x	x	x		x
University of York	Societies and the Climate Crisis		x		x	x
University of Technology Sydney	Climate Justice and Climate Policy		x	x	x	x
University of Technology Sydney	Environmental Communication		x	x	x	x
University of Auckland	Environmental Communication		x	x	x	x
University of Exeter	Communications and the Climate Crisis		x	x	x	x
Stockholm University	Environmental Communication		x	x		x
NUS Singapore	Communication, Culture & the Environment		x		x	
UAE University	Sustainability	x	x			x
University of Canberra	Climate Change and Sustainable Business Futures	x	x			
Free University of Bozen-Bolzano	Sustainable Development Communication	x	x			
Dublin City University	Communication, Culture & the Environment			x		

Source: The authors

The findings from this part of the analysis show that courses in climate communication focus on areas such as social transformation, media representations, and social movements, while the classical scientific communication model has a more limited place. It is seen that the courses are mostly designed with an interdisciplinary approach, shaped around more than one theme, and are more intertwined with social and cultural dynamics due to the nature of the discipline. A significant portion of the courses are also designed to cover the dimension of action and activism, not only equipping students with knowledge but also mobilising them for climate justice and environmental advocacy by using communication and its sub-dimensions correctly. This shows that understanding critical citizenship and participatory learning is at the forefront of the curriculum.

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On the other hand, it is observed that the critical and alternative approach perspective finds a place in a relatively limited course. This shows that discussions on climate change remain mostly within traditional environmentalist frameworks, while structural critiques and proposals for systemic transformation remain more limited. More emphasis should be placed on environmental media literacy and cultural ecology.

Overall, the findings reveal that climate-focused courses have a structure that integrates cognitive (knowledge-based) and affective and social (action-based) forms of learning. This diversity is extremely important as it shows that universities globally are addressing the climate crisis not only as a scientific problem but also as an issue of communication, politics, ethics, and justice. Topics such as the media's approach to the issue, the place of mass media and especially social media use in the climate crisis, and climate-oriented campaign designs also draw attention to the content of the courses.

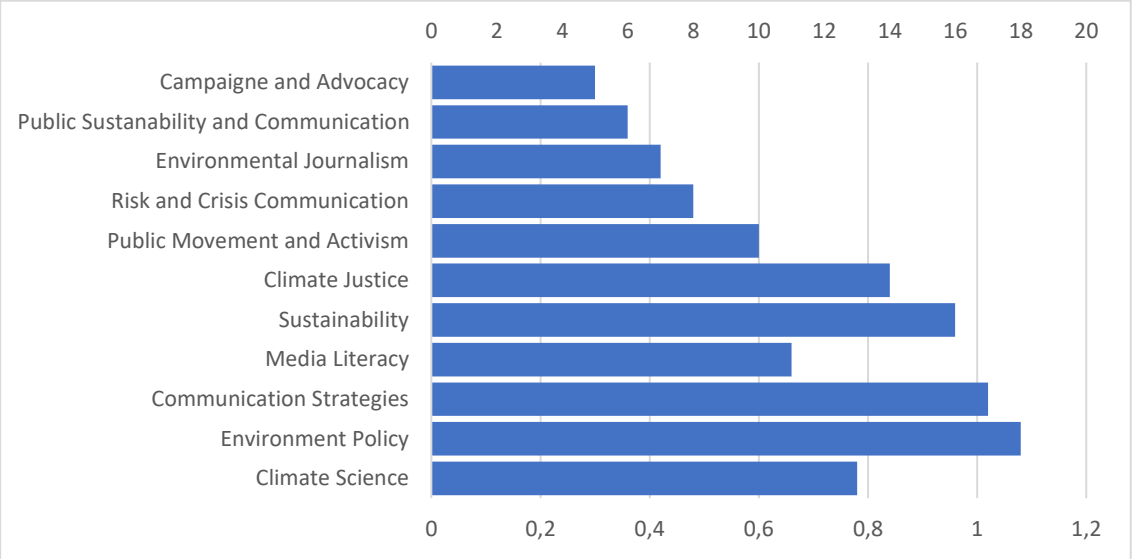


Figure 3. Frequently Used Concepts in Subject Headings
Source: The authors

In the analyses, the topics in the course syllabi were categorised according to their content and ranked according to their frequencies. The data obtained shows that the most emphasised themes in climate communication courses are Environmental Policies (n=18), Communication Strategies (n=17), Climate Science (n=16), Media Literacy (n=14), and Sustainability (n=14), respectively. This result emphasised that the courses have a multidimensional structure, not only limited to the transfer of scientific knowledge but also frequently used concepts should be used in practice areas (media, documentary, public relations, communication design, advertising etc).

However, topics such as Climate Justice (n=13) and Social Movements and Activism (n=10) also occupied an important place. This shows that the climate crisis is not only an environmental problem but also addressed with social justice and collective action dimensions. The more technical areas of Risk and Crisis Communication (n=9) and Environmental Journalism (n=8) aim to provide students with knowledge and skills in media content production and the importance of effective communication strategies in times of crisis. Practice-oriented topics such as Corporate Sustainability and Communication (n=7) and Campaigning and Advocacy (n=6) show that, in some cases, the courses try to produce professional outputs. This diversity reveals that climate communication courses are not only theoretical but also oriented toward practical application and professional competence. In general, the topics of the 22 different courses analysed show that a multifaceted academic approach to climate change is adopted and that both theoretical, applied, and social transformation-oriented contents are covered in a balanced manner.

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4.3. Findings

This study systematically examined the courses and evaluated the content, objectives, and epistemological orientations of these courses through a multidimensional analysis process. The findings reveal the strategic role that communication education has already begun to assume in the face of the climate crisis. At this point, although universities with courses that include the keywords climate, environment, and sustainability do not seem to be spread homogeneously all over the world, the fact that 123 courses with these keywords are actively taking place in communication faculties reveals the importance of communication in the climate crisis.

Most of the analysed courses address climate change as a scientific or environmental issue and as a communicative, cultural, ethical, and political phenomenon. In this context, the courses are categorised using different approaches. Each approach offers different theoretical and pedagogical frameworks for addressing the climate crisis. The combination of theory and practice in many of these courses, the invitation of expert guests to many of the courses, and the development of concrete project proposals have revealed that communication professionals in climate change, environmental policies, and sustainability studies should be actively involved in the public, civil society, academia, and private sector not only to raise awareness but also to lead to concrete behavioural changes.

European universities such as the University of Oslo, Leeds, Southampton, and York adopt an approach that makes issues such as environmental justice, activism, media performances, and digital citizenship more visible. In particular, the courses “Framing the Environment in Media & Communication” at the University of Oslo and “Sociology and the Climate Crisis” at the University of Leeds take an interdisciplinary approach to how media narratives and forms of political action interact. Themes of critical media literacy, activism, and environmental justice are at the forefront of these courses. This conceptual density shows that the discipline of communication is not only a transmission tool but also an active subject of environmental transformation processes.

Pedagogically, both theoretical and practical methods are used together in the courses. Universities such as the University of Technology Sydney and the University of Exeter offer students the opportunity to produce media content, design digital campaigns, and develop public communication strategies. The research also examined courses where traditional methods such as traditional exams and academic essay writing are preferred, and it was observed that such courses are particularly common in communication theories and journalism courses. In addition, the focus on the concepts of climate, environment, and sustainability in courses where content such as documentaries and TV programs are produced in film and media schools shows that students are directly involved in creating solutions to climate crisis issues in their cities and countries. All these data show that communication education contributes to providing students with professional qualifications and as individuals who will take responsibility for building a sustainable future. Graduates of these courses can communicate climate policies in public institutions, develop sustainable brand strategies in the private sector, or design communication models and practices that will mobilise public opinion on environmental and climate issues in international NGO's.

Conclusions

Considering the data obtained within the scope of the research, some conclusions and suggestions for communication faculties in countries where courses with keywords are not included, and communication academics who will design courses with these keywords are as follows:

Structures that integrate natural sciences, political science, and communication should be encouraged in course content. In this context, the course content to be created to increase students' knowledge and experience in this field must be interdisciplinary. Practical learning should be enhanced by expanding projects, media production workshops and digital campaign simulations that provide field experience for students from different departments in communication faculties. Graduation projects, mid-term assignments or research topics should address real-time climate crisis-oriented problems in the cities and countries where the universities are located.

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Courses should be developed in collaboration with local, national and international environmental organisations to increase students' contribution to policy-making processes and the process of producing solutions to the problems that civil society organisations focus on. In this way, students can put their theoretical knowledge into practice by receiving briefings directly from the institutions and organisations directly addressing the issue at the point of producing content. Courses should be diversified to include regional impacts and cultural approaches to the climate crisis. The sensitivities of local people and civil society should be addressed in terms of communication in increasing agricultural production, sustainable marketing and climate-friendly campaigns.

In conclusion, climate-oriented courses offered in faculties of communication have the potential not only to transmit knowledge but also to create transformation. This transformation will only be possible if the curricula have a multifaceted and action-oriented structure that supports critical thinking. As the universities and course contents examined in this study reveal, this model will directly contribute to communication faculties and universities by determining the internal dynamics and needs of different countries and cities.

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SUSTAINABLE ENTREPRENEURSHIP INTENTIONS: A CASE STUDY OF YOUTH IN VIETNAM

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Abstract. The study's objective is to investigate the sustainable entrepreneurship intentions of the youth in Vietnam. An anonymous questionnaire survey was administered to collect data from 1,289 youths of Generation Z in Vietnam. The gathered data underwent a hierarchical regression analysis to examine the moderating role of entrepreneurship support organizations. The findings indicate that attitude toward sustainability entrepreneurship, perceived feasibility, entrepreneurship desirability, and sustainability orientation significantly impact the sustainable entrepreneurship intentions of Vietnamese youth. Furthermore, the research results substantiate that the entrepreneurship support organization positively moderates the relationship between determinants of sustainable entrepreneurship intention and directly influences it. Drawing upon the research findings, several implications are proposed to assist governments, entrepreneurship support organizations, policymakers, and investors in acquiring a more profound understanding necessary for designing effective and suitable support programs. As a result, contribute to advancing a sustainable entrepreneurship ecosystem in the future.

Keywords: intentions; sustainable entrepreneurship; youth; moderate role; Vietnam

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JEL Classifications: L26, Q56, M13, I25

1. Introduction

Entrepreneurship plays a crucial role in creative activities, economic development and job creation for workers (Liu et al., 2019). Numerous studies have proven that increasing entrepreneurship within a country promotes better social well-being and reduces poverty (Tomy & Pardede, 2020; Barba-Sánchez et al., 2022).

Located in Southeast Asia, Vietnam is ranked among the emerging economies with the highest economic growth rates in the region (an average of 6.8 per cent from 2016 to 2019) and 8.02 per cent in 2022, and ranked 30th largest economy in the world measured by nominal gross domestic product (GDP) by International Monetary Fund. Nevertheless, unemployment among young people aged 15 to 24 in Vietnam is becoming increasingly severe. According to a report by the General Statistics Office (2024), Vietnam has nearly 1.5 million unemployed young people. In that context, the Government has approved the "Scheme to support the national innovation entrepreneurship ecosystem by 2025" to promote and motivate young people's entrepreneurship activities. However, entrepreneurship is not simply about setting up a new business; it must be carefully examined throughout the process, from intention to action (Hisrich et al., 2013).

The investigation of youths' intentions, particularly regarding sustainable entrepreneurship, remains a subject of considerable interest among scholars. The research conducted by Vuorio et al. (2018) examined the factors influencing the sustainable entrepreneurship intentions of 393 university students across three countries within

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the European region, utilizing the theory of planned behaviour as a framework. Their findings indicate that a positive attitude towards sustainability and entrepreneurship desirability significantly enhances the ability to improve sustainability-oriented entrepreneurship intentions. Furthermore, through the application of multiple regression analysis, Romero-Colmenares and Reyes-Rodríguez (2022) demonstrated that the sustainable entrepreneurship intentions of 314 university students in Bucaramanga, Colombia, significantly relate to their attitudes towards sustainable business creation, the perceived difficulty in executing such actions, and existing subjective norms. Recently, Ho et al. (2024) conducted a survey involving 583 young individuals across six North Central provinces of Vietnam, ranging from Thanh Hoa to Thua Thien–Hue, to evaluate the impact of entrepreneurship support policies on their preparedness and intention to initiate a business venture. Recently, Gimenez-Jimenez and Harc (2024) utilized the theory of planned behaviour alongside the values literature to investigate how sustainable values - specifically pro-environmental and solidarity values - impact sustainable entrepreneurship intentions across two distinct cultural contexts: Ecuador and Germany. The findings reveal that pro-environmental values do not correlate with the behavioural mechanisms that facilitate sustainable entrepreneurship intentions in Germany or Ecuador. Conversely, behavioural mechanisms in Ecuador fully mediate the relationship between solidarity values and sustainable entrepreneurship intentions. In Germany, a partial mediation is observed through attitudes towards sustainable entrepreneurship and perceived behavioural control regarding sustainability.

Despite the existing research on the sustainable entrepreneurship intentions of young individuals, there is a notable scarcity of studies specifically addressing the sustainable entrepreneurship intentions of youth in Vietnam. Moreover, previous research has not adequately examined the moderating influence of entrepreneurship support organizations in fostering socially and environmentally responsible entrepreneurship within sustainable business (Yun & Zhao, 2020). Consequently, this study aims to fill the research gap by investigating the sustainable entrepreneurship intentions of young people in Vietnam, with particular emphasis on the moderating effect of entrepreneurship support organizations.

2. Theoretical background and hypothesis development

2.1. Sustainable Entrepreneurship Intention

Intention is a cognitive state reflecting an individual's readiness to start a new business venture (Tubbs & Ekeberg, 1991). According to Kuckertz and Wagner (2010), it goes beyond mere desire, involving opportunity identification, resource mobilization, and environmental support.

Shi et al. (2020) explain that business intention stems from personal traits, social context, and attitudes about autonomy, creativity, and risk-taking to create value. Intention is essential for driving entrepreneurship behaviour (Alakaleek et al., 2025).

Due to a scarcity of jobs, fierce labour competition, and economic uncertainties, starting a business is considered a valuable career path. Environmental issues and social challenges highlight the need for sustainable entrepreneurship models. Sustainable entrepreneurship links business efforts with sustainable development goals. As per Farny and Binder (2021), it involves starting a business and leveraging market opportunities for sustainable advancement. Businesses that commit to sustainability generate economic value while tackling environmental and social issues. This approach prioritizes solutions for environmental protection and social justice (Farny et al., 2016; Belz & Binder, 2017; Binder, 2017; Benavides-Sánchez et al., 2025).

Entrepreneurs must identify viable opportunities that promise societal and environmental benefits, with a focus on long-term growth rather than short-term gains (Greco & de Jong, 2017). Sustainable entrepreneurship aims to positively impact economic, environmental, and social dimensions (Gerlich et al., 2025). Unlike traditional models, it integrates these factors, balancing profitability with social and environmental responsibilities (Parrish & Tilley, 2006; Czyzewska et al., 2025; Winkler et al., 2025). Profitability is significant but not the sole objective; it complements broader goals (Lepoutre et al., 2013; Audretsch et al., 2025).

In this research, sustainable entrepreneurship intention encompasses individuals' desire, motivation, and commitment to initiate a business that simultaneously ensures economic efficiency and contributes positively

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to society and the environment. This intention reflects individuals' propensity to identify and exploit business opportunities, not merely for short-term profits, but to pursue long-term sustainable development.

2.2. Analytical framework and hypotheses development

The foundational theory employed to construct the research model is Ajzen's (1991) Theory of Planned Behavior (TPB), a critical framework for elucidating an individual's behavioural intention development. TPB posits that the intent to engage in a particular behaviour is influenced by three primary factors: attitude, subjective norms, and perceived behavioural control. By this theory, young individuals' intentions to initiate sustainable business ventures are motivated by a favourable attitude towards sustainability and a propensity to engage in environmentally conscious business activities when opportunities present themselves (Vourio et al., 2018). Consequently, this study has adopted the components of the TPB model and modified it to suit the context of sustainable entrepreneurship. Moreover, the Delphi method has been utilized in this research, which involves consulting a panel of experts possessing extensive experience in entrepreneurship, including mentors from entrepreneurship support centres and founders currently leading sustainable enterprises. This approach has enabled the study to develop several comprehensive factors pertinent to an emerging economy, such as Vietnam, as outlined below (see Figure 1).

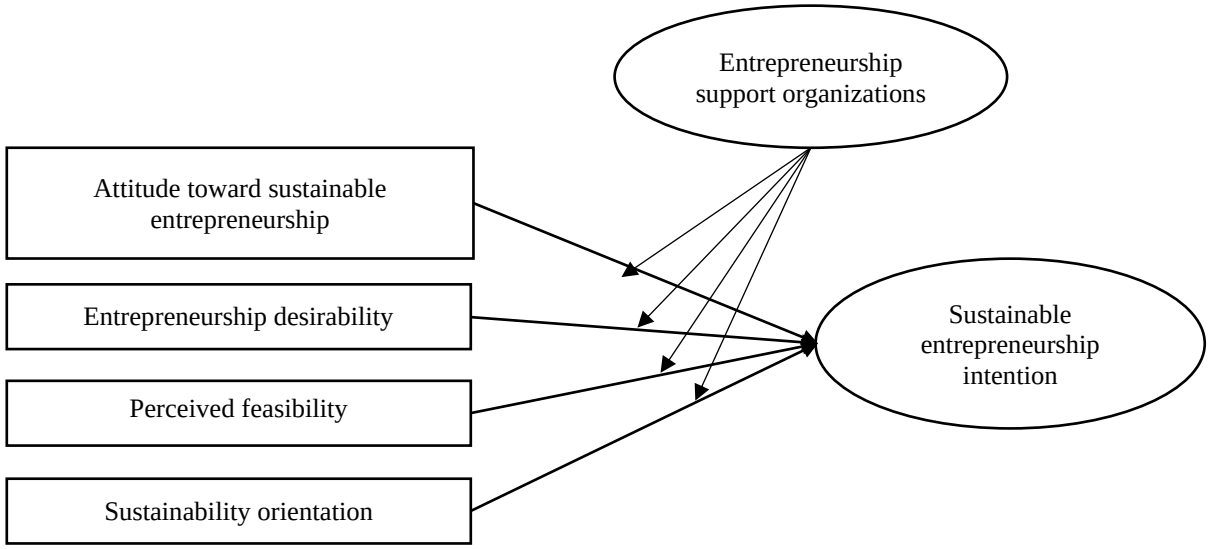


Figure 1. Analytical framework

The attitude towards sustainable entrepreneurship indicates individuals' degree of evaluation and sentiment regarding this concept. According to Ajzen's (1991) Theory of Planned Behavior, attitude represents a significant factor influencing intention to engage in a particular action. Individuals who maintain a favourable attitude towards sustainable entrepreneurship are inclined to believe that this business model offers long-term advantages, facilitates the equilibrium between economic development and social responsibility, and generates sustainable value for the community. As Bruyere and Rappe (2007) and Wagner (2012) highlight, integrating business objectives with sustainable development enhances economic efficiency and aids in preserving natural resources and enhancing social value. Consequently, a positive disposition towards sustainable entrepreneurship is crucial in shaping the intention to establish a business within this sphere (Dean & McMullen, 2007). In light of the aforementioned considerations, the following research hypothesis is proposed:

H1: The attitude toward sustainable entrepreneurship positively affects the sustainable entrepreneurship intention.

Entrepreneurship desirability pertains to how an individual perceives a business as appealing, encapsulating a profound inclination to embark on the entrepreneurship journey (Krueger, 1993). Fitzsimmons and Douglas (2011) assert that entrepreneurship desirability is a pivotal factor in forming business intent, influencing the individual's commitment to the entrepreneurship endeavour and their capacity to surmount challenges in realizing a business concept. Sher et al. (2019) underscore that endogenous and exogenous rewards shape

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entrepreneurship desirabilities. Endogenous rewards encompass personal motivation, the gratification derived from mastering one's role, the opportunity to express creativity, and the ability to resolve complex issues. Conversely, exogenous rewards consist of financial gains, social prestige, and acknowledgement from the community. These rewards facilitate identifying and assessing business opportunities and encourage individuals to pursue the entrepreneurship pathway persistently. In light of the preceding arguments, the following research hypothesis is proposed:

H2: Entrepreneurship desirability positively affects the intention to sustain entrepreneurship.

Perceived feasibility strongly impacts entrepreneurship intentions by shaping individuals' views on their abilities, resources, and opportunities for launching a business (Piperopoulos & Dimov, 2015). Bandura's social cognition theory (1977) asserts that belief in one's competence affects decision-making, specifically in entrepreneurship. Those confident in their skills are likelier to see business initiation as feasible, increasing their entrepreneurship intent. Sher et al. (2019) found a direct link between self-capacity and entrepreneurship intention, influenced by perceived feasibility. Individuals who view themselves as capable are more motivated to pursue entrepreneurship, while those seeing it as daunting may reduce their intentions. Bosma et al. (2012) suggest observing others' business successes enhances self-confidence in one's entrepreneurship abilities. Witnessing peers succeed makes starting a business seem more attainable. This leads to the following research hypothesis:

H3: Perceived feasibility positively affects sustainable entrepreneurship intention.

Sustainability orientation refers to the propensity of individuals or organizations to contemplate and act in a manner that seeks to harmonize three dimensions: economic, social, and environmental, within the developmental process (Dean & McMullen, 2007; Cohen & Winn, 2007). This orientation embodies a strategic perspective that prioritizes achieving business objectives for profit maximization and generating enduring value for society and ecosystems. When an individual embraces a sustainable orientation in establishing a business, they are inclined to pursue environmentally responsible solutions and management practices aimed at mitigating adverse impacts on natural ecosystems. In light of the aforementioned considerations, the proposed research hypothesis is articulated as follows:

H4: Sustainability orientation positively affects the sustainable entrepreneurship intention.

Entrepreneurship support organizations provide resources, training, and networking to foster start-ups. Ecosystem play an important role in connecting individuals with investors and experienced entrepreneurs, enhancing skills and knowledge for better business models and market opportunities (Winters et al., 2009; Leendertse & van Rijnsoever, 2025; Bonfanti et al., 2025). Supporting organizations are crucial in promoting sustainable entrepreneurship and responsible practices (Yun & Zhao, 2020). A positive attitude towards sustainable entrepreneurship can lead to greater access to resources and confidence in pursuing sustainable models. This support bolsters the impact of entrepreneurship attitudes on intent (Dean & McMullen, 2007). Training and consulting from these organizations help individuals better implement business ideas, improving their assessment of sustainable entrepreneurship's feasibility (Sher et al., 2019).

Additionally, support organizations enhance the influence of entrepreneurship desirability on sustainable intentions. Fitzsimmons and Douglas (2011) emphasize that organizational support provides motivation, strategic direction, and practical help, enabling aspirations to turn into actions. A sustainability focus in business improves when organizations guide individuals in integrating economic, social, and environmental elements into their models (Cohen & Winn, 2007).

Thus, this study suggests that strong organizational support positively affects the dynamics among attitudes, perceived feasibility, desirability, and sustainability in sustainable entrepreneurship intentions. Based on this, the following research hypothesis is proposed:

H5: Entrepreneurship support organizations actively moderate the relationship among (a) attitudes toward sustainable entrepreneurship, (b) perceived feasibility, (c) entrepreneurship desirability, (d) sustainability orientation, and sustainable entrepreneurship intentions.

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3. Methodology

3.1. Measurement scales

The preliminary scale is constructed based on both domestic and international studies conducted by Winters et al. (2009), Reyad et al. (2019), Yun and Zhao (2020), Le et al. (2022) and Giao (2022). Discussions were held with a number of young individuals from Generation Z who aspire to start their own businesses in conjunction with consultations with several experts. This collaborative effort aimed to assess the relationship and relevance of the observed variables, ensuring their alignment with the target audience and the objectives of the study prior to their inclusion in the formal survey. The findings from these discussions indicated that the participants were in agreement with the proposed scales. The finalized scale comprises 27 observed variables, which correspond to four independent factors, one dependent factor, and one moderating factor. The items within the questionnaire were rated using a five-point Likert scale (1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree). A description of the questionnaire items is presented in Table 2.

3.2. Sample and data collection

The research used a sample size ratio of 10:1, as recommended by Hair et al. (2010), analyzing 27 variables, resulting in 270 required samples. To account for data cleaning losses, the authors surveyed 1,500 respondents. They employed a non-probability survey distributed through online questionnaires to young individuals in Hanoi and Ho Chi Minh City from January 2024 to January 2025, yielding 1,289 valid responses. Of these, 44.6% identified as male and 55.4% as female. Most participants were aged 21-23 (46.7%), followed by 18-20 (31.5%) and 24-26 (21.8%). Educationally, 71.3% were undergraduates, 22.5% were graduates, and 6.2% were postgraduates. Professionally, 38.4% studied business and management, 22.8% information technology, 18.3% economics and finance, 12.1% social sciences, and others 8.4%. There were 58.1% who had no experience, 27.3% who were testing a business idea, 9.3% who had faced failure, and 5.3% who were running a project. Regarding income, 42.9% earned less than 5 million VND monthly, 33.2% earned 5- 7 million VND, and 23.9% earned over 7 million VND.

3.3. Data analysis

The study employed the MMR moderator regression model developed by Saunders (1956). In accordance with this model, prior to their inclusion in the regression analysis, all factors are centred by subtracting each variable's mean value. This technical interaction factor is derived sequentially from the centring of the independent factors and the moderating factor. Subsequently, the moderating factor is multiplied by the centred independent factors. The research model is represented by three regression equations as follows:

(1) The regression equation represents the effect of independent factors on the dependent factor:

$$SEI = \beta_0 + \beta_1*cATSE + \beta_2*cPF + \beta_3*cED + \beta_4*cSO$$

(2) The regression equation expresses the effect of the independent factor and the moderating factor (independent factor) on the dependent factor:

$$SEI = \beta_0 + \beta_1*cATSE + \beta_2*cPF + \beta_3*cED + \beta_4*cSO + \beta_5*cESO$$

(3) Regression equations represent the effects of independent factors, moderating factors, and interacting factors on the dependent factor:

$$SEI = \beta_0 + \beta_1*cATSE + \beta_2*cPF + \beta_3*cED + \beta_4*cSO + \beta_5*cESO + \beta_6*cATSE.ESO + \beta_7*cPF.ESO + \beta_8*cED.ESO + \beta_9*cSO.ESO$$

Where: SEI (Dependent factor): Sustainable entrepreneurship intentions
ESO (Moderating factors): Entrepreneurship support organizations
Independent factors (X_i): Attitude toward sustainability entrepreneurship (ATSE); Perceived feasibility (PF); Entrepreneurship desirability (ED); and Sustainability orientation (SO).
Interacting factors: Entrepreneurship support organizations and attitude toward sustainability entrepreneurship (ATSE.ESO); Entrepreneurship support organizations and perceived feasibility (PF.ESO); Entrepreneurship support organizations and entrepreneurship desirability (ED.ESO); Entrepreneurship support organizations and sustainability orientation (SO.ESO).
β_k: Regression coefficients

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4. Results

The descriptive analysis presented in Table 1 indicates that entrepreneurship desirability has the highest mean value (4.11), reflecting a pronounced entrepreneurship desirability among the youth of Vietnam. Additionally, perceived feasibility and orientation towards sustainability exhibit relatively high means (3.87 and 3.94, respectively), suggesting that most survey participants view the implementation of entrepreneurship endeavours as feasible and show an interest in sustainability factors. Conversely, entrepreneurship support organizations received an average value of 3.75, signifying a commendable level of effectiveness in fulfilling their role in supporting entrepreneurship. Furthermore, attitudes towards sustainable entrepreneurship and sustainable entrepreneurship intention (averaging 3.62 and 3.80, respectively) indicate a positive inclination among Vietnamese youth towards sustainable entrepreneurship, though some assessment divergence remains evident.

Table 1. Descriptive statistics

Measurement scale	Min	Max	Mean	SD
Attitude toward sustainable entrepreneurship	1.00	5.00	3.62	0.84
Perceived feasibility	1.00	5.00	3.87	0.71
Entrepreneurship desirability	1.00	5.00	4.11	0.93
Sustainability orientation	1.00	5.00	3.94	0.72
Entrepreneurship support organizations	1.00	5.00	3.75	0.68
Sustainable entrepreneurship intentions	1.00	5.00	3.80	0.77

Source: Data from authors' survey

The reliability results indicate that the Cronbach's Alpha coefficient exceeds the threshold of 0.7, ensuring the instrument's reliability. Additionally, the corrected item-total correlation is greater than 0.3, and removing any observed variable does not significantly increase the Cronbach's Alpha. Consequently, it is confirmed that the scales are reliable and discriminant, meeting the necessary criteria for further exploratory factor analysis (Hair et al., 2010) (refer to Table 2).

Table 2. Reliability analysis results

Sign	Items	Cronbach's Alpha	Corrected item – total correlation	Cronbach's Alpha if items are deleted
Attitude toward sustainable entrepreneurship				
ATSE1	Sustainable entrepreneurship contributes to poverty reduction	0.856	0.615	0.841
ATSE2	Sustainable entrepreneurship increases job opportunities		0.634	0.837
ATSE3	Sustainable entrepreneurship increases equality		0.598	0.829
ATSE4	Sustainable entrepreneurship increases the efficiency of natural resource use		0.572	0.815
ATSE5	Sustainable entrepreneurship helps protect biodiversity		0.606	0.808
ATSE6	Sustainable entrepreneurship brings many benefits to society and the environment		0.581	0.796
ATSE7	Sustainable entrepreneurship promotes the use of environmentally friendly energy		0.573	0.752
Perceived feasibility				
PF1	I can afford to start a sustainable entrepreneurship project	0.792	0.647	0.785
PF2	I can attract and persuade partners and investors to support sustainable entrepreneurship projects		0.618	0.779
PF3	I can identify and exploit successful sustainable business opportunities		0.593	0.764
PF4	Sustainable entrepreneurship brings many long-term benefits		0.562	0.758
Entrepreneurship desirability				
ED1	I am interested and passionate about sustainable entrepreneurship	0.834	0.588	0.814
ED2	Sustainable entrepreneurship is the ideal career path		0.571	0.805
ED3	I am willing to take risks to start a sustainable entrepreneurship		0.562	0.796
ED4	I look for opportunities to develop sustainable entrepreneurship ideas		0.554	0.781
Sustainability orientation				
SO1	Sustainability is a factor that helps businesses survive for a long time	0.816	0.570	0.801
SO2	I am willing to adopt environmentally friendly business methods		0.553	0.794
SO3	I need to be responsible for contributing to sustainable development through entrepreneurship		0.546	0.776

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Sign	Items	Cronbach's Alpha	Corrected item – total correlation	Cronbach's Alpha if items are deleted
Entrepreneurship support organizations				
ESO1	I have easy access to training programs on sustainable entrepreneurship	0.841	0.576	0.833
ESO2	I receive financial support and mentorship from entrepreneurship support organizations		0.549	0.826
ESO3	Entrepreneurship support organizations provide helpful information about the market and business opportunities		0.531	0.813
ESO4	Entrepreneurship support organizations that create market opportunities and networks with investors		0.525	0.800
ESO5	I improved business and management skills thanks to the entrepreneurship support organization		0.508	0.797
ESO6	I gained confidence thanks to the entrepreneurship support organization		0.497	0.785
Sustainable entrepreneurship intentions				
SEI1	I aspire to establish a business that balances profit and social responsibility	0.807	0.648	0.799
SEI2	I would prioritize sustainable start-ups instead of traditional business models		0.623	0.781
SEI3	I believe that sustainable entrepreneurship aligns with the orientation of future development		0.601	0.775

Source: Data from authors' survey

The EFA of independent factors produced a KMO coefficient of 0.821, exceeding the required threshold of 0.5. Bartlett's test yielded a Chi-square statistic of 9726.513 with a significance level of 0.000, confirming correlations among observed variables and the appropriateness of exploratory factor analysis. Additionally, principal component analysis (PCA) with Varimax rotation identified four factors (Eigenvalue> 1) that together accounted for 75.188% of the variance. The factor loadings of observed variables surpassed 0.5, grouping into four scales to clarify the factors (see Table 3).

Table 3. EFA of independent factors

Items	Factors			
	1	2	3	4
PF1	0.825			
PF2	0.819			
PF3	0.803			
PF4	0.792			
SO1		0.824		
SO2		0.817		
SO3		0.809		
ATSE1			0.836	
ATSE2			0.820	
ATSE3			0.811	
ATSE4			0.802	
ATSE5			0.793	
ATSE6			0.771	
ATSE7			0.765	
ED1				0.780
ED2				0.767
ED3				0.754
ED4				0.741
KMO = 0.821, Approx. Chi-Square = 9726.513, df = 1.829, Sig. = 0.000				
% of Variance	42.718	56.973	63.924	75.188
Eigenvalue	4.269	3.515	2,788	1.462

Source: Data from authors' survey

The EFA results show a KMO coefficient 0.832, indicating good sample adequacy. Bartlett's test (p = 0.000) confirms variable correlation, with factor loadings over 0.5. One factor has an Eigenvalue of 1.107 and explains 80.133% of the variance, meeting Hair et al.'s criteria (Hair et al., 2010) (see Table 4).

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Table 4. EFA of the dependent factor

Factor	Items	Factor loadings
Sustainable entrepreneurship intentions	SEI1	0.839
	SEI2	0.826
	SEI3	0.815
KMO = 0.809, Approx. Chi-Square = 378.126, df = 3, Sig. = 0.000		
% of Variance = 80.965, Eigenvalue = 1.987		

Source: Data from authors' survey

The EFA results show a KMO coefficient 0.812, exceeding the 0.5 requirement. Bartlett's test has a significance coefficient 0.000, indicating correlations among the observed variables. Six variables of the regulatory scale have factor loadings over 0.5, confirming that the analysis data meet Hair et al.'s criteria (2010) (see Table 5).

Table 5. EFA of the moderating factor

Factor	Items	Factor loadings
Entrepreneurship support organizations	ESO1	0.849
	ESO2	0.835
	ESO3	0.823
	ESO4	0.806
	ESO5	0.795
	ESO6	0.782
KMO = 0.812, Approx. Chi-Square = 335.264, df = 6, Sig. = 0.000		
% of Variance = 79.081, Eigenvalue = 1.953		

Source: Data from authors' survey

The results of the correlation analysis demonstrate a strong correlation between independent and dependent factors, as indicated by a correlation coefficient greater than 0.5 and a significance coefficient less than 0.05. Furthermore, there is no multicollinearity among the independent factors. The centring technique does not affect the correlation coefficient between the variables before and after centring, indicating that the variables are suitable for regression analysis (see Table 6).

Table 6. Correlation analysis

	SEI	ATSE	PF	ED	SO	ESO
SEI	1					
ATSE	0.675**	1				
PF	0.712**	0.247**	1			
ED	0.689**	0.198*	0.261**	1		
SO	0.768**	0.253**	0.184**	0.238**	1	
ESO	0.704**	0.209**	0.272*	0.253*	0.219**	1
**** significant at p < 0.05; ** significant at p < 0.01***						

Source: Data from authors' survey

The MMR regression analysis using the hierarchical method shows adjusted R^2 coefficients of 0.607, 0.633, and 0.681, indicating effective explanation of sustainable entrepreneurship intention variability. The F and t test significance coefficients are below 0.05, confirming the models' statistical significance. The Durbin-Watson coefficient ranges from 1.685 to 1.782, upholding the autocorrelation assumption, while the VIF coefficient below 2 indicates no multicollinearity. Residual variance analysis via histogram and P-P plot reveals a mean near 0 and standard deviation close to 1, suggesting near-normal distribution. The Normal P-P plot confirms residuals concentrate near the diagonal, supporting normal distribution assumptions. Model 3 has the highest adjusted R^2 at 68.1%; hence, it is used for interpreting study results (see Table 7).

Table 7. Results of regression weights of models

	Model 1		Model 2		Model 3	
	Beta	**VIP**	**Beta**	**VIP**	**Beta**	**VIP**
cATSE	0.217**	1.189	0.228**	1.194	0.251**	1.245
cPF	0.239*	1.203	0.247*	1.288	0.229*	1.291
cED	0.198**	1.254	0.202*	1.316	0.234**	1.195

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	Model 1		Model 2		Model 3	
	Beta	**VIP**	**Beta**	**VIP**	**Beta**	**VIP**
cSO	0.204**	1.199	0.236**	1.151	0.208 *	1.216
cESO			0.199**	1.342	0.246**	1.184
cATSE.ESO					0.187**	1.267
cPF.ESO					0.195*	1.218
cED.ESO					0.173**	1.239
cSO.ESO					0.183**	1.172
R^2	0.642		0.695		0.739	
R^2 adjusted	0.607		0.633		0.681	
F (Sig.)	0.000		0.000		0.000	
Durbin – Watson	1.685		1.749		1.782	
***, ** p < 0.05, p < 0.01* **a. Dependent Variable: SEI**						

Source: Data from authors' survey

The five proposed research hypotheses were accepted with the regression-weighted results in Model 3. The final regression equation according to the normalized Beta coefficient is as follows:

$$SEI = \beta_0 + 0.251*cATSE + 0.246*cESO + 0.234*cED + 0.229*cPF + 0.208*cSO + 0.195*cPF.ESO + 0.187*cATSE.ESO + 0.183*cSO.ESO + 0.173*cED.ESO$$

5. Discussion and implications

5.1. Discussion

The results confirm that Ajzen's (1991) theory of planned behavior can determine young people's intention to pursue sustainable entrepreneurship in an emerging economy like Vietnam. In which:

Hypothesis 1 (H1): The attitude toward sustainable entrepreneurship positively affects young people's intentions in Vietnam to start a sustainable business. This finding aligns with the work of Vuorio et al. (2018) and Wagner (2012). An individual's positive attitude is crucial in promoting the intention to act in general and specifically for sustainable entrepreneurship intentions. In this study, when the attitude toward sustainable entrepreneurship increases by 1 unit, the sustainable entrepreneurship intention rises by 0.251 units.

Hypothesis 2 (H2): Perceived feasibility greatly influences Vietnamese youth's sustainable entrepreneurship intentions, as noted by Sher et al. (2019) and Bui et al. (2025). Positive attitudes towards sustainable entrepreneurship and belief in the success of green businesses enhance these intentions. Given Vietnam's numerous risks, understanding feasibility helps youth assess their capabilities and navigate challenges effectively. In this study, each unit increase in perceived feasibility corresponded to a 0.209 unit rise in sustainable entrepreneurship intention.

Hypothesis 3 (H3): Entrepreneurship desirability positively influences Vietnamese youth's sustainable entrepreneurship intentions, as supported by Vuorio et al. (2018) and Sher et al. (2019). Young people are motivated by climate change impacts to pursue improved lives for themselves and future generations, leading to increased engagement in environmental protection through sustainable business practices. In Vietnam, national policies and a growing entrepreneurship ecosystem bolster personal aspirations, helping youth tackle challenges like capital shortages and limited skills. This study shows that a 1 unit increase in desirability leads to a 0.234 unit rise in sustainable entrepreneurship intention.

Hypothesis 4 (H4): Sustainability orientation positively affects the sustainable entrepreneurship intentions of Vietnamese youth. This finding supports the conclusions of Dean and McMullen (2007). Currently, Vietnam is implementing various programs to support green entrepreneurship and social enterprises while promoting entrepreneurship linked to community responsibility. These efforts help raise awareness and motivate young people to integrate sustainability elements when they develop a business idea. In this study, when sustainability orientation increased by 1 unit, sustainable entrepreneurship intention rose by 0.208 units.

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Hypothesis 5 (H5): The relationship between attitudes toward sustainability entrepreneurship, perceived feasibility, entrepreneurship desirability, and sustainability orientation is influenced by entrepreneurship support organizations. Specifically, these organizations enhance their effect on the sustainable entrepreneurship intentions of Vietnamese youth. Therefore, the more young people perceive support from entrepreneurship support organizations, the more positive their attitudes, awareness, desirability, and orientations will become. Consequently, this will increase their sustainable entrepreneurship intentions.

Furthermore, the study found that entrepreneurship support organizations directly impact the sustainable entrepreneurship intentions of young people in Vietnam. This finding supports the conclusions of Yun and Zhao (2020). In the Vietnamese context, many young people still lack practical experience and access to resources, making the proactive role of entrepreneurship support organizations even more crucial. In this study, when the role of entrepreneurship support organizations increased by 1 unit, the sustainable entrepreneurship intentions rose by 0.246 units.

5.2. Implications

Theoretically, this study enriches the theory of planned behaviour (TPB). Additionally, it expands the moderating role of entrepreneurship support organizations, indicating that assistance from these organizations will enhance the sustainable entrepreneurship intentions of Vietnamese youth who possess Eastern cultural characteristics and value traditional norms while resisting change. According to the authors, this is the first study to clarify this mechanism of influence in the context of a developing country like Vietnam, making this model a useful reference for other developing nations.

The research results also enhance knowledge and broaden the perspective of sustainable entrepreneurship as a new business model for Generation Z in Vietnam. From a business standpoint, the findings will assist young people in orienting themselves and developing green business models, such as producing recycled products, organic food, green fashion, and utilizing renewable energy, among others. The contributions of this study and the results of the analysis have produced several appropriate policy implications to promote sustainable entrepreneurship intention among young people in Vietnam as follows:

Firstly, to improve attitudes towards sustainable entrepreneurship, the government and entrepreneurship support organizations need to encourage this by implementing communication programs and promotional campaigns about successful young entrepreneurs in sustainable entrepreneurship. It aims to change mindsets and increase young people's interest in sustainable business models. Additionally, entrepreneurship support organizations can integrate significant sustainable development content into their training programs and build practical experience opportunities, such as visits to sustainable businesses and internships at socially responsible companies, so that young people gain awareness of the long-term benefits of sustainable entrepreneurship. Moreover, entrepreneurship support organizations should implement extracurricular activities like seminars and competitions to raise awareness and encourage young people to develop sustainable thinking from school.

Secondly, entrepreneurship desirability can be promoted by building a community of young entrepreneurs, connecting individuals with the same passion for sustainable entrepreneurship to create an environment that supports each other and inspires them long-term. Organize seminars and cooperate with successful entrepreneurs to organize experience-sharing sessions and career orientation to help young people have a practical perspective and motivation to pursue the path of entrepreneurship. Local governments must launch many entrepreneurship idea contests and entrepreneurship acceleration programs with topics related to sustainable development to encourage young people to realize their ideas.

Thirdly, the Government needs to enhance the perceived feasibility of sustainable entrepreneurship by improving entrepreneurship support infrastructure, building business incubators, co-working spaces, and innovation support centres to help young people have favourable conditions to develop sustainable entrepreneurship projects. Additionally, credit institutions need to have programs to support entrepreneurs to access capital easily, specialized investment funds for young people to start a business according to a sustainable business model, and create conditions for young enterprises to reduce barriers and financial burdens when implementing business models. Moreover, entrepreneurship support organizations must provide training

courses on sustainable business governance skills, guidance on making business plans, market analysis, and risk control to strengthen young people's confidence in the feasibility of sustainable entrepreneurship.

Fourthly, the Government needs to establish a clear sustainability orientation in entrepreneurship by promulgating specific standards and guidelines for sustainable entrepreneurship, enabling young people to adopt environmentally friendly and community-oriented business models easily. The Government should encourage entrepreneurs to implement circular economy principles, utilize recycled materials, reduce waste, and adopt green production practices. Simultaneously, the criteria for sustainable development assessment should be included in entrepreneurship evaluation programs, providing investors and supporting organizations a basis to prioritize sustainable entrepreneurship.

Finally, entrepreneurship support organizations should promote coordination among the state, enterprises, and entrepreneurs to build a strong and sustainable entrepreneurship ecosystem. The Government also needs to enhance preferential policies regarding finance, taxes, and legal support to assist young people in launching sustainable businesses, thereby creating favourable conditions for them to begin their entrepreneurship journeys. Additionally, mentorship programs involving experienced entrepreneurs in sustainable entrepreneurship should be developed to help young people gain knowledge and practical experience.

Conclusions

This study focuses on explaining the sustainable entrepreneurship intention of Vietnamese youth based on the TPB model, which has been adapted for sustainable entrepreneurship. Although this study has achieved specific results, it inevitably has limitations. First, the survey sample is concentrated solely in two major cities in Vietnam, Hanoi and Ho Chi Minh City, which are known for their high-level characteristics. This concentration affects the ability to generalize the results. Therefore, further studies could expand the scope of the survey to improve representativeness. Secondly, the study explores the moderating impact of overall entrepreneurship support organizations. However, it does not delve into aspects of these organizations, such as training programs, networks, human resources, or other factors, including gender, age, and experience. Therefore, future studies should broaden the exploration of the moderating role of various factors. Ultimately, the study only focused on young people at a single point in time, so additional studies that employ longitudinal and time-based research could yield more in-depth results.

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IMPACT OF HRM DIGITALISATION ON COMPANIES' PERFORMANCE*

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Abstract. The article's main aim is to specify the importance of HR digitalisation from two points of view: economic short-term impact and perceived meaning for the company. Two questionnaire surveys were carried out: in the Czech Republic in 2020-2021 to determine the short-term impact of selected elements of digitalisation on the change in economic performance during a pandemic; in Bulgaria in 2023-2024 to determine the perceived meaning of HRM digitalisation during a pandemic and post-pandemic recession. There was no association between the change in the level of digitalisation and the change in economic performance. Data and document sharing are associated with improved economic performance in the short term. Although HR training in IT is not related to improving the financial result in the short term, it is perceived by the podcasts as part of the long-term development plan of the companies and as an opportunity to improve the employees' work. The main recommendation for the target segment is to monitor the long-term impact to specify the expected effect on the company's overall efficiency. The results have limitations in the field of the specific research period, the geographical aspect of entrepreneurship, and the limited scope of examined links. The basic directions for future research include conducting international research on a broader scale and over extended periods, involving more aspects of HRM digitalisation among the elements studied.

Keywords: HR digitalization; training; support activities; effectiveness

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JEL Classifications: M10, M15, M53

1. Introduction

Changing economic, political, and societal conditions have significantly influenced the nature of the business environment (Nguyen, 2022; Peterková et al., 2022; Necula et al., 2023) and requirements for sustainable efficiency of the enterprise (Butt, 2022; Straková & Talíř, 2020). Digitalisation is one of the often-discussed tools to ensure adaptability to external changes and sustainable competitiveness (Vadana et al., 2020; Chen et al., 2022; Dabbous et al., 2023). Digitalisation is an essential mechanism for increasing the sustainable competitiveness of economies worldwide (Petkovski et al., 2022; Szanyi-Gyenes & Almási, 2023). Digital

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technologies have created new business opportunities for entrepreneurs and institutions (Zimmermannova et al., 2022; Galindo-Martín et al., 2023). Competitiveness factors depend on macroeconomic factors, business environment and consumer demand (Boikova et al., 2021).

One of the advantages of a value chain is the ability to assess which links in the Global Value Chain (GVC) contribute to value creation and what extent (Gereffi, 2019). The pandemic has significantly affected the performance of supply chains (Zighan, 2022). The traditional approach to measuring corporate performance focuses on monetary terms (Dyckhoff & Souren, 2020). Business performance is influenced by, among other things, business process innovation (Wei et al., 2020).

It can be concluded that the digitalisation of business models impacts the HR field (Minbaeva, 2021). Recent years have shown that the use of ICT in human resource management opens new horizons for both employees and their managers (Aliane et al., 2023; Angelova et al., 2023; Vevoda et al., 2023; Mugunzva & Manchidi, 2024).

The effectiveness of HR is based on complex factors such as organisational structure (Váchal & Talíř, 2020), knowledge management (Koh et al., 2022; Mohapatra et al., 2023) and others. The analysis of digital transformation in human resource management is one of the key issues in the corporate environment (Zhao et al., 2024). Digital technologies are changing the way business functions operate, which is also true for the HRM function (Chapano et al., 2022).

The scientific aim can be summarised as follows: specify the importance of HR digitalisation from two points of view: economic short-term impact and perceived meaning for the company. Based on the aim of this study, the following research questions were formulated:
RQ1: How has enterprise digitalisation affected the economic results during the recession?
RQ2: How do enterprises perceive the role of digitalisation in corporate training?

2. Review of literature

The number of studies focusing on digitalisation from an HR management perspective is relatively high. Below are some of the key aspects considered. Galanti et al. (2023) researched the impact of digitalisation on the work environment. The interview method was used for data collection, and data processing was done using mixed methods (Galanti et al., 2023). Angelova et al. (2023) focused on understanding young people's views on using ICT and AI in companies. Data collection was conducted through a questionnaire survey among students. Similarly, Zhou et al. (2021) collected data through a questionnaire survey. Data was processed using hierarchical regression analysis.

Zhao et al. (2024) explored the mechanism of digital transformation in organisations' human resource management (HRM). The research was based on multiple case studies. Chapano et al. (2022) investigated the rate of adoption of digital strategy in HRM. Data collection was done through a questionnaire survey in companies, and data processing was done through exploratory factor analysis (EFA), descriptive, paired-sample tests, Pearson correlations and regression analysis.

Fellman et al. (2020) studied working memory (WM) training to determine whether WM generates task-specific strategies that facilitate performance on the trained task and its untrained variants. Data collection and processing were a large-scale, pre-registered, randomised controlled trial using a 4-week adaptive WM training with a single-digit back task (Fellman et al., 2020).

Kortmann et al. (2023) investigated the link between participation in training and the extent of digitalisation in employees' occupations in the second half of their working lives. Data from the German Ageing Survey was used for the research. Data processing was carried out using logistic regressions. The research findings indicate, among other things, positive associations between changes in the level of occupational digitalisation and (the desire for) participation in training (Kortmann et al., 2023).

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The question of the potential of online training, the reasons for it and the reactions of trainees are addressed in a study (Batita et al., 2023). Data collection was conducted using online training in user interface and user experience (UIX) and social media marketing, which more than 400 Indonesian participants attended. The study revealed that the learners responded positively to the training procedures and learning approaches. The authors concluded that skill-based online training can improve industry-required skills (Batita et al., 2023).

The organisation's knowledge acquisition and sharing issue is addressed by Mehner et al. (2024). Data was collected through a questionnaire survey among the employees and qualitative interviews with the trainees. Data processing was done through Cronbach's alpha method. The study's results suggest that training transfer and knowledge sharing significantly affect individual organisational outcomes. The qualitative research results reported that participants gain new contacts within their organisation. That knowledge transfer allows for the change in the number of contacts in the network (Mehner et al., 2024).

The above studies look at HR digitalisation in terms of the perceived benefits of digitalisation by HR employees, the performance of trainee programmes, etc. However, there is a gap in a comprehensive assessment of the perceived importance and real impact of HR digitalisation with international overlap.

3. Research objective and methodology

The article discusses the importance and impact of digitalisation from an HR management perspective. To achieve the objective, two surveys were conducted as a questionnaire survey. The first research was carried out in the years 2020-2021 in the Czech Republic and focused on the perceived level of digitalisation of the company, its longer aspects (internal communication management, communication between organisational units within the company, data and document sharing, use of internal data, education and training) and the impact on the change in economic performance in the recession period.

The second research focused on the role of digitalisation in HR training and was conducted in Bulgaria in 2023-2024. The role of digitalisation will be investigated from two perspectives: training in the IT fields (IT, digital marketing) and the perceived meaning of training as a tool for the realisation of the strategy and/or a tool for the development of the knowledge potential of the company. Another perspective is the change in the share of online training and its relation to the perceived shift in efficiency. The following table presents the hypotheses tested to answer the research questions.

Table 1. A framework of research questions and hypotheses

Impact of digitalisation on economic results, Czech Republic survey, "digitalisation and economic results"	**Digitalisation training impact, Bulgarian survey, "digitalisation and training"**
RQ1: How has enterprise digitalisation affected the economic results during the recession?	*RQ2: How do enterprises perceive the importance of digitalisation in corporate training?*
H1.1. There exists a correlation between the change of perception, the level of digitalisation, and economic results	H2.1. There exists a correlation between digitalisation training (IT and digital marketing) and the perception of training as part of the company's improvement strategy
H1.2. There exists a correlation between the direction of digitalisation (H1.2.1-internal communication management, H1.2.2-communication between organisational units within the company, H1.2.3-data and document sharing, use of internal data, H1.2.4-education and training) and the change in the economic result.	H2.2. There exists a correlation between digitalisation training (IT and digital marketing) and the perception of training as part of the strategy to increase knowledge in the company
H1.2.5. There exists a correlation between at least one of the previous measures and a change in economic result	H2.3. There exists a correlation between the share of online training and the perceived effectiveness of training

Source: own processing

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The minimum number of responses in every questionnaire survey is set at 200. The questions in the questionnaire in the first survey, "digitalisation and economic results", are defined as follows. Relevant questions of the survey focused on the economic impact of HR digitalisation include descriptive questions: business size, business sector:

- Change in sales: How do you rate the change in sales between 2020 and 2021? Response options: sales growth, no change (stagnation), slight to moderate decrease in sales (0.01-30 per cent), significant to a very substantial reduction in sales (more than 30 per cent).
- How do you rate the state of digitalisation of HR processes in 2020 and 2021? Answer options are basic, medium, advanced, and excellent.
- HR digitalisation measures: Have you implemented any of the following measures in HR? (Internal communication management, Communication between organisational units within the company, Data and document sharing, use of internal data, Education and training). Response options: yes, no.

The questions in the questionnaire in the second survey "digitalisation and training", are defined as follows:

1. Descriptive questions: business size, business sector,
2. Topics of training in the enterprise during the last two years (Company-specific training, Quality management, Customer Service, Teamwork training, Marketing and sales, Communication training, Motivational training, Project management, Information Technology, Language training, Strategic and business planning, Management, Financial management, Accounting, Business Economics, Human resource management, Digital marketing, Other (please specify)),
3. Continuing training and education from the company's point of view is:
    - Part of the company's overall improvement strategy,
    - Part of the strategy to increase knowledge in the company,
    - Beneficial to all staff,
    - Based on an analysis of employee training needs,
    - Part of the company's long-term development plan,
    - Regulatory requirement,
    - Loss of money.

Each statement could be rated on a scale from 1 (strongly disagree) to 5 (strongly agree).

4. Costs for training during COVID-19: grew, didn't change, decreased, didn't apply.
5. Training effectiveness during COVID-19: grew, didn't change, decreased, didn't apply.
6. Share of online training during COVID-19: grew, didn't change, decreased, didn't apply.

A one-factor ANOVA model will be used within the Recommander software tool to test each hypothesis. The significance level will be set at 5 per cent.

3 Research outcomes

3.1. Description of respondents

251 Czech enterprises participated in the questionnaire survey under dimension 2 (Economic impact of HR digitalisation) in 2020-2021. After cleaning, the sample consisted of 233 enterprises. A total of 280 Bulgarian enterprises participated in the questionnaire survey that was conducted in the year 2024. Table 2 presents the distribution of respondents from the Czech Republic and Bulgaria by business sector.

Table 2. The sector of entrepreneurship

	Core sample, Bulgaria	**Core sample, Czech Republic**
Number of respondents	*280*	*251*
A_Agriculture, forestry and fisheries	2,50%	2,39%
B Extractive industries	2,14%	0,00%
C Manufacturing	30,36%	15,54%
E_Water supply; sewerage services, waste management and remediation	1,79%	3,98%
F_Construction	6,79%	10,36%

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G_Trade; car and motorcycle repair	33,93%	8,37%
H_Transport, Warehousing and Posts	3,57%	5,98%
I_Hotel and restaurant industry	5,71%	15,54%
J_Creation and dissemination of information and creative products; telecommunications	2,14%	3,19%
L_Other services (Real estate operations, Professional activities and research, Education, Culture, sports and entertainment)	5,00%	24,70%
M_Human health care and social work	0,71%	3,19%
N_Other activities	3,21%	6,77%
Total	100,00%	100,00%

Source: own processing

Table 3 presents the composition of respondents by size (number of employees).

Table 3. Composition of respondents by size of enterprise

	Core sample, Bulgaria	**Core sample, Czech Republic**
Number of respondents	*280*	*251*
Micro companies (0-9 employees)	30,71%	43,43%
Small businesses (10-49 employees)	30,36%	19,92%
Medium and large companies (50+ employees)	38,93%	36,65%
Total	100,0%	100,00%

Source: own processing

Given the similarity in the composition of the respondents (both in terms of size of business and type of business activity), research results can build on each other.

3.2. Description of survey results

3.2.1. Digitalisation and economic results

Aspects of digitalisation and the development of the economic situation of enterprises in the Czech Republic are presented in Figures 1-3.

Figure 1 shows the responses to the question about the change in the economic situation of the enterprise during the pandemic.

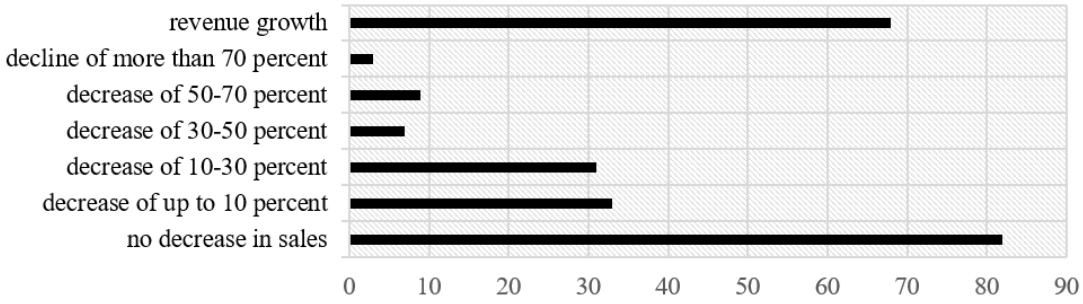


Figure 1. The change of economic results during the COVID-19 pandemic, Czech Republic

Source: own processing

It can be noted that almost a third of the respondents did not experience a change in profitability during the COVID-19 pandemic. A quarter of the respondents even admitted that profits increased during the pandemic. Figure 2 shows the response distribution in the task of digitalisation directions during COVID-19.

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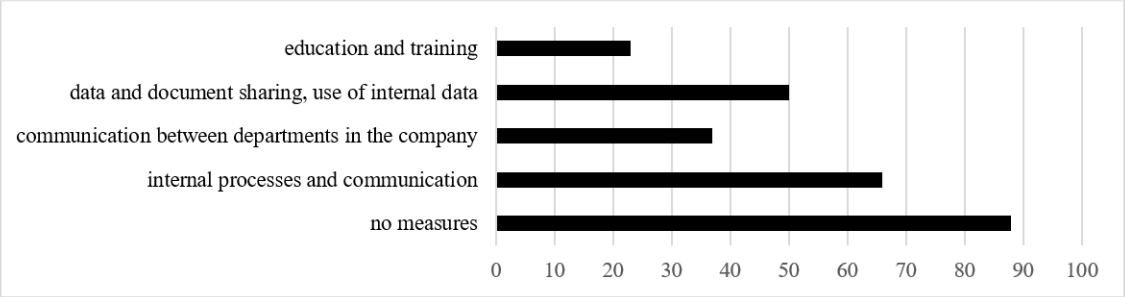


Figure 2. Digitalisation directions during COVID-19 pandemic, Czech Republic
Source: own processing

Respondents mentioned internal processes and communication as the most common direction of digitalisation. The second most common answer was data and document sharing using internal data. Nearly 90 respondents indicated that digitisation did not strengthen during the pandemic. According to the initial results of the evaluation of the questionnaire survey, digitalisation was a pressing issue for businesses during the pandemic. Figure 3 shows responses to questions about the perceived level of the company's digitalisation in the years 2020 and 2021.

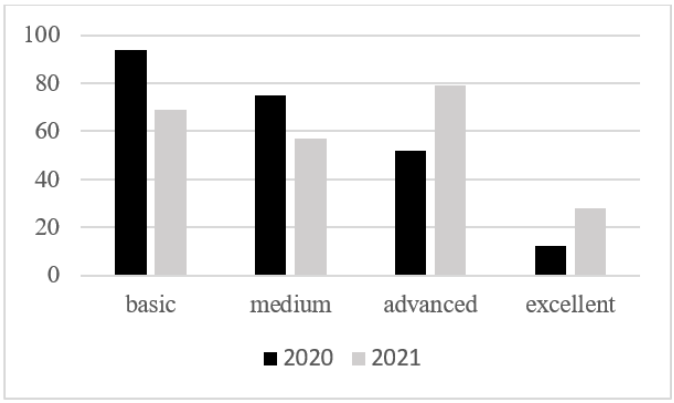


Figure 3. The perceived level of the company's digitalisation, Czech Republic
Source: own processing

From Figure 3, it can be concluded that during the pandemic, businesses developed measures that led to an increase in the perceived level of digitalisation. If, at the beginning of 2020 (before the pandemic), most respondents perceived the level of digitalisation in the enterprise as basic, by the end of 2021 (during the pandemic), most respondents rated their level of digitalisation as advanced.

3.2.2. Digitalisation and training

Figures 4-6 show the results of the survey in Bulgaria. Figure 4 presents responses to questions about training topics in the last two years.

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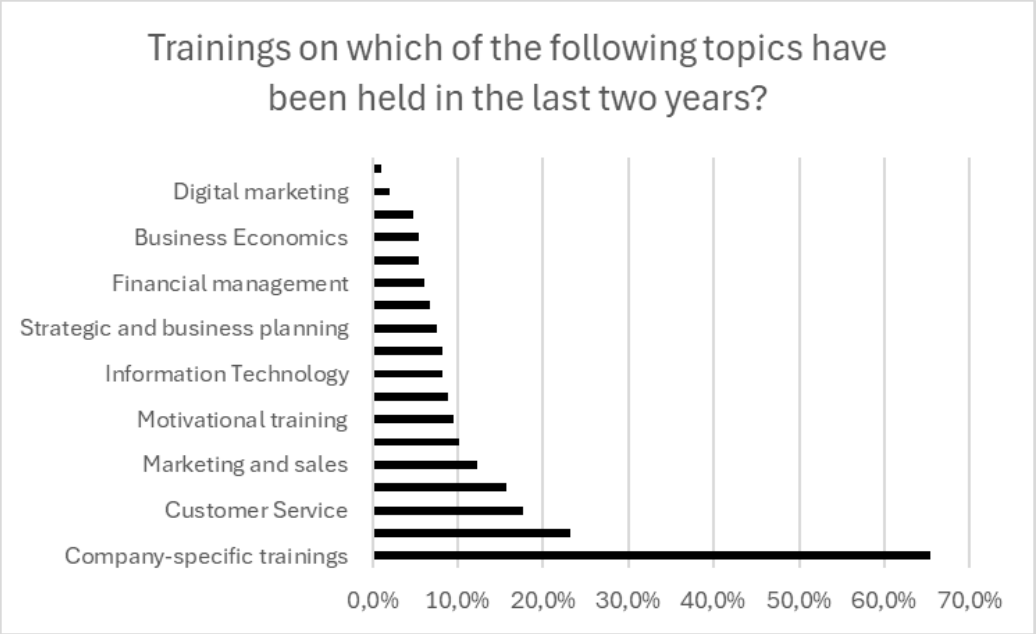


Figure 4. Topics of training in the enterprise during the last two years, Bulgaria
Source: own processing

The majority of the training focused on areas specific to the company. The next most common training topic was customer service. IT training was delivered in less than 10 per cent of enterprises. Less than 5 per cent of respondents focused on digital marketing as part of their training. Figure 5 shows responses about the perceived meaning of training for the enterprise.

Most respondents strongly agree that training is a part of the company's overall improvement strategy. However, a significant number of respondents (more than 20 per cent) indicated that they do not see training as part of their corporate strategy. Almost 60 per cent of respondents agreed that training is part of the strategy to increase the company's knowledge. More than 50 per cent of respondents perceived training as part of a long-term plan for enterprise development.

Only 15 per cent of respondents do not think training benefits all employees. Conversely, I strongly agree with the benefits of training for all employees, more than 30 per cent of respondents. Training is not perceived as a regulatory requirement by more than 20 per cent of respondents. The company's training is based on employee needs, according to 50 per cent of respondents.

Even more surprising is the distribution of responses on whether training is a loss of money. Less than 40 per cent strongly disagree, but almost 20 per cent think that, indeed, in the case of training, it is a loss of money.

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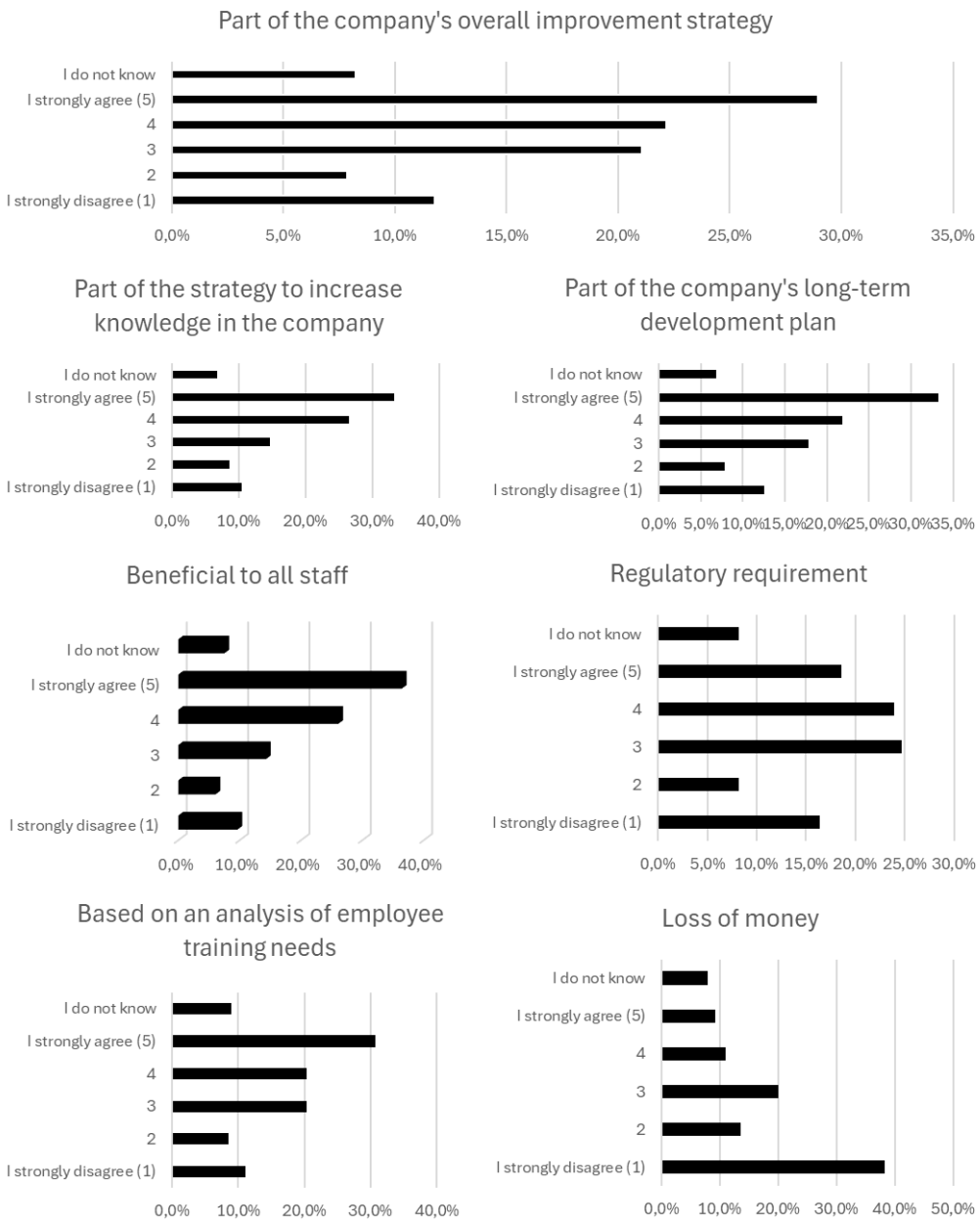


Figure 5. Continuing training and education are, from the company's point of view, Bulgaria
Source: own processing

Figure 6 presents responses to questions about the impact of the COVID-19 pandemic on costs, the effectiveness of enterprise training, and the sharing of online training from all training conducted during the COVID-19 pandemic. Over 35 per cent of respondents reported that the cost of training remained unchanged during the pandemic. Nearly 20 per cent of respondents reported a rise in costs. When asked about changes in training effectiveness during a pandemic, more than 40 per cent of respondents perceived no difference. The proportion of online training increased for nearly 10 per cent of respondents, with no change for more than 35 per cent.

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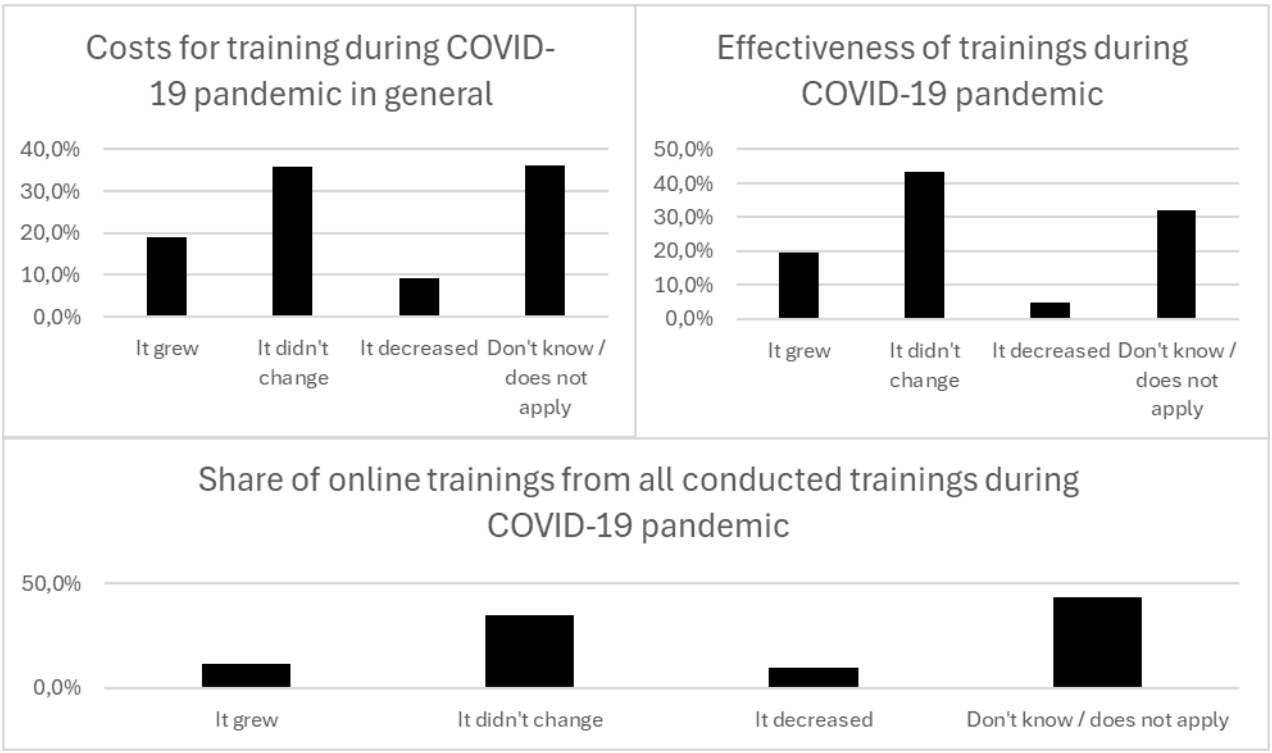


Figure 6. Impact of the COVID-19 pandemic on costs and effectiveness of enterprise training in Bulgaria
Source: own processing

3.3. Hypothesis testing results

3.3.1. Digitalisation and economic result

The first part of the survey (from the Czech Republic) is focused on the economic impact of HR digitalisation aspects. In Table 4, hypothesis H1.1 is shown. Testing shows the correlation between the change of perception, digitalisation level, and economic result.

Table 4. H1.1. testing results

Test H1.1, one-criterion ANOVA test					
	Correlation between the change in perception of the level of digitalisation and economic results				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
H1. Digitalisation HR improvement					
Changing of economic results	7	9.57	1.3665	1.57	0.145
Residuals	227	197.61	0.8705		

Source: own processing

Based on the results of the testing, it can be concluded that hypothesis H1.1 was not confirmed; there is no direct correlation between the development of HR digitalisation and the development of sales. Table 5 presents the results of testing H.2.

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Table 5. H1.2 testing results

Test H1.2, one-criterion ANOVA test					
	Change of economic result				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
H 1.2.1 Internal communication management					
Changing of economic results	1	1.48	1.4807	1.697	0.194
Residuals	231	201.56	0.8725		
H 1.2.2. Communication between organisational units within the company					
Changing of economic results	1	1.4	1.3999	1.604	0.207
Residuals	231	201.6	0.8729		
H 1.2.3. Data and document sharing, use of internal data					
Changing of economic results	1	3.49	3.488	4.038	0.0457*
Residuals	231	199.55	0.864		
H 1.2.4. Education and training					
Changing of economic results	1	0.01	0.0061	0.007	0.934
Residuals	231	203.03	0.8789		
H 1.2.5. Total (at least one from previous measures)					
Changing of economic results	1	2.08	2.078	2.388	0.124
Residuals	231	200.96	0.870		

Source: own processing

Based on the results of the testing, it can be concluded that only hypothesis H1.2.3. was confirmed. Data and document sharing and the use of internal data correlate with the changes in the economic results. The digitalisation of training has not primarily led to an improved financial situation. Thus, internal data is associated with improving economic results from the above-mentioned areas of digitalisation, data, and document sharing. In a temporal context, document disclosure is a tool for achieving flexibility and resilience during the recession.

3.3.2. Digitalisation and training

The second part of the survey (from Bulgaria) is focused on digitalisation training.
Table 6 shows the results of testing H2.1.: *there exists a correlation between IT training and the perception of training as part of the company's improvement strategy*

Table 6. H2.1. testing results

Test H2.1., one-criterion ANOVA test					
	Correlation between digitalisation training (IT and digital marketing) and perception of training as part of the company's improvement strategy				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Training as a part of the company's improvement strategy					
Training in IT and digital marketing	5	0.719	0.14372	2.544	0.0285*
Residuals	274	15.478	0.05649		

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Source: own processing

H2.1. is confirmed. There exists a slight correlation between the realisation of IT training and the perception of training as a part of an improvement strategy. Thus, it can be summarised that currently, companies that see the potential of training to fulfil the strategy are implementing IT training for their employees. Table 7 shows the results of testing H2.2: the correlation between IT training and perception of training as a part of the strategy to increase knowledge in the company.

Table 7. H2.2. testing results

Test H2.2, one-criterion ANOVA test					
	Correlation between digitalisation training (IT and digital marketing) and perception of training as part of the strategy to increase knowledge in the company				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Training as a part of the strategy to increase knowledge in the company					
Training in IT and digital marketing	5	0.547	0.10935	1.915	0.092
Residuals	274	15.650	0.05712		

Source: own processing

H2.2. is not confirmed. There is no correlation between digitalisation training (IT and digital marketing) and the perception of training as part of the strategy to increase knowledge in the company. IT training is not considered a tool for expanding knowledge in the company.

For testing H2.3, respondents who answered "Don't know/does not apply" were excluded from the following questions: share of online training and perceived training effectiveness. Table 8 shows the testing results of H2.3: There is a correlation between the share of online training and the perceived training effectiveness.

Table 8. H2.3. testing results

Test H2.3, one-criterion ANOVA test					
	Correlation between the share of online training and the effectiveness of training				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Effectiveness of training					
Online training during COVID-19	2	9.29	4.646	14.18	0.00000223***
Residuals	154	50.48	0.328		

Source: own processing

It can be stated that H2.3. is confirmed. There exists a correlation between the share of online training and the perceived effectiveness of training. Test results indicate that the use of online training is directly related to the perceived effectiveness of training. Thus, digitalisation in the form of online training increases the effectiveness of training in the eyes of entrepreneurs. Table 9 shows the results of testing H2.4: There exists a correlation between the share of online training and the effectiveness of training.

4. Discussion

The study poses two research questions.
RQ1: How has enterprise digitalisation affected the economic outcome during the recession?
The answer to RQ1 can be summarised as follows t

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- There was a slight correlation between the improvement in the level of digitalisation in the enterprise and the change in the economic result. In the short term, during a recession, the digitisation of business processes does not bring an immediate effect in the form of an improvement in the economic result.
- Looking in detail at the individual measures in the area of digitalisation of business processes, it can be concluded that only Data and document sharing and use of internal data correlate with changes in the economic results. In times of recession and in the short term, internal data sharing can support the positive development of the economy. Yet, the digitalisation of the training process has no direct correlation with positive economic growth.

The findings of other studies are similar to our results. Silverio-Fernández et al. (2021) describe, among others, the positive impact of digitalisation on the efficiency of enterprises in the construction industry. Szalavetz (2022) states that one of the main objectives of digitalising business processes is to achieve competitiveness through technological diversification. (Donaldson, 2022) states that digitalisation in agriculture contributes to increasing the competitiveness of enterprises. According to Chapano et al. (2022), HRM digitalisation supports achieving business goals.

RQ2: How do enterprises perceive the role of digitalisation in corporate training?

The answer to this RQ2 can be summarised in the following points:

- Implementing training focused on digitalisation (IT and digital marketing) is linked to the perception of training as a tool to fill the corporate strategy. Thus, enterprises that perceive training as a tool for strategy fulfilment tend to implement training in IT and digital marketing. On the other hand, digitalisation training (IT and digital marketing) is not associated with the perception of training as a tool to increase the knowledge potential of the enterprise. Thus, in the eyes of entrepreneurs, IT training is a necessary tool for properly functioning business processes, not for achieving the greater knowledge potential of the enterprise.
- The strengthening of online training is linked to the evolution of perceived efficiency and the rising training costs in the pandemic era. Thus, on the one hand, the digitisation of training does not have a short-term positive effect on the bottom line; it is associated with perceived cost growth, but on the other hand, the digitisation of training is a symptom of the streamlining of training in the eyes of entrepreneurs.

Chapano et al. (2022) conclude that the contribution of digital strategies to achieving corporate goals is high. The results of their research follow the claim that digital technology in HRM is used as a performance management tool (Zhao et al., 2024). Zhou et al. (2021) state that firm performance depends on HRM digitalisation, system maturity and HR strategic engagement. HRM digitalisation and system maturity can interact in predicting firm performance, and the effect of their interaction will be influenced by the level of HR strategic and business engagement (Zhou et al., 2021).

5. Conclusions

The scientific aim can be summarised as follows: to specify the importance of HR digitalisation from two points of view - economic short-term impact and perceived meaning for the enterprise.
This objective was fulfilled with the help of primary quantitative research in the Czech Republic and Bulgaria. The following contexts were confirmed:

1) there is a positive relationship between data and document sharing, internal data use and changing economic results;
2) there is a positive relationship between the realisation of IT training and training in digital marketing and perception of training as a part of improvement strategy;
3) there is a positive relationship between the share of online training and the perceived effectiveness of training.

Recommendation for the target segment to monitor the real impact in the long term. The introduction of digitalisation makes information flows more flexible, which was confirmed during the pandemic. Despite the

increased cost of implementing HRM training, performance and efficiency can be expected to increase. The following recommendation is to adapt the elements of digitalisation implementation to the needs of the enterprise. IT training is a necessary step for digitalising core and support processes in an enterprise. The research results have *some limitations*. First of all, it is a specific research period. Thus, the findings may not be valid outside of pandemic and recessionary periods. Another limitation is geographical. Despite the similarity in the composition of respondents in both surveys, it does not mean that the findings will be valid for other territories. The last limitation is object-based. The study discusses only selected aspects of HR digitalisation. Thus, it cannot be excluded that different aspects of HRM digitalisation will have the same or similar correlation with perceived cost, efficiency, and changes in economic performance.

The results of the study suggest some directions for *future research*. To achieve research validity internationally, conducting research with the same focus in more countries would be advisable. Future research could focus on the qualitative parameters of digitalisation in enterprises. Another research direction is developing a model to assess the effectiveness of using the digitalisation element from an HRM perspective and the impact of HRM digitalisation on value chain performance.

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SUSTAINABLE CONTAINER TERMINAL OPERATIONS: THE CASE OF THE PORT OF LITHUANIA

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Abstract. This paper analyses the activities of a marine container terminal to assess the integration of sustainability principles in container storage, handling and service processes. This study aims to identify measures that would facilitate more sustainable operations in container terminals, to minimise their adverse impact on the environment. The empirical data were obtained through semi-structured interviews, document analysis and internal company operational documents. The results of the study showed that sustainable operations at the terminal include pollution abatement measures, infrastructure improvements, efficient use of storage areas, and the management of hazardous and temperature-sensitive cargoes per environmental standards. The main operational challenges were found to be related to the lack of storage space, ageing machinery and limited staff training to work with upgraded systems. The paper makes recommendations to improve the sustainability and competitiveness of the terminal's operations by applying innovative technologies and enhancing staff skills.

Keywords: sustainability; seaport; terminal; terminal operations

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JEL Classifications: Q56, L90, O19

1. Introduction

Container terminals play a vital role in the global trade system, and their operational efficiency and sustainability are emerging as key challenges in implementing the green port concept. According to Svetikaitė (2021), a container terminal is an infrastructural complex designed to load and distribute maritime containers. To ensure sustainable and responsible logistics operations, all terminal processes - from loading to storage - must focus not only on efficiency but also on minimising negative environmental impacts (Moros-Daza et al., 2024; Santos, 2025; Lu & Lu, 2025).

Roy, De Koster, and Bekker (2020) emphasise that analysing terminal operations not only enhances operational efficiency but also facilitates the integration of sustainability measures. Continuous modernisation, adopting digital solutions, and implementing smart control systems are becoming essential to reduce energy consumption and emissions, thereby contributing to green logistics goals (Budiyanto & Shinoda, 2020; Saleh et al., 2024).

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Loading processes remain among the most critical activities at container terminals (Wang et al., 2019). Their organisation must prioritise efficiency and safety, aligning with broader environmental objectives. Kuo and Lin (2020) point out that, to reduce the risk of accidents and container damage, it is necessary to implement advanced safety systems and ensure a transparent process for weighing and reloading operations.

Budiyanto (2020) noted that high-quality terminal operations are unattainable without consistent evaluation and updating of existing equipment and infrastructure. Batarlienė (2020) highlights that container wear monitoring and the development of technical maintenance systems play a crucial role in ensuring operational reliability and sustainability, both within and beyond the terminal premises.

To successfully implement the principles of a green port, container terminal operations must be guided by logistical efficiency and environmental stewardship, safety standards, and social responsibility.

This study aims to identify measures that would facilitate more sustainable operations in container terminals, to minimise their adverse impact on the environment.

2. Theoretical background

Modern container terminals play a strategic role in global supply chains, with their operational efficiency directly linked to the achievement of sustainability goals (Hu et al., 2025; Wang, Jin & Luo, 2025; Duan, Xiong & Li, 2025).

Given the increasing volume of freight and the environmental impact of logistics, growing attention is being paid to how terminal storage and related processes can contribute to reducing emissions, conserving energy, and optimising resource use (Gao, Chang, & Chen, 2022; Yang et al., 2023; Mahmud, Chowdhury & Shaheen, 2024)

According to Martin, Martin, and Lai (2019), container storage at terminals requires specialised infrastructure and solutions that enable efficient flow management while ensuring the sustainable use of resources. Sustainable storage practices begin with assessing the technical condition of containers and implementing continuous monitoring (Hu et al., 2021; Jakovlev et al., 2025).

Further distribution should be based on spatial optimisation and reduced energy consumption (Abu, Ouhimmou, & Paquet, 2020), and efficiency of operation (Hsu et al., 2024; Li et al., 2024).

Cargo with special requirements, such as excise goods or temperature-sensitive items, demands heightened attention to environmental protection and safety (Roy et al., 2020; Kusrini & Parmasari, 2020). These goods must be maintained at stable temperatures, undergo regular technical maintenance, and be subject to effective risk management to prevent spoilage and food waste (He & Tan, 2018; Wang et al., 2019).

In the context of international logistics, maintaining container hygiene is also critical. Vicrihadi, Sembiring, and Ayutia (2021) highlight the geometric versatility of containers as a factor necessitating strict hygiene control. As noted by Walker et al. (2021), containers are cleaned and disinfected to eliminate hazardous residues, while Rasulov, Masharipov, and Ismatullaev (2021) emphasise that the intensity of cleaning depends on the container type, the nature of the cargo, and the geographic region in which the container is used.

Accurate container weighing is another essential component of sustainability. Youssef and Aly (2020) argue that incorrect weight determination can result in equipment damage and financial losses. Belova and Krochina (2019) assert that precise weighing is vital for compliance with safety and legal standards. Data logging and digitisation (Luo & Wu, 2020) support operational transparency and efficiency, while, as highlighted by Huang et al. (2019), they also help avoid errors and improve service quality.

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Digital solutions - such as internal accounting systems and load monitoring technologies - are equally important in promoting sustainability.

Li et al. (2022) emphasise that these systems facilitate more accurate operational forecasting, reduce error probability, and contribute to CO_2 emissions reductions. Moreover, adherence to safety protocols (El Mahi, 2021), routine technical maintenance (Svetikaitė & Plačienė, 2021), and precise container identification (Ilesaliev, Makhmatkulov, & Abduvakhitov, 2020; Ilesaliev et al., 2019) are all critical components of sustainable terminal operations.

Implementing modern technologies and infrastructure upgrades enhances the ability to detect defects efficiently, save time, and prevent the unnecessary use of resources. As Puzinavičius and Vaitiekus (2021) observe, rapid fault detection ensures the continuity of terminal operations. Zhao et al. (2020) further emphasise that regular technical inspections reduce downtime and promote modernisation and resource conservation.

In summary, container terminal operations, particularly in seaports, are intrinsically tied to sustainability principles. The integration of maintenance, weighing, hygiene procedures, and efficient loading processes not only optimises performance but also significantly contributes to environmental objectives by reducing emissions, conserving energy and resources, and enhancing the long-term resilience of the logistics system.

The growing flow of containers is increasing cargo volumes and, along with it, environmental pollution, noise, and energy consumption. Such activities inevitably have a negative impact on the environment, so every terminal should look for ways to reduce this impact.

3. Research objective and methodology

A Lithuanian seaport terminal specialising in maritime container services was selected for the study. This terminal is distinguished by its wide range of services, which include cargo storage, weighing, container loading and transhipment (including CFS - Container Freight Station operations), handling of all types of containers, and their repair and cleaning. The terminal also manages the loading of various types of railway wagons and provides technical maintenance for reefer containers.

A mixed qualitative research strategy was employed, incorporating the analysis of scientific literature, content analysis of documents, and semi-structured interviews. A semi-structured interview method was chosen because it allows for the integration of pre-formulated questions and their flexible adaptation to the participants' responses. The interview questions were formulated logically and coherently, maintaining clarity and specificity, and were designed to support an in-depth analysis of container terminal operations.

Informants were selected using a criterion-based sampling method, which facilitated the identification of experts who met the research criteria and possessed relevant experience. Selection was based on participants' positions at the terminal, professional experience, and specialised knowledge, which enabled them to provide diverse and in-depth perspectives on the research subject. A key selection criterion was the participants' openness-their ability to reflect on organisational strengths and challenges and problem areas encountered in practice. This approach ensured both the depth and analytical value of the data collected.

The qualitative data gathered through interviews were processed using a verbatim transcription method. To ensure the anonymity of the participants, all personal information was anonymised, and the informants were coded (e.g., I1, I2, I3). Transcripts included participants' professional profiles, interview location, date, duration, and complete responses to the research questions.

The textual data were analysed thematically by creating structured categories, sub-categories, and tables of supporting statements. This analytical approach made it possible to identify the most significant research themes, examine their interrelationships, and ground the conclusions in empirical evidence.

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Additionally, primary documents were used as one of the main sources of information to explore container terminal operations in greater detail. The content analysis focused on a defined area of the research topic and utilised both paper-based and digital documents. According to Tidiki (2003), the use of such sources ensured the reliability, validity, and relevance of the data. Following Kudinovienė (2008), a classical content analysis method was applied, enabling the collected information to be systematised and the research findings to be logically structured and illustrated using tables and other visual tools. This approach enhanced both the informativeness of the results and the scientific rigour of the study.

4. Results and discussion

The Container Terminal pays significant attention to storage activities, recognising their importance for operational efficiency and achieving sustainability objectives. Container terminal storage is part of the logistics chain and a key activity with high requirements for responsibility and diligence. Depending on the type of containers, they are placed in specially adapted areas in accordance with the company's internal storage rules: full containers are stacked up to five floors, and empty containers are stacked up to six floors. This system not only helps to rationalise the use of space, but also contributes to optimising energy consumption and working time, reducing the intensity of the movement of technical equipment and thus indirectly contributing to the reduction of CO_2 emissions.

The terminal's storage model, based on the AUTOSTORE programme's container layout scheme, ensures that each type of container is stored according to its specific requirements, guaranteeing individual supervision and control. This approach is in line with the principles of sustainable development, aiming to maximise the use of available resources, minimise the logistical impact on the environment and ensure a safe and efficient operating environment.

To analyse the measures taken to improve storage efficiency and their impact on sustainability, the study used a semi-structured interview method, the data collected from which is presented in Table 1.

Table 1. Warehousing activities

Category	Sub-category	Supporting statements
Optimal use of storage areas	Planning	**I1**,"<...> Containers are stored in the terminal at the highest possible capacity to accommodate incoming ships <...>, planned use of the area". **I2**, "<..> Arriving ships are further planned to fill the terminal area accordingly <..>".
	Responsible persons	**I1**, "The persons responsible for the optimal use of <...> shall be the Chief Executive Officer. KDO, Head of Planning and Site Planner". **I2**, "The Head of Planning, the Site Planners and the Chief Planning Officer shall be responsible for the management of the site. KDO are responsible for <..>". **I3**, "<..> the site planners, the head of the unit and other staff are responsible".
Operational efficiency Improving efficiency	Optimal use of storage areas	**I2**, "This storage method allows for optimal use of storage areas". **I3**, "<...> Placing one container on top of another <...> helps to make more efficient use of available storage space".
	Measures to increase productivity	**I1**, "The efficiency of storage operations is ensured by planning the placement of containers/cargo in storage areas". **I3**, "Operational efficiency is improved by the proper adaptation of the terminal area for container storage".

The results of the study showed that container storage planning is an essential process to ensure the smooth running of operations and to solve problems related to limited storage capacity. Informants highlighted that optimal use of areas would not be possible without coordination between responsible staff and effective information dissemination.

Storage activities at a container terminal start when the sea containers arrive at the terminal by different modes of transport. The largest volume of containers arrives by ship and is unloaded using STS cranes. Containers are then transported to the storage yards, where they are assigned to storage areas by RTG or RS forklifts and the

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AUTOSTORE software, according to the following criteria: completeness, size, nature of contents (excise, hazardous, refrigerated) and export direction.

Efficient warehousing contributes to logistics sustainability by reducing the intensity of machinery movements, fuel consumption and emissions. "The AUTOSTORE system ensures transparent container accounting, allowing rational distribution of cargo and reducing the need for excess movements. In addition, dispatchers and planners play an important role in ensuring that information flows quickly. The centralised accounting system allows the movement and storage of containers to be controlled, thus contributing to the organisation of efficient, safe and environmentally friendly operations.

The terminal stores different types of containers, which require different levels of maintenance depending on their technical characteristics, the nature of the cargo and safety requirements. The storage of particular groups of containers - for example, dangerous, temperature-controlled or excise containers - requires tailor-made infrastructural solutions and increased control.

In order to identify the main problems encountered during the warehousing process, the study carried out semi-structured interviews with terminal staff. The results obtained were summarised and presented in Table 2 to highlight the main categories of challenges and their impact on the sustainability and efficiency of operations.

Table 2. Challenges identified

Category	**Sub-category**	**Supporting statements**
Fixed problems	FIFO process malfunction	**I1**, "<...> normal FIFO process is disrupted". **I2**, "<...> adversely affects the FIFO principle used in the terminal". **I3**, "<...> freight flows affect the FIFO process".
	Lack of storage space	**I2**, "Lack of storage space in the terminal is the most important problem". **I3**, "Lack of space in the terminal is a problem which affects the pace of work".
Container control	Inaccuracies occurring	**I1**, "<...> there are many inaccuracies in container control". **I2**, "<...> Makes it difficult to control containers in storage". **I3**, "There are many inaccuracies <...> in the control of containers".
Measures to avoid problems	Adaptation of the site	**I1**, "More space <..> or better use of existing space". **I2**, "Expansion of the terminal area or better use of the existing area <..>". **I3**, "<...> development opportunities or redevelopment of the currently managed area".

The interviews revealed that one of the main challenges for sustainable container storage is the limited amount of storage space. The lack of space hampers smooth operations, slows down work rates and threatens the quality of service. To make more efficient use of resources and to reduce environmental impacts, it is proposed that the storage strategy be reviewed, infrastructure be optimised, and the possibility of expansion or redevelopment of the site be considered.

The terminal has an exclusive service for temperature and excise containers. Refrigerated containers are connected to the electricity supply in accordance with the instructions in the digital documents and are regularly checked to ensure the quality of the cargo and to reduce energy waste. Excise containers are stored in secure areas, in compliance with legal and security requirements, and their condition is checked daily.

As container volumes increase, there is a noticeable increase in the capacity of the handling equipment and a decrease in working speeds, especially when cars are placed in the terminal area. This leads to storage disruptions, and it is therefore proposed that the less active activities be relocated to the peripheral areas and that the road markings be updated for better traffic management.

Sustainable operations are not only ensured by an advanced container management system, but also by the entire service infrastructure, such as repair workshops, scales and cleaning facilities. The terminal uses dust-reducing measures and regularly cleans containers, machinery and grounds. These measures contribute to reducing emissions and maintaining a clean working environment. Repair work is carried out at the terminal, saving customers' time and reducing logistics costs.

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The terminal operates in an integrated and sustainable manner, focusing on efficient use of infrastructure, providing safe and quality services and reducing environmental impact.

All relevant container information is available in the container dashboard of the AUTOSTORE application. During loading, container sealing is carried out in accordance with the specified requirements, taking into account the AUTOSTORE data, the transhipment acts and the customer's requests. Unless the presence of an authorised representative is specified in the notes, containers shall be sealed in accordance with the internal standards of shipping lines such as Hapag-Lloyd, Maersk Line, COSCO Shipping, CMA CGM, etc. The seals differ in numbering and colour identification according to the owner and the type of container. Excise containers are sealed in accordance with customs requirements, on the basis of information from the KIPIS system or in the presence of a customs officer. In order to analyse the organisation of the sealing processes in more detail, interviews were carried out, and the results are presented in Table 3.

Table 3. Container sealing (table of categories, sub-categories, supporting statements)

Category	Sub-category	Supporting statements
Provision of seals	The terminal does not have seals	**I2**, "The terminal does not have its own seals <..>". **I3**, "The terminal does not produce seals and does not have assigned seals".
Shipping lines	Transfer of seals	**I2**, "<...> are delivered by the line representatives to the control room, where they are handed over to the Talmans <..>". **I3**, "Each shipping line shall hand over the seals to the forwarders".
Incorrectly selected seals	Inspection of seals	**I1**, "<..> only an "eye test" is used to check whether a seal is present". **I2**, "<...> carries out a visual inspection of the seals". **I3**, "<...> inspection and control<...> is carried out".
Activities carried out	Responsibilities	**I1,** "The terminal is not currently responsible for any liability <..>". **I3** '<...> arrives already sealed and is therefore not the responsibility of the terminal'>
Problems to be solved	Liability of lines/carriers	**I1**, "It is the responsibility of the lines/carriers". **I2**, "Sealing of export containers is the responsibility of the lines/carriers <..>".

Based on the interview data, it can be said that the sealing of export containers is not the responsibility of the terminal, as these containers arrive at the terminal already loaded and sealed by the consignor or customer. Only containers that are loaded on site, in accordance with the loading documents, customer requests or the provisions of the internal operational strategy 'Restrictions', are sealed at the terminal. The sealing process is based on a precise allocation of resources and division of responsibilities, and the seals themselves are provided to the terminal by the shipping lines' agents or forwarders. As the terminal does not have individual seals, their logistics are optimised by centralising their distribution through a control room, thus reducing excess seal storage and associated waste. Responsible staff - the cargo accountants - ensure that seals are used precisely as intended and that potential errors are minimised through systematic seal checks.

It is important to note that effective management of sealing processes contributes to sustainable operations by optimising time, reducing paperwork and avoiding unnecessary re-work. In this context, moving away from physical (paper) excise documents towards digital documentation is recommended, thereby reducing paper consumption, speeding up data processing and reducing the carbon footprint associated with the physical movement of documents. This step would meet both efficiency and sustainability objectives for the container terminal operations.

The terminal carries out complex cargo handling activities, including loading different types of cargo into different types of vehicles. Based on emission permits and digital applications (AUTOSTORE, KIPIS), the handling processes are organised in such a way as to ensure efficiency and minimum environmental impact. In Q1 2024, the terminal recorded a 16.5% growth in cargo through the use of modern, energy-efficient machinery and automated management systems. For bulk cargo (e.g., sulphur, grain), specialised forklifts and rotainers are used to reduce the risk of dispersion and speed up operations. The MANTSINEN 70 crane, with up to 35% less energy consumption, ensures efficient handling of grain loads. Loading activities are planned using digital systems - ship planners optimise container loading according to the capacity of the STS cranes, with real-time information.

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Loading complies with the requirements of the pollution permits: controlling the height and speed of the embankment, and ensuring that the cargo is loaded with the minimum level of pollution. Warehouses in the terminal area are designed for the storage and handling of bulk cargo, and the load is distributed among transport modes (cars, ships, rail wagons) according to an agreed schedule. The terminal's handling technologies and organisational solutions are geared towards sustainable logistics - minimising environmental impact, optimising the use of resources and ensuring safe and efficient processes. Cargo is delivered to the loading bays according to a pre-defined schedule and arrives at the terminal by different modes of transport. The breakdown of the results of the interviews by mode of transport is shown in Table 4.

Table 4. Transport of containers.

Category	Sub-category	Supporting statements
Container transport	Type of transport	**I1**, "<...> The modes of transport bringing containers to the terminal are container ships, road transport, trucks and rail transport". **I2**, "<...> containers are transported by <...> road transport, namely trucks". **I3**, "Containers are mainly brought to the terminal by trucks, rail and container ships".
Advantages	Well-developed roads	**I1**, "<...> ship routes as well as land routes are the best developed <...>". **I3**, "<..> Extensively developed network of land and water roads <..>".

Based on the interview data, it can be assumed that efficient container logistics at the terminal is closely linked to a favourable geographical location and a well-developed transport infrastructure. Most of the containers arrive at or depart from the terminal by container vessels, which ensures the simultaneous transport of large volumes of cargo, contributing to lower emissions per unit. Road transport remains popular due to its flexibility, mobility and responsiveness to logistics needs, while rail, with its four sidings within the terminal area, provides an environmentally friendly means of transporting bulk cargo. There is a convergence of views among informants on the dominant modes of transport, which provides a reliable assessment of the current situation. To strengthen sustainable logistics and ensure smoother management of handling processes, it is recommended to invest in upgrading the terminal's road infrastructure. Improved road conditions would improve transport safety and reduce the need for maintenance, contributing to a long-term reduction in environmental impact. It is proposed that the smart gates, which currently cause congestion in and out of the terminal, be upgraded. Introducing smart solutions would contribute to more efficient flow management, reduce pollution from parked vehicles and increase the overall sustainability of operations.

The warehousing strategy also reinforces the sustainability principles: to reduce the dwell time of empty containers, handling is carried out on a FIFO basis. This allows for a smooth logistics flow and efficient use of resources. The most common load in containers is used tyres, which are diverted from storage areas to containers, semi-trailers or rail wagons. Once loaded, the containers are then transported by land or sea in accordance with the AUTOSTORE system. To further analyse how the load planning process works at the terminal, the results of the interviews are presented in Table 5.

Table 5. Load planning process

Category	Sub-category	Supporting statements
Load planning process	Planning	**I2**, "<..> The planning process at the terminal is carried out using smart technologies and applications". **I3**, "The load planning process at the terminal is carried out using <..> applications <..>".
	Tracking	**I1**, "<...> where the fast-tracking processes at the terminal can be monitored and controlled". **I2**, "<...> can monitor the handling activities with video cameras<...>".
	Control	**I2**, "The fast pace of work is ensured by monitoring and controlling the loading process <...>".
	Systems used	**I1**, " <...> processes are recorded in various systems (AUTOSTORE, VBS, VISY) where they can be monitored and controlled <...>". **I2**, "VBS system, AUTOSTORE internal program, KIPIS program (VISY)". **I3**, "<..> the digital applications used: AUTOSTORE terminal internal application, VBS timing system, VISY, KIPIS".

The results of the interviews confirm that the freight planning activity is based on the use of smart digital technologies. Digital systems and skilled staff allow for efficient organisation of handling processes, optimisation of the use of resources and reduction of the risk of human error. This technological basis helps to

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ensure the rapid and accurate distribution of cargo to the different modes of transport - sea, road and rail - thus contributing to sustainable logistics management.

The terminal's infrastructure, integrated with smart systems, enables detailed control of the handling process, which is essential for productivity and reducing environmental impact. Automated data management and operational planning reduce unnecessary manoeuvres, save energy and reduce emissions. For even more sustainable operations, it is recommended that the digital skills of staff be continuously improved, internal communication strengthened, and infrastructure upgraded, including traffic management measures in the terminal area. Such actions would enhance the terminal's international competitiveness and contribute to the green logistics objectives.

Conclusions

The study identified practical measures that, if implemented at container terminals, would support more sustainable operations and reduce environmental impact.

The digital systems used at the terminal allow efficient planning, monitoring and control of all handling and storage processes. This reduces the likelihood of errors, optimises the use of resources and saves time and energy, directly contributing to the organisation of sustainable operations.

The efficient arrangement of containers according to type, content and purpose reduces the movement of machinery and fuel consumption, thus indirectly contributing to the reduction of emissions.

Modern handling equipment increases the speed of work while reducing energy consumption by up to 35% and helps to avoid dust dispersion and environmental pollution.

Most containers arrive at the terminal by sea or rail, helping to reduce the carbon footprint compared to road transport alone.

The sealing of export containers is outsourced to the carriers, and only locally loaded containers are sealed at the terminal. This allows for a rational distribution of responsibilities, avoiding excessive use of seals and reducing the circulation of physical documents. Introducing digital solutions in this area would help reduce the use of paper and increase the transparency of processes.

The survey revealed that limited storage space and the state of the road infrastructure are major challenges. Investments in site development, upgrading smart gates and improving signage are proposed. This would help optimise traffic flows, reduce wear and tear on machinery, and reduce the long-term environmental impact.

During the study, limitations in data availability were encountered, as not all aspects of terminal operations were publicly documented or accessible due to commercial confidentiality. As a result, some parts of the analysis relied on secondary sources or aggregated data.

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CIRCULAR ECONOMY AND "POLLUTER PAYS" PRINCIPLE IN BULGARIAN MUNICIPALITIES *

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Abstract. The current method of defining waste fee (as a percentage of the property tax) does not stimulate citizens and economic entities to prevent waste generation and separate recyclable waste at source. Although Bulgaria amended its legislation to address the issue back in 2015, the application of the provisions has been postponed several times in the course of nearly ten years. The way to overcome this challenge is to optimise waste management and introduce municipal waste charges based on actual waste quantities produced by each household or economic entity generating municipal waste. In mid-2023, the European Commission services launched an infringement procedure against Bulgaria for failure to comply with the 'polluter pays' principle. In 2024, appropriate regulatory and guidance documents should be established to ensure full-fledged implementation of the principle. This article analyses the results of a demonstration project performed at a small scale on the territory of the municipality of Gabrovo inspired and supported by one of the authors. At ten waste collection points in the city, state-of-the-art equipment was installed to measure the quantity of waste disposed by individual households (more than 300 households agreed to participate). The data was stored in tailor-made software, providing feedback and motivation through a competition that awarded devoted participants. The obtained data from the two demonstration stages (without and with separate collection at source) were used for comparative analysis and forecasts on possible future implementation of pay-as-you-throw schemes. The rate of active participants (24%) and the potential to reduce residual waste generation in case of active participation (23%) are promising. The conclusion is that, based on the cost coverage principle, the expected average fee will not increase much with the new PAYT model. The most serious challenge appears to be the cross-subsidy between households and economic entities generating municipal waste, the latter being the prevailing source of waste fee revenues. The shift to fair calculation of waste fees requires difficult and unpopular decisions by all Bulgarian municipalities.

Keywords: circular economy; security; resilience; municipality; waste management; pay-as-you throw

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JEL Classifications: M12, M15, J24

1. Introduction

In the last couple of decades, Circular Economy emerged as a reliable alternative economic concept able to cope with the imminent global sustainability issues, created by the current unidirectional economic model, Linear Economy (Sillanpää & Ncibi, 2019; Rezk et al., 2023; Lyu & Liu, 2023; Rezk et al., 2025). Regulatory pressures (taxation solutions such as the polluter-pays principle (Ambec & Ehlers, 2011) started to be enforced nationally and internationally (Luppi, Parisi & Rajagopalan, 2012), what caused discussion how to make taxes as fair (Corvino, 2023; Priya, Varghese & Pivato, 2023; Aldeia, 2023; Mukherjee, 2023; Tao & Wu, 2025).

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The European Union has set ambitious waste management targets for member states. To achieve these targets, it encourages using economic and regulatory instruments such as fees according to the amount of waste generated, extended producer responsibility schemes and incineration and landfill fees.

Waste management in EU member states is carried out in accordance with national and/or regional policies and is most often carried out at the municipal and local level. The degree of reaching the set targets varies widely, and the comparison of data from different Member States and even from different settlements is difficult because of the variety of applied models, including data collection and processing methods. Over the past 20 years, significant progress has been made in developing effective schemes for charging households according to the amount of household waste generated. A number of viable fee models and technical solutions are in place that provide individual incentives to comply with the waste hierarchy.

2. Literature review

Pay-as-you-throw (PAYT) schemes are now widely recognised as an efficient tool for managing and financing waste-related activities. Studies have shown that they achieve significantly better results in terms of prevention and separate collection of waste than the flat fee model. Analyses at the EU level recommend a broad campaign to communicate the results and benefits of PAYT to overcome prejudice and encourage its implementation on a larger scale (Eunomia & COWI, 2019). Pay-as-you-throw schemes are quite widespread in Belgium, the Netherlands, Luxembourg, Germany, France and Italy. There have been positive experiences in Austria, Denmark, Finland, Spain, Portugal, and, recently, Greece. Information and data from PAYT implementation are also available for Slovenia, Poland, Hungary and more (Schweitzer & Card, 2016; Morlok et al., 2017; Rasera & Contarina, 2017; Emmanouil et al., 2022; Slučiaková, 2021; Ukkonen & Sahimaa, 2021; Di Foggia & Beccarello, 2023; Messina et al., 2023; Alves, Silva & Soares, 2020).

In general, pay-as-you-throw schemes should meet the following minimum requirements: quantifying at least residual municipal waste (based on volume or weight); unambiguous identification of the waste generator; association of the delivered amounts of waste with specific users (calculation of cost per unit of generated and disposed waste); tracking and encouraging good faith behavior (setting targets or other methods) (URBAN AGENDA FOR THE EU Programme, 2018).

Proper pricing of waste reflects its reduction and strengthens the circular economy. Many researchers correctly substantiate the connection between the circular economy and national security. And not only from the point of view of reducing environmental risks! In addition to ecology and economic effects, other areas of security and sustainability cannot be ignored, which are also significant. The main considerations are based on the fact that, due to sustainable use of resources, reuse and recycling reduce dependence on imports of raw materials and energy sources, strengthening the country's economic and energy independence.

On the other hand, the circular economy supports social stability and economic sustainability by promoting green innovations and creating jobs, and these are key factors for the internal and external security of a state. Gubanova et al provide an example of a circular economy achieving specific socio-economic benefits. Koval et al. (2023) point out the role of environmental investments in strengthening national economic security by mitigating biodiversity loss and managing ecological risks. Birgovan et al. (2024) present circular economy indicators at the organisational level, revealing a lack of standardised and socially inclusive measurement tools.

The main principle for calculating the amount of state and municipal fees is the principle of cost coverage. This also applies to municipal waste fees, which should cover the costs of providing services related to waste management. All the international documents generally suggest utilising almost identical approaches (Loktionov et al, 2023). When determining the fee amount, the annual revenues are expected to cover the waste management costs estimated in the relevant financial plan. Pay-as-you-throw schemes encourage households and economic entities that produce municipal waste to behave responsibly, i.e., prevent waste generation and separate recyclable fractions at source. Negotiations should not be neglected when implementing green policies to facilitate green business transitions (Sileniece, 2024).

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A number of projects under the European Commission centrally financed programmes analyse case studies, implement pilots/demonstrations and elaborate methodologies and toolkits to launch economic instruments. They recommend a flexible approach to applying the polluter pays principle (baseline, advanced and supreme models to define the fixed and variable components of the fee) that allows comparison of the advantages and drawbacks of different alternatives and at the same time prevents from including in the fee costs that are obviously disproportionate to the amount and nature of waste generated. Last but not least, it is considered that fees should be socially affordable for the low-income population (URBAN AGENDA FOR THE EU Programme, 2018; LIFE Programme; Horizon Programme).

In July 2023, the European Commission announced its decision "to open an infringement procedure by sending a letter of formal notice to Bulgaria (INFR(2023)2064) for failing to apply the polluter-pays principle as laid down in the Waste Framework Directive (Directive 2008/98/EC) (European Commission, 2024).

According to the EC Press Release, in Bulgaria, the costs for waste management that citizens and businesses pay are based on the property's tax value and do not consider relevant parameters such as the quantity of household waste. Although Bulgaria amended its legislation to address the issue, applying the provisions has been postponed yearly since 2015. According to the latest information from the Bulgarian authorities, using the provisions could become effective in the following two years. The Commission is therefore sending a letter of formal notice to Bulgaria, which now has two months to respond and address the shortcomings raised by the Commission. Without a satisfactory response, the Commission may decide to issue a reasoned opinion". (European Commission, 2023).

The Bulgarian National Waste Management Plan 2021-2028 and the municipal waste management programmes state that the current method of defining waste fee (as a percentage of the tax on properties) is a serious obstacle to implementing the "polluter pays" principle. The cited documents acknowledge that the above method does not stimulate citizens and economic entities to prevent waste generation and separate recyclable waste at source. The programmes also identify measures to overcome this challenge by optimising the management model and, more specifically, designing municipal waste fees based on the "polluter pays" principle. In 2024, appropriate regulatory and planning documents are expected to be approved for the full-fledged implementation of this principle (Ministry of Environment, 2021; Municipality of Gabrovo, 2021).

As it is very well described in (Stoilov et al., 2022), the general weakness to overcome concerning our national strategic planning documents is the absence of a methodological basis for the elaboration of such documents. Similarly to the methodology for strategic energy planning, it is advisable to elaborate on one for strategic waste management planning. To this end, plenty of preliminary studies need to be performed, e.g., on appropriate research avenues (Wise & Stoilov, 2021), possible optimisation criteria (Hadzhiyska & Stoilov, 2023), significance and influence of public opinion (Nikolova & Stoilov, 2023), etc.

It is crucial to collect, maintain and protect waste management data, as security is a complex concept that covers many aspects, including environmental protection (Stoykov, 2018; Stoykov & Dimitrova 2018). The implemented ICT infrastructure should have sufficient capacity and cover all relevant processes and players, including the responsible municipal units, tax collection service, companies providing waste collection, recycling and landfill of waste, households and businesses that generate municipal waste.

3. Methodology of the study

3.1. Study area

The study is focused on implementing the "polluter pays" principle in municipal waste management systems in Bulgaria. Based on the results of the demonstration project BG16M1OP002-2.009-0078 "IoT Smart Waste Management" cofinanced by the operational programme Environment 2014-2020, as well as historical and forecast data, it analyses the efficiency of waste management processes and opportunities for full-fledged implementation of economic incentives towards reaching sectoral targets.

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3.2. Data collection and analysis techniques

The demonstration took place over a one-year period. Participants were instructed to use the project waste containers in the first six months to dispose of all municipal waste. In the second half, municipal waste without the recyclable fractions was collected separately at source. All participants were households, and the project did not involve any business entities that generate waste similar to household waste.

Each household was granted personal access to the containers using plastic cards (covering 85% of all household members), which open a big compartment (20 l volume) or a small compartment (volume 5 l). The use of an appropriate compartment is guaranteed by providing households with plastic bags 20 l and 5 l and instructing them to dispose of only full bags. Therefore, it is assumed that each container opening and small/ big compartment use represents the disposal of the relevant waste quantity.

After an initial survey with the assistance of the municipality, 200 households agreed to participate, as planned. To ensure maximum success of the demonstration, additional 127 households have been invited. It is important to note that participation was completely voluntary and it was not possible to control whether each person from the 327 households involved strictly followed the instructions of the project team. In order to motivate the participants, a simulation game/competition was organised, and participants who strictly followed the instructions were awarded prizes.

Participation in the demonstration (including the simulation game/ competition) was monitored through the project-developed information system (software) (Information system developed and administered under the project), reporting and maintaining information and data on each household (owner, address, number of household members) and information on the date, time, and compartment used each time the container is opened through the provided personal access. The system can generate reports by aggregating information on the number of container (compartment) openings for a given time span for one or more households, as well as various ratios related to the age structure of the covered households. Information about the 10 containers covered (identifier, address, lat, lan coordinates, service dates of each container) is also supported.

The data collected as a result of the demonstration project were analysed using mathematical, statistical, and econometric methods, as well as expert assessment and qualitative information analysis.

Multi-criteria analysis (comparing possible options based on a set of criteria relevant to defined objectives) and efficiency analysis (comparing the costs of different actions that attain the same objectives) were used to define possible scenarios for the design of household waste fee based on the amount of waste generated by individual households, and propose the most effective calculation model.

4. Summarised survey results and comments

4.1. Analysis of the data obtained from the information system (SWAM IT system, 2023)

Household participation

The system shows that a total of 327 registered households participated in the demonstration, including 614 household members, to whom 548 access cards were distributed. It is interesting to analyse household activity by tracking the average number of openings of project containers per household (Figure 1).

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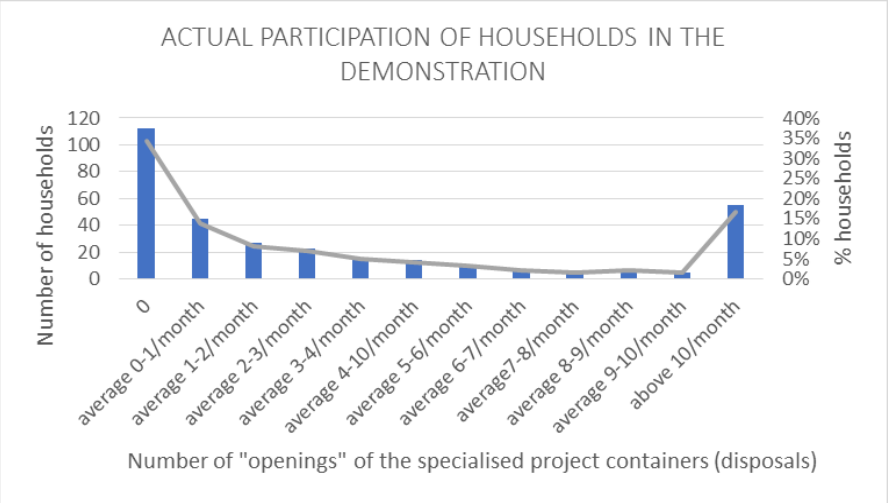


Figure 1. Actual participation of households in the demonstration

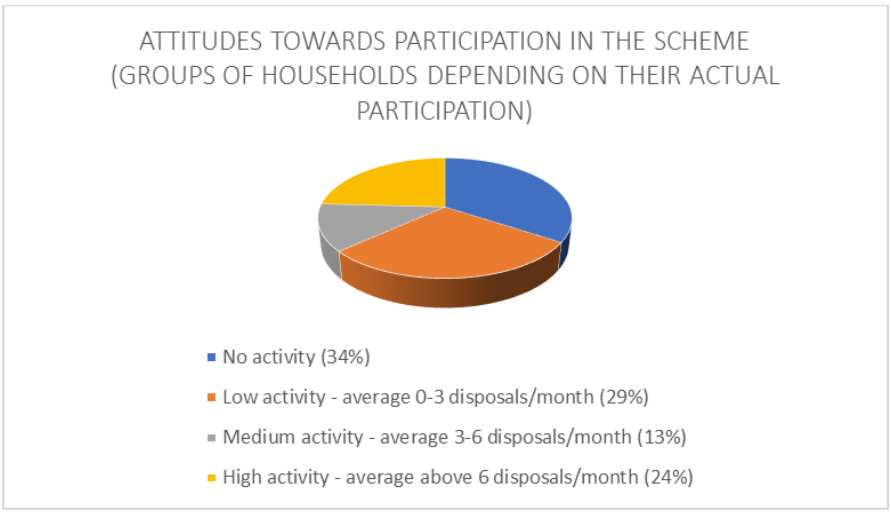


Figure 2. Attitudes towards participation in the scheme (groups of households depending on their actual participation)

As can be seen from Figure 2, 112 households (34% of those registered) have not used the access cards to the containers even once, 95 households (29% of those registered) used the containers on average up to three times per month, 41 households (13%) - on average between 3 and 6 times per month and 79 households (24%) - on average more than 6 times per month. This analysis is interesting as it provides insight into households' attitudes towards participating in such schemes.

Although 215 households (66% of those registered) used the containers with personal access at least once, i.e. formally took part in the demonstration, in order to ensure the reliability of the comparative analysis, it is important to examine the obtained data critically and determine a conservative criterion for forming a basis for the analysis. Based on expert assessment, we assume these are the "high activity" households that used the containers on average more than 6 times per month. 79 of those registered (24%) meet this criterion. The criterion is indeed conservative, and it is possible to exclude bona fide households, which have, however, been away from home for a long time or are regularly away from home. The opposite is also possible – dishonest behavior on the part of sampled households, e.g. more frequent disposal of smaller amounts of waste or simulated disposal (opening the container in vain) during the first six-month phase, as well as disposal of residual waste in other containers with free access located on the sites covered by the project - during the second phase. We assume that the opposite trends described compensate and do not define a % of error.

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Of course, the included 327 households, as well as the "highly active" 24% thereof, are not representative samples. However, the obtained "field data" is a valuable source of information and for the purposes of the analysis of the demonstration (as well as comparison with the current situation), the data for the latter will be extrapolated to the entire municipality. Thus, the results show the possible effect of a well-planned, publicised and implemented scheme, in which households participate actively.

The average number of persons in a household is 1.88 for registered households and 2.13 for "active" households, which is close to the average for the municipality of 2.15 (National Statistical Institute, Demographic and social statistics). It is also interesting to analyse the age structure of the households covered by the demonstration, as well as the ones that showed "high activity" (Figure 3). The larger share of young people up to 18 years old, as well as persons 31-60 years old in the structure of "active" households, versus a decrease in the share of the age group 18-30 years old, is surprising.

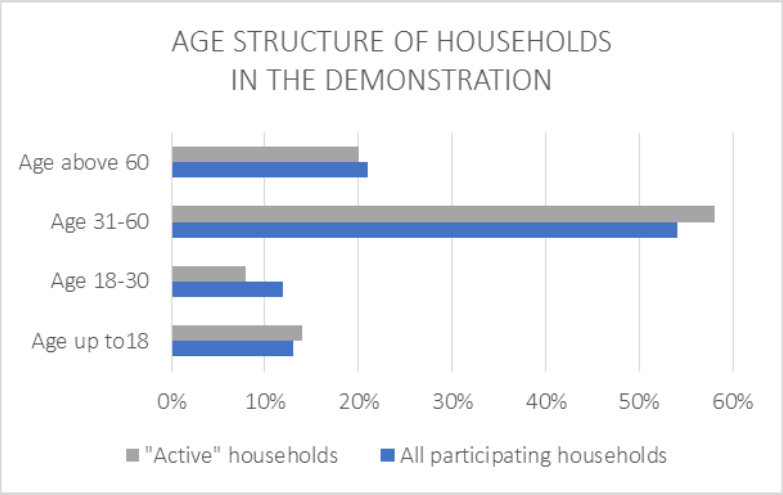


Figure 3. Age structure of households in the demonstration

If we consider the proportion of "active" households in each of the 13 building entrances covered, interesting results are also obtained (Figure 4). It turns out that in three building entrances, there is not a single active household, and in four "entrances", the "active" households are between 30% and 40%. It is possible to explore the motivating factors further, e.g., the form of property management, etc.

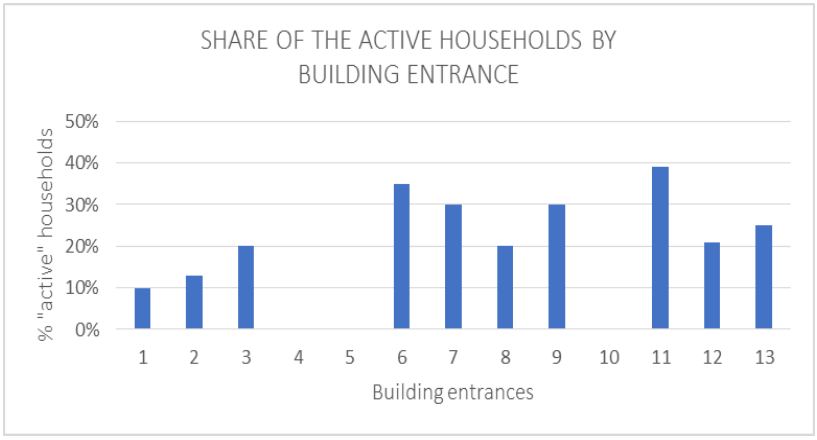


Figure 4. Share of the active households by building entrances

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Quantities of waste disposed

The total amount of disposed waste for the entire duration of the demonstration from all households is 333730 l. The obtained waste volume values are converted into weight by applying the "weight volume" index (also known as "waste density"). Suppose we apply the index level recommended by the Ministry of Environment and Water document "Guide for determining the number and type of necessary containers and equipment for waste collection and transportation" of 2004 (Ministry of Environment and Water, 2004), i.e., (300-340 kg/m3 for settlements 25000-1000000). In that case, we obtain an accumulation rate (total household waste) that significantly exceeds the value for the municipality of Gabrovo according to the National Survey of the morphology of waste of 2019 (Ministry of Environment and Water, 2019). When applying a weight volume of 250 kg/m3 (although the cited old document recommends such levels for larger settlements), we obtain more realistic values of the rate, close to the results of the most recent morphology (see Table 1).

Table 1. Weight volume

Indicator		Number of inhabitants in the settlement			
		Up to 3000	3000 - 25000	25000 - 1000000	Above 1000000
Rate of accumulation	kg/person/day	0.40-0.50	0.90-1.00	1.05-1.15	1.15-1.25
	kg/person/year	150-180	330-365	380-420	420-455
	l/person/day	1.05-1.45	2.30-2.85	3.10-3.85	3.95-5.00
	m^3/person/year	0.40-0.55	0.85-1.05	1.15-1.40	1.45-1.80
Weight volume	kg/m^3	340-380	350-390	300-340	250-290

Source: Guide for determining the number and type of necessary containers and equipment for waste collection and transportation of 2004 (Ministry of Environment and Water, 2004)

This approach enables the following comparisons. We compare the amounts of residual waste generated in the first and second six-month demonstration phases (for all registered households and separately only for the "active" households) (Figure 5).

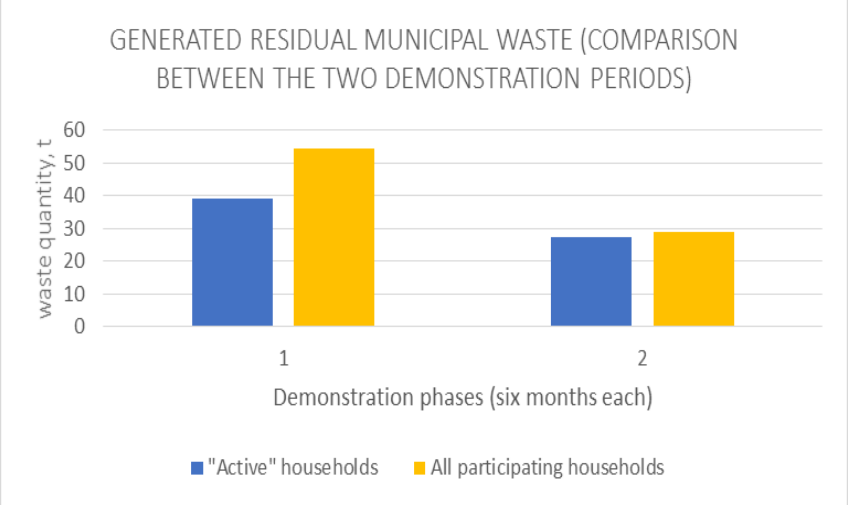


Figure 5. Generated residual municipal waste (comparison between the two demonstration phases)

In the first case, there is a decrease of 47% (from 216960 l. or 54.24 t. to 115235 l. or 28.81 t.) These data seem too inflated and confirm that, for further comparisons, it is appropriate to work only with the sample of "active" households (79 households that used project containers on average more than 6 times per month).

For this sample, the amounts generated during the first six-month phase (155765 l or 38.94 tons) decreased by 30% in the second six-month phase, reaching 108530 l or 27.24 tons. This more realistically shows the possibilities for separate waste collection at the source of their generation.

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Next, we compare the accumulation rate (the amount of household waste generated per inhabitant per year) calculated for the first and second demonstration phases (only for the "active" households) (Fig. 6). The reduction in the amount of residual household waste per inhabitant in the second compared to the first phase of the demonstration is about 30%.

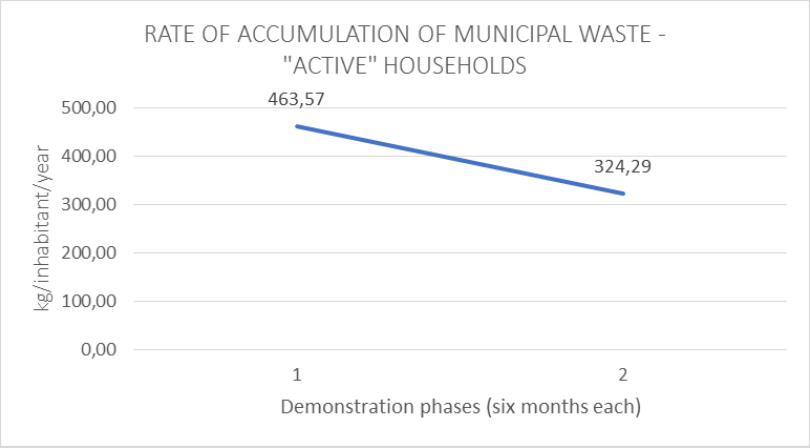


Figure 6. Rate of accumulation of municipal waste – "active" households

The comparison with the results of the National Morphology (the relevant section for Gabrovo municipality) (Ministry of Environment and Water, 2019) is interesting (Figures 7 and 8).

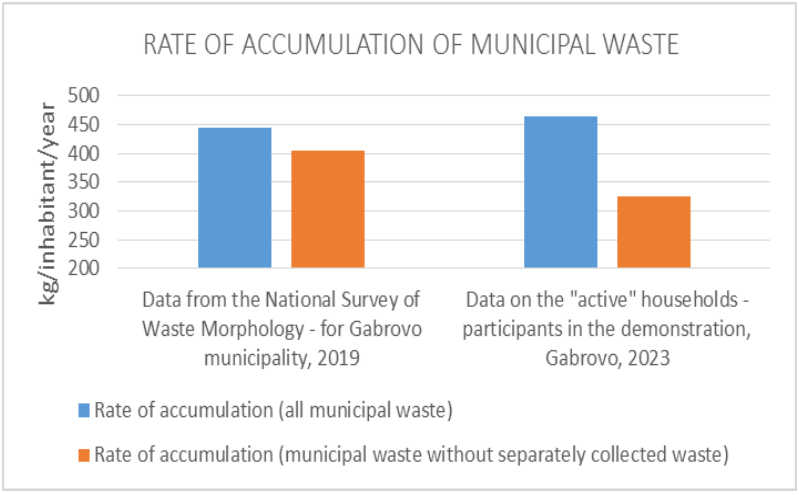


Figure 7. Rate of accumulation of municipal waste

Most interesting is the comparison of the rate of accumulation for the second phase with the rate of accumulation (household waste without separately collected waste) reported in the most recent morphology analysis (Ministry of Environment and Water, 2019) (Fig. 8). This gives us an idea of the expected efficiency of future schemes, or in other words, to what extent it is possible to reduce landfilling of household waste as a result of introducing a "pay-as-you-throw" scheme. From the reduction (24%), it is obvious that, with all stipulations and assumptions, introducing a pay-as-you-throw scheme has a real potential to reduce the amount of residual household waste generated significantly.

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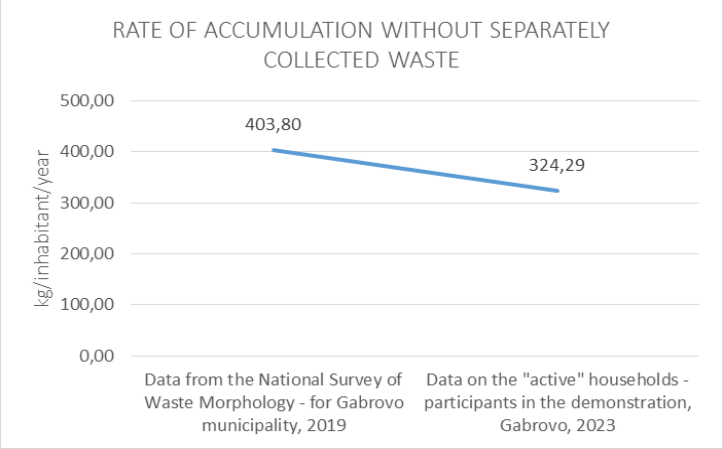


Figure 8. Rate of accumulation (municipal waste without separately collected waste)

The average value of the indicator "municipal waste accumulation rate" for Gabrovo municipality obtained by the National Survey of waste morphology of 2019 (Ministry of Environment and Water, 2019), was used as a reference value. For the purposes of comparison, it is considered more appropriate to use a value of the indicator specific to area "blocks of flats" (based on the categories recommended in the methodology for determining the morphological composition of municipal waste of 2012 (Ministry of Environment and Water, 2012)), however such information was not available in the latest morphology.

Regarding the expected increase in the share of separately collected recyclable waste, we unfortunately do not have "field" data, as the project demonstrates a base model of the "pay-as-you-throw" scheme, where only the amount of residual municipal waste is determined/ measured. It is assumed that the quantities reduced in the second six months correspond to prevented or separately disposed waste in the containers designated for this purpose.

When calculating the municipal waste accumulation rate for the demonstration, it is not possible to account for the seasonal nature of waste generation. The rate (kg/inhabitant/year) for each of the two phases was calculated by extrapolating the available six-month data. It was impossible to plan a two-year demonstration due to the limited maximum duration of the projects under the grant award procedure under the OPE 2014-2020.

4.2. Analysis of the feedback from the project team

The first prerequisite for the successful implementation of the demonstration was the established cooperation with the Gabrovo municipality. It started in 2019, at the stage of developing the project proposal, when a meeting was held with municipal experts to discuss the project purpose and scope, the technical means for determining the amount of waste generated and identifying the households that generated the waste. As a result, consent was issued by the mayor of the municipality for placing specialised equipment at 10 container sites in the city. A series of meetings with municipal experts followed in 2022, after the signature of the Grant Agreement under the OPE 2014-2020, to discuss the criteria for selecting the target group of households and opportunities for assistance. As a result, contacts, data and information were provided for demonstration and analysis purposes.
An agreement has been reached on the participation of the municipal enterprise "Regional Development", a specialised unit of the Municipality of Gabrovo, responsible for the collection and transportation of household waste. To guarantee the correct service of the specialised containers with limited access, technical training was conducted for the employees of the municipal enterprise, with the help of the company responsible for the production and delivery of the boxes, "Senstate Technologies" JSC. The demonstration was carried out in coordination and ongoing communication with this municipal enterprise.

Households were initially instructed at the project start. With the help of an employee of the Municipal Enterprise "Regional Landfill for Non-hazardous Waste" Gabrovo, initial contact with the target group and clarification of the purpose of the demonstration and participation in the scheme took place. At the beginning of the demonstration itself (after installing the specialised container equipment, participants were trained

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technically, with the help of the company responsible for production and delivery of the specialised equipment, "Senstate Technologies" JSC, and the manufacturers of the hardware and software, “Tempus 2000”. Constant contact was maintained with the target group of households, with the help of a key representative with good organisational skills who was recruited by the project (property manager of one of the selected buildings), who is responsible for distributing leaflets and access cards to the project boxes, distributing sealed envelopes with software access credentials, information about waste disposal with reference to the project website, discussing problems or questions, providing waste disposal plastic bags and gifts to the winners of organised competitions, posting contest announcements, etc.

While implementing the demonstration, the project team reported on several main groups of problems, mainly related to the attitudes of households. Initially, there was distrust of the demonstration and a negative attitude towards participation (more specifically, fears that participation in the scheme would increase household waste fee). In response, additional clarifications were provided, a house manager from the target group was recruited, and more households were included than originally planned (327 instead of 200). Another problem is the citizens' dissatisfaction with the volume of the waste disposal compartments, which, according to the project assignment, are 5 L and 20 L, respectively. According to the participants, these openings are insufficient and should be 20 l and 50 l. To avoid inconvenience, households were provided with waste bags volume 20 l and 5 l. The most serious challenge has been the illegal dumping on the sites, outside the containers (probably because of carelessness/ missing cards or unwillingness of certain household members to participate); therefore, complaints have been received in the municipality. Containers for residual household waste with free access had to be placed on the project sites. This contradicts the concept of conducting the demonstration, according to which all containers located at the project sites should be equipped with boxes with limited (individual) access, in order to motivate participation and ensure data reliability maximally. However, a deviation from the concept was necessary to solve the problem, given the voluntary nature of the demonstration.

4.3. Defining possible scenarios for the design of municipal waste fees based on the quantity of waste generated by individual households, including fixed and variable components. Coverage of waste management costs

Out of the possible main scenarios, the following scenario is examined in detail: The amount of municipal waste fee is to be determined based on the volume of the generated waste. The fee comprises a fixed part that covers 40%-60% of the waste management costs and a variable part that covers 40%-60% of the waste management costs, to be charged depending on the amount of waste generated.

Table 2. Description of the parameters of scenario 1

Area	Model	Customers	Data source
Area “Blocks of flats”	Replacement of all free-access waste containers with limited-access containers with RFID (based on waste volume)	Households and economic entities that generate waste similar to municipal waste	Project demonstration
Area “Single-family houses”	Model based on collection frequency (based on waste volume)	Households and economic entities that generate waste similar to municipal waste	Data from other projects, modelled data

Two versions of this most realistic scenario have been elaborated and compared. The reference period for the purposes of the analysis is the period 2016-2023, for part of which data and information are available from the municipal Waste Management Programme 2021-2028 (Minicipality of Gabrovo, 2021). The missing data are modelled using appropriate methods. The year of the investment (or the year of the introduction of the PAYT scheme) was set to 2024, and the effect of the introduction of the scheme was analysed for a subsequent period of the same duration, 2024-2031.

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As shown in Table 3 below, the model is based on the extrapolation of data from the demonstration. We can assume that in 2024, 24% of households in the municipality will be actively involved in the implementation of the scheme and therefore apply the rate of residual household waste generation obtained as a result of the analysis of project data (second phase). For the rest of the households, we assume that they will generate residual household waste equal to the waste accumulation rate, i.e., they will dispose of all their waste without any separate collection.

Data for past years and estimated population data are according to NSI (missing data are modelled linearly). The number of persons in a household for the reference period is also according to NSI data (average 2.15 for Gabrovo municipality) (National Statistical Institute, Demographic and social statistics). For the period 2024-2031, a reduction of this indicator (based on expert assessment) is allowed, given the population decreasing trend.

The share of "active households" (who will participate in good faith in the PAYT scheme) for 2024 is determined based on the results of the demonstration (24% of all registered participants). It is assumed that this share will increase by two points every year, considering there will be real motivation to reduce the household waste fee.

Table 3. Indicators - Demographics

3a. Traditional scheme

DEMOGRAPHICS	TRADITIONAL SCHEME							
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Population of Gabrovo municipality, number	59663	58567	57625	56599	55768	53173	50578	53618
Average household members, number	2,15	2,15	2,15	2,15	2,15	2,15	2,15	2,15
Total households, number	27750	27240	26802	26325	25938	24731	23524	24938

3b. PAYT schemes

DEMOGRAPHICS	PAYT SCHEMES							
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Population of Gabrovo municipality, number	52769	51943	51117	50291	49465	48615	47765	46915
Average household members, number	2,15	2,13	2,11	2,09	2,07	2,05	2,03	2,01
Total households, number	24543	24386	24226	24062	23896	23714	23529	23341
Total of active households (24% to 38%) (PAYT), number	5890	6340	6783	7218	7646	8063	8470	8869
Total non-active households (76% to 62%) (PAYT), number	18653	18045	17442	16843	16249	15651	15059	14471
Total of active household members (PAYT), number	12664	13505	14312	15087	15828	16529	17195	17827
Total of non-active household members (PAYT), number	40104	38437	36804	35203	33636	32086	30569	29087

Table 4 below presents the comparison of the municipal waste costs of the traditional scheme and PAYT schemes. The total cost of waste management for 2016-2020 is according to the Waste Management Programme of Gabrovo Municipality 2021-2028 (Municipality of Gabrovo, 2021). Because of the lack of data on the distribution by groups of activities, the latter was modelled on the basis of practical experience and expert assessment (waste collection and transportation - 50%, disposal of household waste in landfills or other facilities - 30%, cleanliness of the territories for public use - 20% of the total costs). For the same reason, the costs for the period 2021-2023 are modelled using the linear interpolation method.

The costs until 2031 are estimated as follows: after introducing the PAYT scheme, the costs of waste collection and transportation and the costs of municipal waste disposal in landfills or other facilities are expected to decrease pro-rata with the reduced amount of residual municipal waste (it is assumed that the cost of collection and disposal per ton of waste is a constant value and the average value of these costs for the reference period is used for the forecast period). It is assumed that the introduction of the scheme will not affect the costs of

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cleanliness of the areas for public use, and the values for 2024-2031 have been determined by applying the method of linear interpolation.

We should include ERP system development and maintenance costs and costs for specialised equipment in the municipal area "blocks of flats" for all containers (1306 containers, not including "the 12 underground containers). The costs for the ERP system are based on estimates for upgrading the system developed under the project. The costs for the specialised equipment of the containers are determined based on the project budget, considering the economies of scale when awarding major public procurement for the territory of the entire municipality. It is assumed that the price covers the costs of maintaining the equipment throughout the entire period of operation. The additional costs are spread over a period of 7 years, given the possibilities of using EU funding, including grants and financial instruments (Angelova, 2020; Anguelov and Angelova, 2019). Thus, we gain an idea of the potential for reducing the calculated fees after the initial investment is paid off. We tentatively assume that the amount of this cost category in the eighth year (2031) is 10% of the cost per year of the previous years, covering only maintenance costs.

It is assumed that the cost of introducing PAYT in the area "single-family houses" is negligible (set as 0,00 BGN).

Table 4. Indicators – Municipal waste costs

4a. Traditional scheme

MUNICIPAL WASTE COSTS	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Costs for waste collection and transportation, and costs for final disposal per ton of generated waste, thousand BGN	0,19	0,16	0,17	0,27	0,23	0,16	0,17	0,17
Costs for the activities on waste collection and transportation, thousand BGN	2267	1962	2097	2792	2427	2467	2507	2547
Costs for the activities on final disposal of waste in landfills and other facilities, thousand BGN	1360	1177	1258	1675	1456	1336	1504	1528
Costs for the activities on cleanliness of the territories for public use, thousand BGN	906	784	838	1117	970	987	1002	1019
Total costs, thousand BGN	4534	3924	4195	5585	4854	4791	5015	5095

4b. PAYT schemes

MUNICIPAL WASTE COSTS	PAYT SCHEMES							
	2024	2025	2026	2027	2028	2029	2030	2031
Costs for waste collection and transportation and costs for final disposal per ton of generated waste, thousand BGN	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19
Costs for the activities on waste collection and transportation, thousand BGN	2121	2050	1980	1911	1842	1812	1781	1748
Costs for the activities on final disposal of waste in landfills and other facilities, thousand BGN	1561	1538	1515	1491	1467	1465	1461	1456
Costs for the activities on cleanliness of the territories for public use, thousand BGN	1035	1051	1067	1083	1099	1115	1131	1147
Costs for development and maintenance of ERP system (PAYT), thousand BGN	26,00	26,00	26,00	26,00	26,00	26,00	26,00	2,60
Costs for specialised equipment in area "blocks of flats" (PAYT) for 1306 containers (N/A for 12 underground containers), thousand BGN	1632	1632	1632	1632	1632	1632	1632	163,25
Costs for waste containers in the area "single-family houses" (PAYT) - villages in the municipality, 750 containers x 1.1m3, thousand BGN	0	0	0	0	0	0	0	0
Total costs, thousand BGN	6376	6298	6221	6144	6067	6051	6032	4518

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Table 5 presents the indicators related to generated municipal waste. For persons from "active" households, the rate of accumulation of residual household waste, achieved in the second demonstration phase (324 kg/inhabitant/year), was applied. On this basis, the amounts of residual household waste from active households were predicted (basis for calculating the relevant costs).

The generated residual household waste from non-active households was calculated at an accumulation rate according to the realistic forecast for the amount of generated waste in the municipal waste management programme (Municipality of Gabrovo, 2021) (basis for calculating the relevant costs). The total amount of residual household waste generated was also determined based on the above.

Table 5. Indicators – Municipal waste generated

5a. Traditional scheme

MUNICIPAL WASTE GENERATION	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Generated municipal waste (historical and forecast data WMP), tons	19298	19381	19960	16841	17173	24306	24131	23955

5b. PAYT schemes

MUNICIPAL WASTE GENERATION	PAYT SCHEMES							
	2024	2025	2026	2027	2028	2029	2030	2031
Generated municipal waste (historical and forecast data WMP), tons	23777	23606	23433	23259	23084	23399	23714	24030
Rate of accumulation of residual municipal waste for members of non-active households (PAYT) (based on forecast data WMP), tons/inhabitant/year	0,45	0,45	0,46	0,46	0,47	0,48	0,50	0,51
Generated residual municipal waste by non-active households (PAYT), tons	18070	17468	16871	16281	15697	15443	15177	14899
Rate of accumulation of residual municipal waste for members of active households (PAYT) (based on forecast data WMP), tons/inhabitant/year	0,32	0,32	0,32	0,32	0,32	0,32	0,32	0,32
Generated residual municipal waste by active households (PAYT), tons	4106	4379	4641	4892	5133	5360	5576	5781
Generated residual municipal waste by all households (PAYT), tons	22177	21848	21513	21173	20830	20803	20753	20680

Table 6 presents the municipal waste cost per household. When applying average values of the costs of waste collection and disposal and costs of disposal per ton of generated waste, the following are determined: average value of the total costs for one household; average aggregate costs per "active" household and average aggregate costs per "non-active" household. This allows the fee to be determined in compliance with the cost recovery principle.

Table 6. Indicators – Municipal waste costs by household

6a. Traditional scheme

MUNICIPAL WASTE COSTS BY HOUSEHOLD	TRADITIONAL SCHEME							
	2016	2017	2018	2019	2020	2021	2022	2023
Average aggregate costs per household, BGN	163,40	144,08	156,52	212,17	187,17	193,71	213,18	204,31

6b. PAYT schemes

MUNICIPAL WASTE COSTS BY HOUSEHOLD	PAYT SCHEMES							
	2024	2025	2026	2027	2028	2029	2030	2031
Average aggregate costs per household, BGN	259,81	258,29	256,80	255,34	253,90	255,19	256,40	193,58
Average aggregate costs per active household (PAYT), BGN	105,16	105,16	105,16	105,16	105,16	105,16	105,16	105,16
Average aggregate costs per non-active household (PAYT), BGN	203,03	206,53	210,15	213,90	217,78	231,67	246,50	262,35

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The indicators related to municipal waste fees and revenues from fees are shown in Table 7 below. The two PAYT scenarios are as follows:

- Pay-as-you-throw scheme with fixed component 60%, presented in Table 7 (7b);
- Pay-as-you-throw scheme with fixed component 40%, presented in Table 7 (7c).

Notably, in 2024-2031, no significant increase in fees is needed to cover all costs. Estimated revenues from the fixed and variable components of the fee to cover 60% to 40% of total costs, respectively (for the scheme to meet the minimum PAYT criteria), have been calculated. To compare the two phases, an average household fee was calculated. The initial increase in 2024 is from BGN 223.31 to BGN 259.81.

It should also be noted that the average value of a household fee fixed component, or in other words the limit to which the fee can be reduced in the case of zero residual municipal waste generation immediately after the introduction of the model (2024), is 30% lower than the average value of fees paid in 2023 (BGN 155.89 compared to BGN 223.31).

An important aspect of the scheme is the fair definition of the fee, so the following indicators have been calculated:

- average value of variable component per household;
- average value of the variable component per active household;
- average value of the variable component per non-active household.

It is assumed that in case of obtaining negative average values of the variable component, the active households should pay 0,00 BGN variable component, as shown in Table 7 (7b). This means that the waste management system would collect more revenues than the incurred costs. Moreover, the surplus would be paid by the active households who follow the rules of the PAYT scheme, which is not fair.

The obtained negative values show the potential to increase the share of the variable component to 60%. Finally, we arrive at the main indicators, namely:

- average value of the fee per active household;
- average value of the fee per non-active household.

After paying off the investments, the listed indicators reach BGN 116.15 and BGN 262.35, respectively, as shown in Table 7 (7c).

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Tables 7. Indicators – Municipal waste fees and revenues from fees

7a. Traditional scheme

MUNICIPAL WASTE FEES & REVENUES	TRADITIONAL SCHEME							
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Total revenues from waste fees, thousand BGN	2926	3970	4210	4328	4854	4604	5086	5568
Revenues from fees minus waste management costs, thousand BGN	-1607	45	15	-1257	-0,23	-185	71	473
Average amount of the fee per household, BGN	**105,47**	**145,75**	**157,10**	**164,41**	**187,16**	**186,20**	**216,24**	**223,31**

7b. PAYT scheme with fixed component 60%

MUNICIPAL WASTE FEES & REVENUES	PAYT SCHEME WITH FIXED COMPONENT 60%							
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Expected total revenues from waste fees, thousand BGN	6377	6299	6221	6144	6067	6051	6032	4518
Expected revenues from fees minus waste management costs, thousand BGN	50,72	49,81	48,92	48,04	47,18	47,95	48,67	10,99
Average amount of the fee per household, BGN	**259,81**	**258,29**	**256,80**	**255,34**	**253,90**	**255,19**	**256,40**	**193,58**
Revenues from fees (fixed component = 60% of total costs) (PAYT), thousand BGN	3826	3779	3732	3686	3640	3631	3619	2711
Revenues from fees (variable component = 40% of total costs) (PAYT), thousand BGN	2550	2519	2488	2457	2426	2420	2413	1807
Average amount of the fixed component per household (PAYT), BGN	155,89	154,98	154,08	153,20	152,34	153,11	153,84	116,15
Average amount of the variable component per household (PAYT), BGN	103,92	103,32	102,72	102,13	101,56	102,08	102,56	77,43
Potential to decrease the fixed component per household (PAYT), BGN	**-50,72**	**-49,81**	**-48,92**	**-48,04**	**-47,18**	**-47,95**	**-48,67**	**-10,99**
Average amount of the variable component per active household (PAYT), BGN	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
Average amount of the variable component per non-active household (PAYT), BGN	47,14	51,56	56,07	60,69	65,44	78,56	92,66	146,20
Average amount of the fee per active household (PAYT), BGN	**155,89**	**154,98**	**154,08**	**153,20**	**152,34**	**153,11**	**153,84**	**116,15**
Average amount of the fee per non-active household (PAYT), BGN	**203,03**	**206,53**	**210,15**	**213,90**	**217,78**	**231,67**	**246,50**	**262,35**

7c. PAYT scheme with fixed component 40%

MUNICIPAL WASTE FEES & REVENUES	PAYT SCHEME WITH FIXED COMPONENT 40%							
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Expected total revenues from waste fees, thousand BGN	6377	6299	6221	6144	6067	6051	6032	4518
Expected revenues from fees minus waste management costs, thousand BGN	50,72	49,81	48,92	48,04	47,18	47,95	48,67	10,99
Average amount of the fee per household, BGN	**259,81**	**258,29**	**256,80**	**255,34**	**253,90**	**255,19**	**256,40**	**193,58**
Revenues from fees (fixed component = 40% of total costs) (PAYT), thousand BGN	2550	2519	2488	2457	2426	2420	2413	1807
Revenues from fees (variable component = 60% of total costs) (PAYT), thousand BGN	3826	3779	3732	3686	3640	3631	3619	2711
Average amount of the fixed component per household (PAYT), BGN	103,92	103,32	102,72	102,13	101,56	102,08	102,56	77,43
Average amount of the variable component per household (PAYT), BGN	155,89	154,98	154,08	153,20	152,34	153,11	153,84	116,15
Average amount of the variable component per active household (PAYT), BGN	1,24	1,85	2,44	3,03	3,60	3,09	2,60	27,73
Average amount of the variable component per non-active household (PAYT), BGN	99,10	103,22	107,43	111,76	116,22	129,59	143,94	184,92
Average amount of the fee per active household (PAYT), BGN	**155,89**	**154,98**	**154,08**	**153,20**	**152,34**	**153,11**	**153,84**	**116,15**
Average amount of the fee per non-active household (PAYT), BGN	**203,03**	**206,53**	**210,15**	**213,90**	**217,78**	**231,67**	**246,50**	**262,35**

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The average value of a household fee, as well as the levels of fees that active and non-active households are expected to pay, are below the threshold of social affordability, regardless of how it is calculated (1% of annual household income or 1.5% of annual income of the third decile group).

Tables 8. Indicators – Income and social affordability

8a. Traditional scheme

INCOME & SOCIAL AFFORDABILITY	TRADITIONAL SCHEME							
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Average amount of total income per household in Gabrovo municipality, BGN	13306	14887	14091	16885	17210	19534	23216	24867
Social affordability threshold (1% of the income), BGN	133,06	148,87	140,91	168,85	172,10	195,34	232,16	248,68

8b. PAYT schemes

INCOME & SOCIAL AFFORDABILITY	PAYT SCHEMES							
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Average amount of total income per household in Gabrovo municipality, BGN	26519	28171	29822	31474	33126	34777	36429	38081
Social affordability threshold (1% of the income), BGN	265,19	281,71	298,23	314,74	331,26	347,78	364,29	380,81

It is possible to consider further whether it is appropriate to introduce lower fees for vulnerable social groups, given the expected educational effect of higher fees. The income and social affordability are shown in Table 8 above.

Results

This article analyses the results of a demonstration project performed at a small scale on the territory of the municipality of Gabrovo inspired and supported by one of the authors. At ten waste collection points in the city, state-of-the-art equipment was installed to measure the quantity of waste disposed of by individual households (more than 300 households agreed to participate). The data was stored in tailor-made software, providing feedback and motivation through a competition that awarded devoted participants. The obtained data from the two demonstration stages (without and with separate collection at source) were used for comparative analysis and forecasts on possible future implementation of pay-as-you-throw schemes.

As a result of the analysis of the *data received by the project IT system (SWAM IT system, 2023)*, conclusions can be drawn in two main directions:

Attitude to participate in pay-as-you-throw schemes: 34% of registered households did not participate in the demonstration (did not use the specialised containers even once), 42% of registered households showed low/medium activity (used the containers on average up to 6 times per month) and only 24% participated actively (used the containers on average more than 6 times per month). It is assumed that in the presence of a strong communication campaign and real opportunities to reduce the household waste fee, this percentage will increase significantly;

Potential to reduce the amount of generated residual municipal waste: If we compare the amounts of residual municipal waste generated by all registered households in the first and second phases of the demonstration, we get a reduction of 47%, which is rather unrealistic. Therefore, we compare the accumulation rate for the two phases, based on data from only the "active" households (expert assessment of the most reliable data for the purposes of the analysis), and obtain a more realistic reduction of 30%. It is interesting to compare the accumulation rate from the second phase (again based on data on "active" households) with the accumulation rate (without separately collected waste) from the most recent morphology of 2019 (Ministry of Environment and Water, 2019). The resulting reduction of 23% gives an idea of the potential to reduce the generation of residual household waste per capita, with active participation in a future scheme organised by the municipality. This is possible through a strong communication campaign and real opportunities to reduce the household waste fee.

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The feedback received from the project team does not contain specific data, but it also provides important information and a basis for qualitative analysis of the demonstration. In practice, it is confirmed that the introduction of the "pay-as-you-throw" scheme should start with a large-scale and long-term explanatory campaign for households, test introduction and phased coverage of the territory of each municipality. Another key lesson learnt is the need for good cooperation of all stakeholders. Of course, introducing such schemes will also require strengthening control and sanctions for non-compliance with the rules of the introduced scheme, strengthening control and sanctions for illegal disposal, and positive measures such as incentives for conscientious users.

It is recommended that Bulgarian municipalities start a phased introduction of a basic model of the "pay-as-you-throw" scheme, which provides for the measurement of only residual household waste according to the volume of waste generated.

It is proposed to introduce a different model for the collection of household waste in the different municipal areas, defined in the Ministry of Environment and Water document "Methodology for determining the morphological composition of household waste" of 2012 (Ministry of Environment and Water, 2012), for the area "single-family houses" and the area "blocks of flats". Unfortunately, the lack of field data does not allow differentiated consideration of the two types of areas, but it is generally known that for areas with prevailing single-family houses, it is more appropriate to introduce a model based on the frequency of waste collection. Finding an appropriate way to collect field data from such municipal areas is advisable.

Last but not least, it is important to carefully analyse the propensity to generate waste of households and economic entities that generate municipal waste and to decide on how to fairly define the fixed and variable parts of the fee for both groups of users. Based on available data and information, the model only calculates average values of the two components for active and inactive players.

The analysis uses averaged indicators, but in reality, the share of households in the revenues from the household waste fee for cities of the size of Gabrovo is below 10% (according to data from the National Waste Management Plan 2021-2028 (Ministry of Environment and Water, 2021)). The main revenue from waste fees comes from economic entities. It is time to put an end to this cross-subsidy practice and finally start to apply economic instruments to meet the waste targets. This requires difficult and unpopular decisions at the municipal level, but the process must be launched. A possible solution is to provide a phased coverage of all waste management costs through municipal waste fees.

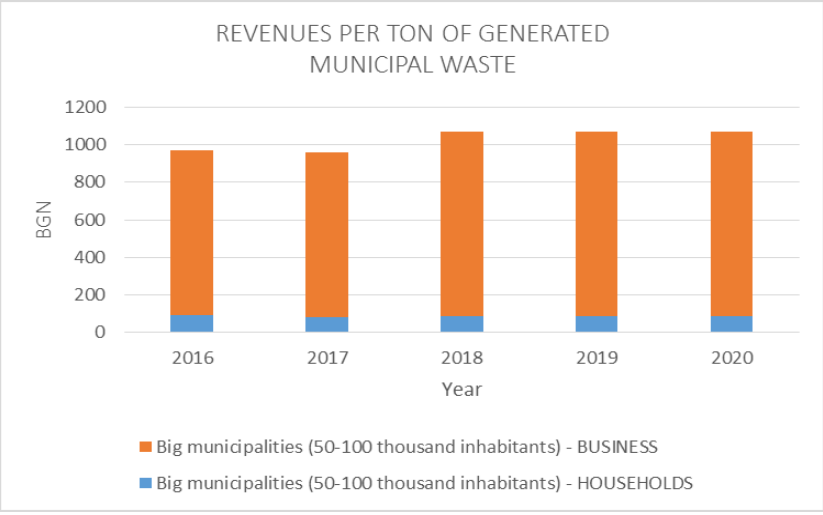


Figure 9. Revenues per ton of generated municipal waste in big municipalities
Source: National Waste Management Plan 2021-2028.

At first glance, the results of the model outline a more pessimistic scenario regarding the achievement of landfill and recycling targets compared to forecasts in the municipal waste management programme. However, the analysis steps on "field" data and, based on the modest experience and scale of the demonstration, reaches some interesting conclusions and may support Bulgarian municipalities in the process of introducing economic incentives to apply the waste hierarchy and "polluter pays" principle.

Conclusions

The article examines the possibilities for reducing waste through the application of the polluter pays principle. Not only the environmental consequences of the application of this model — especially in relation to strengthening the circular economy — but also its social dimensions are analysed. The authors emphasise the need for a preliminary assessment of the social sustainability of the model before it is implemented in real conditions. In this context, the study demonstrates the possibilities for applying the model in a medium-sized Bulgarian city's specific social and institutional environment. The results obtained have both theoretical value and practical applicability for decision-makers in sustainable waste management.

The study contributes to expanding knowledge in the field by empirically confirming the model's applicability based on the polluter pays principle in the context of municipal waste management. In addition, the article proposes an analytical framework that should be used to assess the conditions for its implementation. This framework includes an analysis of the socio-economic characteristics, institutional capacity and public perception of the model. Thus, the study provides a practically applicable methodological tool for municipalities planning to introduce such an approach.

The analysis in the article is based on the results of a demonstration project implemented on a limited scale in the municipality of Gabrovo, Bulgaria. Therefore, the data obtained are most applicable to cities of similar size and characteristics within the country. The application of the same model in significantly larger or smaller settlements and regions with different institutional and social contexts requires further adaptation and validation of the approach according to local conditions.

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CORPORATE TAX RATES IN THE EU: HARMONISATION AND COMPETITION FROM THE PERSPECTIVE OF CONVERGENCE ANALYSES*

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Abstract. Tax policy plays a key role in shaping the economic environment and the competitiveness of states within the common European market. Given the deepening economic integration within the EU, analysing tax system convergence is becoming increasingly important. This paper aims to analyse the development of tax rates in European Union countries, focusing on identifying long-term trends and assessing the degree of their convergence. The empirical part of the paper focuses on examining whether corporate tax rates are converging within the European Union, based on two analytical perspectives – Beta convergence and Sigma convergence. Regression analysis was used to test the hypothesis that member states with higher initial tax rates experienced a faster rate of reduction during the period 2013–2023 (Beta convergence). At the same time, the variability of tax rates among countries was examined using a trend analysis of the standard deviation to determine whether differences between countries are decreasing over time (Sigma convergence). The results of this study confirmed the existence of convergence in corporate tax rates within the European Union. Based on both Beta and Sigma convergence analyses, it can be concluded that differences between EU member states are gradually decreasing, indicating a partial trend toward harmonisation of tax policies in EU countries.

Keywords: corporate tax rates; tax harmonisation; effective tax rates; Beta convergence; Sigma convergence

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JEL Classifications: H25, H71, F38, O521

1. Introduction

Tax harmonisation and competition within the European Union are crucial in ensuring the smooth functioning of the single market and creating a level playing field for businesses across EU member states. The convergence of tax systems helps eliminate issues such as double taxation, tax evasion, and aggressive tax planning. This contributes to a fairer, more stable and transparent tax environment within the EU and increases the efficiency of tax collection, which is essential for the stability of public finances and the support of economic growth.

On the other hand, tax competition between member states can lead to lower tax rates to attract investment and boost employment. However, this phenomenon also risks fiscal stability, as it may result in lost tax revenues and disrupt market balance. Therefore, it is necessary to balance tax harmonisation, which ensures uniform rules, and tax competition, which promotes efficiency and innovation within national economies. Overall, tax

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harmonisation in the EU contributes to removing barriers to cross-border trade and investment, enhances the competitiveness of European companies and supports sustainable economic growth. At the same time, it requires respect for national sovereignty in tax policy and a sensitive approach to the differences between member state economies, to minimise negative impacts on individual countries and their fiscal capacity (Abidi & Taugourdeau, 2024; Martínez-Vázquez et al., 2024).

This study focuses on analysing the development of corporate tax rates in EU countries with the aim of assessing whether they are converging. Through convergence analyses, specifically Beta and Sigma convergence, we evaluate the dynamics of tax policies during the 2013–2023 period and identify whether differences between member states are decreasing over time. With this contribution, we aim to enrich the academic debate on the extent of tax system harmonisation in the EU and the impact of tax competition on the convergence of corporate taxation within the single market.

2. Theoretical Background

Tax harmonisation in the European Union (EU) represents one of the key issues of contemporary economic policy. Differences in corporate tax rates between member states can create distortions in the single market, encourage capital shifts to countries with lower tax burdens and threaten the tax revenues of countries with higher rates. This phenomenon, known as tax competition, can lead to the destabilisation of national tax bases (Dabla-Norris & Lima, 2023; Balasoiu, Chifu, & Oancea, 2023).

The debate on the need for harmonisation has intensified in recent years, focusing particularly on the extent to which the EU should be authorised to influence the tax policies of its member states. While high-tax countries prefer a more coordinated approach, some smaller or peripheral economies see tax competition as a legitimate tool to attract investment and stimulate economic growth (Feld & Heckemeyer, 2011; Delgado et al., 2014; Todorovic et al., 2024).

An important part of this discussion is the difference between nominal and effective tax rates. While the nominal rate is set by law, the effective tax rate (ETR) reflects the actual tax paid after deductions and exemptions. This difference plays a crucial role in the competitive positions of the countries and in the foreign decision-making of investors (Devereux et al., 2008; Wilde & Wilson, 2018; Konečná & Andrejovská, 2020; Andrejovska et al., 2024). Mutti and Ohrn (2019), Helcmanovská and Andrejovská (2021), Víghová et al. (2023, 2024) and Devereux et al. (2008) document a long-term downward trend in nominal rates due to globalisation and increasing competition. Feld and Heckemeyer (2011) show that smaller and peripheral countries, in particular, benefit from lower rates, thereby increasing their competitiveness. Heimberger (2021) also confirmed that active tax competition in the EU depends on country size and economic context.

Historically, efforts to harmonise began as early as the 1970s and 1980s, aiming to curb harmful tax competition and preserve the integrity of the single market. Delgado et al. (2014), based on an analysis of 27 member states, pointed to persistent differences in ETR (ranging from 10% to 35%) and the need for greater convergence.

Recently, major tax harmonisation measures have come into effect. As of February 1, 2024, the EU implemented a minimum effective tax rate of 15% for multinational corporations (European Commission, 2024), marking a significant step in the global effort for a fairer tax environment. Harmonisation of corporate taxation in the EU is a long-term effort to ensure fair competition conditions and minimise harmful tax competition, destabilising public finances and disrupting market balance in high-tax countries. Nevertheless, the harmonisation of direct taxes remains a politically sensitive issue, as member states wish to preserve their tax sovereignty.

Introducing a 15% minimum ETR (European Commission, 2024) represents a significant move toward a fairer tax environment. According to Johannesen (2022), implementing a global minimum tax could reduce profit shifting to tax havens, thereby strengthening fiscal stability (Garcia-Bernardo et al., 2021). In terms of the impact of the global minimum tax (GMT) at a 15% rate, which applies only to large multinational companies, it has been shown that partial GMT coverage leads to different tax competition equilibria between tax havens and other countries (Haufler & Kato, 2024). Delgado & Presno (2017) analyse tax convergence in the EU-15

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from 1975 to 2011, finding that full convergence occurred mainly in the taxation of goods and services, where harmonisation is most advanced, while other tax types developed differently.

Bušovská (2014) confirms Beta convergence of tax systems in EU countries in the period 1965–2011, showing convergence of tax burdens and tax mixes (income, indirect and property taxes) across all current member states and those that joined later. These trends are driven by globalisation, tax competition, and aspirations of the countries to join the EU.

Regis, Cuestas, and Chen (2015), in their study of corporate tax rate convergence in Europe from 1980 to 2014 using Beta and Sigma convergence and cluster analysis, found that although overall convergence among all states did not occur, a phenomenon of "club convergence" was present, i.e., the formation of tax clusters with internal convergence. The log-t test identified three (later four) stable convergence clubs, each showing rate reductions at varying speeds. For example, “tax haven” countries (Cyprus, Ireland) reduced their rates the most, while high-tax countries (e.g., France) remained at higher levels. Sigma convergence confirmed declining variability within clubs, indicating internal convergence, while divergence between clubs persisted.

In summary, differences in corporate taxation affect not only investment behaviour but also the competitiveness of countries and the trajectory of their economic growth (Attard, 2023; Lopez-Garcia, 2024; Mikou, Vallet & Guivarch, 2024; Diller et al., 2025). Within the EU, further harmonisation remains a key challenge in pursuing a stable and fair single market.

3. Research Objective and Methodology

This paper empirically examines whether corporate tax rates are converging within the European Union, using two analytical perspectives, Beta convergence and Sigma convergence. Through regression analysis, we test whether member states with higher initial tax rates experienced a faster rate of reduction during the period 2013–2023 (Beta convergence). In parallel, we analyse the evolution of tax rate variability among countries using a trend analysis of the standard deviation to determine whether differences between countries are decreasing over time (Sigma convergence). From a research perspective, we focused on the following research question:

Research Question:
Is there convergence of corporate tax rates within the European Union in the context of harmonisation and tax competition, and what are the implications of this development for the effective functioning of the single market?

Methodological Approach for Beta and Sigma Convergence
Beta Convergence
This concept makes it possible to analyse whether EU countries with higher initial tax rates (both nominal and effective) in 2013 experienced a faster rate of reduction during the period 2013–2023. Based on this, we formulated the following hypotheses:
Hypothesis H1: There is Beta convergence of corporate tax rates (both nominal and effective) in the EU, meaning that countries with higher initial rates show a higher reduction rate in the subsequent period. The analysis was conducted using a simple regression analysis, where the average annual growth rate of the tax rate was explained by its initial level.

Calculation of the average annual growth rate:

$$g_i = \frac{1}{T} \times \ln\left(\frac{Y_{iT}}{Y_{i0}}\right)$$

Where:
- g_i is the average annual growth rate for country i.
- Y_{iT} is the value of the variable (e.g., tax rate, tax revenue) in the final year T.
- Y_{i0} is the initial value of the variable (in our research, in the year 2004).
- T is the number of years in the analysed period.

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Regression Model for Beta Convergence:

$$g_i = \alpha + \beta \times \ln(Y_{i0}) + \varepsilon_i$$

Where:
- α is the intercept (constant), capturing the average growth when the logarithm of the initial value is zero.
- β is the Beta coefficient, expressing the relationship between the initial value of the variable Y_{i0} and the average annual growth rate. A negative β indicates convergence.
- $\ln(Y_{i0})$ is the natural logarithm of the initial value for country i.
- ε_i is the error term, capturing deviations not explained by the model.

Sigma Convergence

The concept of Sigma convergence involves monitoring the evolution of variability in a given indicator, in our case, effective (ETR) and nominal (NOM) corporate tax rates, among a group of countries over time. A decline in variability, represented by the standard deviation between countries, is interpreted as a sign of convergence.

In contrast to Beta convergence, which focuses on testing whether countries with lower initial levels of the indicator grow faster (i.e., converge toward the average), Sigma convergence evaluates the overall degree of dispersion of the observed indicator across the studied group over time. It is thus considered a stronger test of homogenisation between countries.

Following Delgado et al. (2014) and Heimberger (2021), as well as current legislative trends in EU corporate tax harmonisation (e.g., the introduction of a global minimum tax under Council Directive (EU) 2022/2523 of 14 December 2022 on ensuring a global minimum level of taxation for multinational enterprise groups and large domestic groups in the Union), we formulate the following research hypothesis:

Hypothesis H2: There is Sigma convergence of corporate tax rates (both effective and nominal) in the EU, meaning that variability between member states decreases over time.

In our analysis, we expressed Sigma convergence through the trend of the standard deviation of the logarithm of the observed indicator's value across EU member states each year. Logarithmic transformation is used for better statistical robustness and to eliminate potential asymmetries in the distribution of the indicator (Heimberger, 2021).

The formula for calculating the standard deviation in year t is as follows:

$$\sigma_t = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Y_{it} - \mu_t)^2}$$

Where:
σ_t is the standard deviation in year t,
N is the number of countries in the analysed group,
Y_{it} is the value of the variable (e.g., tax rate) for country i in period t,
μ_t is the average value of the variable in period t.

Interpretation:
If σ_t decreases over time, convergence is occurring – differences between countries are shrinking.
If σ_t increases, divergence is occurring – countries are moving further apart.

Analysis Procedure:
We performed the calculation for the period 2013–2023 for EU member states. In both cases, ETR and NOM, we applied a linear regression of the trend of σ_t on the time variable (year) to statistically verify the existence of a convergence trend.

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Regression Model:

$$\sigma_t = \alpha + \beta \times Year + \varepsilon_t$$

The key parameter is the β coefficient, where a negative and statistically significant β confirms the existence of Sigma convergence. If the β coefficient is positive, we are observing divergence, i.e., differences between countries are increasing. If the β coefficient equals 0, there is no significant trend.

4. Convergence and Regression Analysis

Results of Beta Convergence – Nominal Tax Rate and Effective Tax Rate

Beta convergence is a key analytical tool used to examine whether countries with higher initial tax rates experience a faster decline in those rates over time, thereby gradually converging. Within the European Union, this analysis allows us to assess whether countries such as France, Belgium, or Germany, with historically higher corporate tax rates, have reduced their rates more quickly than countries like Ireland, Hungary, or Bulgaria, which have maintained low tax burdens over the long term.

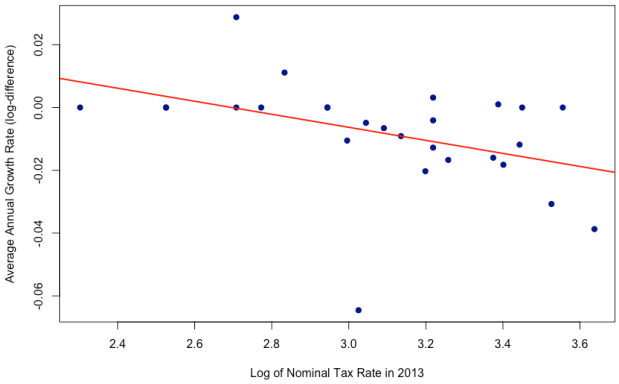


Figure 1. Beta convergence – Nominal Tax Rates (2013-2023)
Source: Own processing

The negative slope of the line depicting the relationship between the initial value of the logarithm of the nominal tax rate in 2013 and the average annual growth rate of that rate over the 2013–2023 period, expressed as a logarithmic difference (Figure 1), suggests that countries with higher initial rates (e.g., France, Belgium, Germany) tended to reduce their tax levels, while countries with lower rates grew more slowly or remained stable.

In the case of effective tax rates as well, we observe a negative slope of the regression line, which visually supports the Beta convergence hypothesis (Figure 2). This means that countries with higher effective rates (e.g., Germany, the Netherlands, Sweden) in 2013 saw a decrease in those rates during the observed period.

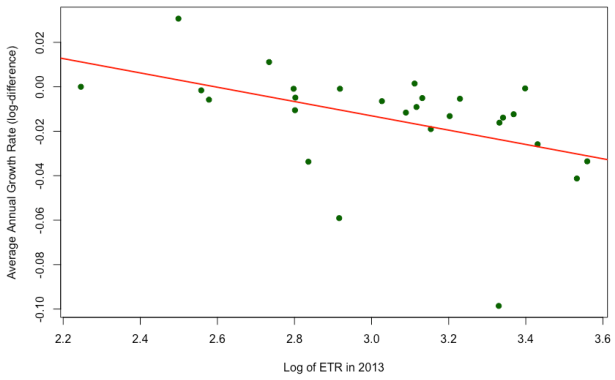


Figure 2. Beta convergence – Effective Tax Rates (2013-2023)
Source: Own processing

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The result confirms the existence of Beta convergence in nominal tax rates, meaning that countries with higher rates in 2013 (e.g., France, Belgium, Germany) tended to reduce them over the following decade, thereby moving closer to the average. This negative correlation between the initial level and the subsequent growth of the tax rate indicates a narrowing of differences among member states. Regression analysis (Table 1) showed that the β coefficient = –0.02869 is statistically significant at the 5% level (p-value = 0.0268), with $R^2 = 0.205$, meaning that the initial nominal rate explains 20.5% of the variability in its growth.

This result also confirms the existence of Beta convergence in effective tax rates, indicating that countries with higher rates in 2013 (e.g., Germany, the Netherlands, Sweden) tended to reduce them in the following decade, approaching the average. This negative correlation between the initial level and the subsequent growth of the tax rate signals a convergence among member states. Regression analysis (Table 1) showed that the β coefficient = –0.03218 is statistically significant at the 5% level (p-value = 0.0179), with $R^2 = 0.204$, meaning that the initial effective rate explains 20.4% of the variability in its growth.

Table 1. Statistical Results of the Regression

Variable	Nominal rate	Effective rate
Dependent variable	log(nom2023/nom2013) / 10 (average annual growth rate)	log(etr2023/etr2013) / 10
Independent Variable	log(nom2013)	log(etr2013)
Coefficient β	–0.02869	–0.03218
p-value	0.0268 (statistically significant at the 5% level)	0.0179 (statistically significant at the 5% level)
$R^2 = 0.205$	0,205 (20.5% of the variability explained by the initial rate level)	0.204 (20.4% of the variability explained by the initial rate level)

Source: Own processing

Results of Sigma Convergence – Nominal and Effective Tax Rate

The declining trend of the standard deviation of the logarithm of nominal tax rates during the observed period indicates convergence in nominal rates (Figure 3).

The most significant fluctuation occurred in 2017, when the standard deviation increased sharply. This rise can be explained by sudden changes in rates in several countries (e.g., France, Hungary, Italy), which temporarily increased disparity. However, after this fluctuation, the dispersion began to decline again, and since 2019 there has been a steady decrease, culminating in very low values in the years 2021–2023.

Thus, Sigma convergence also occurs in nominal tax rates. Despite temporary fluctuations in the middle of the analysed period, the differences between member countries are decreasing. The negative slope of the trend line statistically supports this convergence.

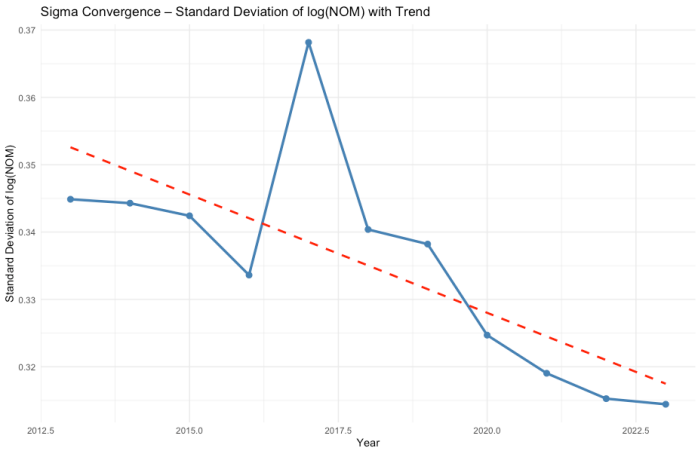


Figure 3. Sigma convergence – Nominal Tax Rates (2013-2023)
Source: Own processing

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A negative and statistically significant coefficient indicates a reduction in differences in nominal rates among member countries. Although the dispersion temporarily increased in 2017–2018, likely due to major tax rate changes in some countries (e.g., Belgium, Latvia, France), the trend line confirms an overall converging development.

The trend line of the standard deviation of the logarithm of the effective tax rate among EU member states from 2013 to 2023 clearly shows a downward trend, indicating that differences in ETR between countries are decreasing over time (Figure 4).

While a slight fluctuation and increase in variability can be observed in 2017–2019, a more significant decline follows after 2020, culminating in the lowest level of dispersion in 2021–2022. The last observed year shows a slight increase, but it does not disrupt the overall convergence trend.

The observed development confirms the existence of Sigma convergence also in the area of ETR, i.e., the convergence of effective tax rates across EU member states. A statistically significant negative coefficient of the trend line (in the regression output) supports this conclusion. The regression of the standard deviation over time confirmed a negative trend, supporting the existence of Sigma convergence in effective tax rates.

Table 2. Regression Output for Nominal and Effective Tax Rates

Variable	Nominal rate	Effective rate
Coefficient	−0.00351	−0.00286
p-value:	0.01096 (statistically significant)	0.00065 (statistically highly significant)
R^2	53.1 %	66.7 %,
adjusted R^2	47.9 %	63.7 %
F-statistic	10.19, p = 0.01096	22.05, p < 0.001

Source: Own processing

A negative and statistically significant coefficient for the variable "Year" indicates that the dispersion of effective tax rates among EU countries has been decreasing over time (Table 2). A high R^2 suggests that the time variable explains a substantial portion of the variation in dispersion (Table 2). This result strongly supports the hypothesis of Sigma convergence of effective tax rates in the EU.

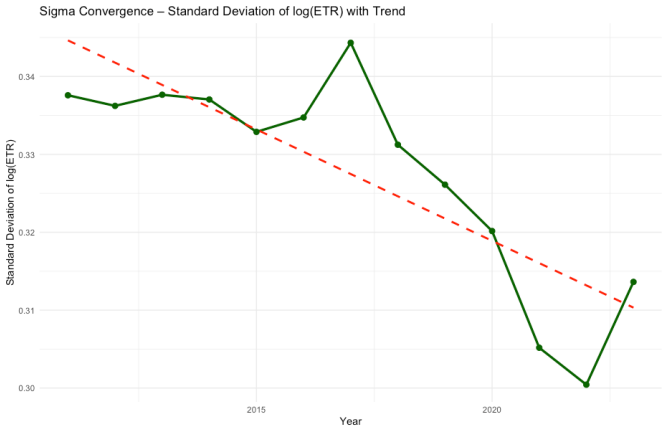


Figure 4. Sigma convergence – Effective Tax Rates (2013-2023)
Source: Own processing

The results of both types of convergence (σ-convergence and β-convergence) show that between 2013 and 2023, there was a gradual convergence of tax rates among EU member states. In the case of nominal tax rates (NOM), a clear downward trend in variability (σ-convergence) was recorded, and countries with higher initial rates tended to reduce their rates more rapidly (β-convergence). A similar trend was observed for effective tax rates (ETR), where convergence was even more pronounced, suggesting that statutory rates and tax burden on

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businesses are becoming more aligned across countries. Among the converging countries, Belgium, France, Germany, and Italy stand out for implementing reforms during the period that reduced their tax rates.

On the other hand, some low-tax countries (e.g., Ireland, Hungary, Bulgaria) maintained their low rates steadily, thereby contributing to the overall reduction in variability within the EU, even though they did not directly converge toward the average. Some divergence occurred in 2017, when legislative changes in certain countries increased variability, but this effect was later offset in the following years.

The results indicate that both harmonisation and competition were simultaneously at play in the EU during the observed period. The harmonisation effect is visible in the results of Sigma convergence, which indicate that differences between countries are narrowing. However, tax competition continues to exist, as seen through Beta convergence, where countries with higher tax rates have lowered them under pressure to remain competitive.

The introduction of a 15% minimum effective tax rate in 2024 (in line with the OECD global agreement and the EU initiative) may strengthen this trend toward further harmonisation. In practice, however, competition still prevails over full harmonisation, mainly because member states retain significant tax sovereignty and use tax instruments as part of their economic policy.

5. Results and Discussion

The results of this study confirmed the existence of convergence in corporate tax rates within the European Union during the period 2013 to 2023. Based on both Beta and Sigma convergence analyses, we can conclude that differences among EU member states are gradually decreasing, indicating a partial trend toward the harmonisation of tax policies. Similar conclusions were presented by Delgado and Presno (2017), who, while acknowledging persistent differences, identified a trend of convergence, particularly in the area of goods and services taxation.

Hypothesis H1, which assumed the existence of Beta convergence, was confirmed for both nominal and effective corporate tax rates. For nominal rates, a statistically significant negative relationship was identified between their initial level in 2013 and their subsequent development. Countries with higher tax rates tended to reduce them more rapidly, thus approaching the average. A similar trend was confirmed for effective tax rates, suggesting that the actual tax burden on businesses also became more aligned across countries. These findings are consistent with Bušovská (2014), who identified a long-term trend of convergence in both the tax mix and overall tax burden, even among countries with different EU accession dates.

Hypothesis H2, assuming Sigma convergence, was also confirmed. For nominal tax rates, a long-term downward trend in variability (standard deviation) was observed, despite a slight fluctuation in 2017. In the case of effective rates, the decline in variability was even more significant, illustrating a stronger convergence in real tax burdens across member states. These results are also supported by the study of Regis, Cuestas, and Chen (2015), who identified “club convergence” using Beta and Sigma convergence methods, i.e., the formation of country clusters with internal convergence, but persistent divergence between those groups.

Among the converging countries, Belgium, France, Germany, and Italy can be identified, all of which implemented reforms during the observed period that led to lower tax rates. On the other hand, countries like Ireland, Hungary, and Bulgaria have long maintained low tax rates. While this does not directly contribute to convergence, it does help reduce overall variability in the EU. Similar country patterns were identified in Regis Cuestas and Chen (2015), where Ireland and Cyprus formed their own "tax clubs" characterised by steep rate reductions.

The findings suggest that two opposing forces, harmonisation and competition, operate simultaneously within the EU. Sigma convergence results point to a harmonising effect, with differences between countries diminishing. However, Beta convergence reflects ongoing tax competition, as countries with higher rates adjust their policies to remain competitive. Similarly, Haufler and Kato (2024) identified a tension between

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harmonisation through the global minimum tax and the continued use of selective taxation, especially by tax havens.

The introduction of a 15% minimum effective tax rate in 2024, in line with OECD and EU initiatives, may represent a further step toward greater harmonisation. Nevertheless, competition between states still outweighs full harmonisation. Haufler and Kato (2024) point out that while countries are adopting new rules for large multinationals, they still preserve room for tax policy targeted at smaller entities, creating various equilibria between "havens" and other countries.

In conclusion, differences in corporate tax systems influence not only investment behaviour but also the competitiveness of the countries and their economic growth trajectories. Within the EU, the issue of further harmonisation remains a key challenge for achieving a stable and fair single market. In line with Delgado & Presno (2009), it can be concluded that fiscal coordination is a necessary condition for more successful integration, although national interests and tax sovereignty continue to pose complications.

Based on the analyses from 2013 to 2023, we can answer our research question affirmatively: corporate tax rate convergence is occurring within the European Union in terms of harmonisation and tax competition. The Beta and Sigma convergence results confirm that differences among member states are gradually diminishing, with countries with higher rates lowering them more quickly and effective tax burdens becoming more similar.

At the same time, it is clear that harmonisation efforts (e.g., the global minimum tax) coexist with ongoing tax competition, where some countries maintain low rates to attract investment. This combination affects the functioning of the single market, contributing to fairer business conditions, but persistent differences may slow fiscal integration. The results thus indicate that although convergence is happening, complete harmonisation is not yet a reality.

Conclusions

The results of the empirical analysis of corporate tax rates in EU member states for the years 2013–2023 confirmed that both nominal and effective rates have been converging over time. Negative and statistically significant coefficients in the β-convergence models showed that countries with above-average initial rates, particularly Belgium, France, Germany and Italy, reduced their rates more rapidly than low-tax countries such as Ireland, Hungary, and Bulgaria. Parallel σ-convergence analysis demonstrated a decline in rate variability across the Union, with a stronger effect observed for effective rates, indicating real convergence in corporate tax burdens.

These results suggest the simultaneous influence of harmonisation pressures and ongoing tax competition. From the perspective of the single market, the findings are twofold. Convergence supports a fairer and more transparent business environment, reducing profit-shifting incentives and aggressive tax planning. At the same time, persistent differences, especially in "low-tax peripheries", slow the pace of fiscal integration and may create pressure for a renewed round of tax competition if harmonisation reforms proceed too slowly.

The conclusions of this paper thus confirm a positive answer to the research question: corporate tax rate convergence is occurring within the EU, but the process is partial and uneven. For EU legislation, further harmonisation steps should consider the persistent differences in member states' economic performance and fiscal priorities. Future research could extend the analysis to the post-pandemic years, assess the effectiveness of the new global minimum tax rules, and apply panel models with variables capturing structural factors (such as economic openness, innovation levels, and institutional quality) to explore better the motivations and constraints individual countries face when setting corporate tax policies.

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CHANGE IN THE WORKLOAD OF SME EMPLOYEES DURING THE PANDEMIC*

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Abstract. The article explores the workload of employees trained for selected jobs during a crisis, filling the gap in the present research. Global thinking tends to believe that recent surveys examined the means of lessening impacts caused by the pandemic rather than focusing on timely detection and prevention. Our methodology combines socio analysis, bibliometric analysis from the Web of Science database, mathematical statistics of the enterprises' database, correlation matrix, ANOVA tests, and dimensional analysis. Bibliometric analysis revealed the same frequency of the words 'impact', 'performance', and 'innovation'. Mathematical statistics showed that most enterprises did not have to cut salaries given effective government aid. Occasional wage adjustments reflected changes in the workload, seen throughout the size and sectoral differentiations. The double-axed factors, regardless of remuneration, included: '*The overall strategy of the Company* and '*Flexibility and responsiveness*'. Office workers saw the most significant difference in remuneration consistency, suffering a total wage growth arrest. The top management witnessed only a weaker salary increase, while IT and marketing positions spotted no wage fluctuations. Small enterprises applied a 'work organisation' factor, which was later detected in large companies, leaving no trace in medium-sized organisations. The work concludes by proposing the synergy of digitisation and the circular economy on corporate competitiveness and employees during a crisis.

Keywords: employees; jobs; crisis; SME; organisational change and strategic business management; the impact of business change on regional development; bibliometric analysis; dimensional analysis

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JEL Classifications: O39, L16, L29

1. Introduction

People are an invaluable asset to all organisations, constituting an essential tool to beat competitors. All existing companies currently face massive global changes, fierce competition, and increasing pressure on cost reduction, all of which are attributable to the success or failure of employees and their performance. Competing small and

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medium-sized enterprises must listen to and understand the needs of the changing Generation Z, which is more flexible and quicker in responding to the ever-changing environment, heavily relying on innovations and creativity. Conditions for creating flexible and individualised jobs have recently changed to align with the Czech economy's changes and global transformation. Labour market flexibility has become an integral part of modernisation and an effective way to resolve current market issues (Ndubisi, Zhai & Lai, 2020; Navickas et al., 2022). Creating flexible jobs underlies the competitiveness of the Czech economy and partly solves social problems, including the increasing unemployment rate (Kollmann et al., 2024). Individualisation and adaptation of working hours or work itself amply reward company employees, managers, and workforce management. The current Czech corporate culture follows the social trends of large corporations from Western countries, adapting to new conditions arising from the onset of the COVID-19 pandemic.

The COVID-19 outbreak disastrously impacted healthcare, spreading like wildfire through all social spheres. The follow-up global and national restrictions and measures triggered an unprecedented economic crisis, badly damaging the world (World Bank Group, 2020; James et al., 2021; Apanovych et. al., 2023). Small and medium-sized enterprises overcame these obstacles through various innovations like working online to prevent the spread of the infection and giving specific jobs more flexibility. These novelties allow corporate management to ensure better working conditions for employees. Perks like half-time equivalent, home-office, online working, job-sharing or flexitime effectively combine work and family life. The crisis required companies to respond promptly to the unexpected situation, causing deep dissatisfaction among workers and massive labour turnover (Lu et al., 2021). New trends, tools, and working environments to adapt to harmed employees, creating excessive stress, leading to discontent and burn-out (Bautista et al., 2020; Boudrias, 2020; Chang et al., 2019; Hatamizadeh et al., 2019; Pollák et al., 2022). The presented article explores these burning issues.

2. Research objective and methodology

Human capital and its management underlie all successful enterprises. The last three years have witnessed a sudden twist in human resource activities triggered by the onset of the COVID-19 pandemic. The violent economic upheaval gave rise to new obstacles, making people revise their daily personal interactions, leading to newly shaped topics and trends in working with human resources. Human resource management involves deep insight into new flexible job positions and foreseeing ideal jobs for employees during the COVID pandemic. Buchanan and Denyer (2013) suggest that studies have been analysing crises since the 1980s, constituting a widely recognised up-to-date topic rather than a novelty. The surveys tackle various issues, including global financial meltdowns, natural disasters, terrorist attacks and armed global conflicts. Exploring these problems requires considerable effort, profoundly affecting people and participants throughout social strata (Celesnik, Radujkovic & Vrecko, 2018; Gazzola & Suciu, 2018; Boyd, De Nicolo & Rodionova, 2019; Dobrowolski, 2020; Flood, 2021; Wincott, Davies & Wager, 2021; Ioan-Franc & Diamescu, 2021; Petrosky-Nadeau & Zhang, 2021; O'Hara, 2021; Lee, Sung, Choi & Kim, 2021; Tilica, 2022; Rak et al. 2022; Strakova, 2024).

The COVID crisis radically changed the discourse and discussed topics on companies paralysed in their business activities, emerging HR trends, job perks and home office (Alashhab et al., 2021). Many changes in human resource management also occurred, which grew in importance during the COVID-19 pandemic, facing new tasks and challenges (Lehnert et al., 2017; AlShamsi & Ajmal, 2018; Antony & Gupta, 2019). Yousfi et al.(2019) list multiple effective methods and techniques to improve the HR process, like lean manufacturing, Kaizen, Benchmarking, Six Sigma, ISO 9000, etc. The COVID-19 outbreak led to hybrid teams, ensuring online cooperation between staff and managers and following specific online communication rules. Online conversations have become essential for many enterprises and their management, raising questions about cybersecurity, data protection, and the need for digital literacy. Most authors agree that digital know-how underpins the successful transition to the home office (Vytásková, 2020).

The COVID-19 pandemic impacted various industries, substantially boosting the productivity of IT, media and technologies (Boogaard & Moller, 2020). The IT sector immediately felt the effects of the outbreak when companies had to allow employees to work from home to prevent the infection from spreading (Alashhab et al., 2021). The transition to the online environment placed enormous pressure on developing and supporting digital

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technologies. By introducing digital transformation, many enterprises increased corporate productivity, stimulated innovation, reduced costs and facilitated business processes (Greer & Payne, 2014; Hamouche, 2020; Borowiecki et al., 2021). On the flip side, digital technologies cause discomfort and increased stress to specific groups. The immense complexity of the working environment requires analysing major determinants, including a new approach to exploring jobs and human capital. All posts produce idiomatic cultures different from 'omnipresent' macro-level corporate culture (Wolonciej, 2018; Sharma & Singh, 2018; Bulut et al., 2019; Ivani, Muchtar & Rasyid, 2019; Rahmat et al., 2020; Alagarsamy, Mehrolia & Aranha, 2020).

The Covid-19 pandemic put the global labour market to a severe endurance test of corporate sustainability and ability to adapt to the new situation (Sharma & Singh, 2018; Akgunduz, Alkan & Gok, 2018; Emery et al., 2019; Alagarsamy, Mehrolia & Aranha, 2020). Tuzovic and Kabadayi (2020) explore three vital personality factors to cope with crises: abilities and competencies to perform the job and access to indispensable tools (technologies, social support, etc.). The pandemic also put increased pressure on work management and the uniqueness of each employee, like temperament, personality traits and habits (Bartsch et al., 2020). Based on previous emergencies, Hamouche (2020) frames insecurity and a fear of infection as the main stressors. The outbreak aroused deep anxiety (Brooks et al., 2020), a fear of the unknown and information overload (Bontcheva et al., 2013; Gao et al., 2020; Elsafty & Ragheb, 2020). Adequate care of employees and keeping them updated on the situation and its consequences for the company have come a long way (Smith et al., 2007; Greer & Payne, 2014). The management had to impart information only from relevant sources to encourage a friendly and team environment (Brooks et al., 2018).

Restriction of movement involves another significant stressor, threatening people's mental health and workers' financial stability (Hawryluck et al., 2004; Xiang et al., 2020; Brooks et al., 2020). Economic insecurity and fear of job loss comprise negative impulses towards employees and sole traders, who have had to suspend or terminate their business. Many studies revealed that small and medium-sized enterprises faced enormous challenges handling the situation (Tuzovic & Kabadayi, 2020; Kochhar & Barroso, 2020; Braverman, 2020; Ghosh, 2020; Brooks et al., 2020; Msosa et al., 2024).

The European Commission considers small and medium-sized enterprises (SMEs) providers of economic growth, innovations, and job vacancies (European Commission, 2020). SMEs ensure European competitiveness, prosperity, economic or technological sovereignty and resistance to external shocks (European Commission, 2021). The Covid-19 crisis has considerable potential to go down in history as a catalyst in various public and private spheres, irreversibly disturbing the labour market. Having incurred tremendous financial losses, SMEs must learn to respond to imminent threats to survive the shakeout. The crisis profoundly impacted the labour market, differentiating it according to demographic groups, territory, economic sectors, and industries (Sostero et al., 2020; Musil & Kocmanova, 2024). The presented article explores how the pandemic affected the working environment in the Czech Republic, reflecting global changes in the labour market. The literary research outlines the repercussions of COVID-19 on companies and employees to address the current social demand, suggesting the following hypotheses and research questions.

- H1: Addressing impacts of the pandemic on companies, the current scientific community has been using the words' pandemic' and 'impact' with the highest frequency for the last two years.
- H2: The Covid-19 pandemic affected corporate subjects regarding their market life, the main field of business (NACE), the main scope of the company and the business size.
- H3: The change in the workload impacted the remuneration.
- RQ1: Is there a differentiation by which we can prove that the COVID-19 pandemic affected certain enterprises more than others?
- RQ2: Which factors mostly contributed to the change (RQ2A) / consistency (RQ2B) in the remuneration regarding the size differentiation?

We use Bibliometric Analysis and Visualization, One-Factor Analysis of Variance (ANOVA), Dimensional Analysis - Scale Reliability and Correlation Analysis to answer the research questions and hypotheses. We also included Bibliometric Analysis and Visualisation qualitative methods to assess the quality of the studies. Selected topics and mathematical modelling allowed a network graph, including the intensity of the adopted and interconnected criteria (Szomszor et al., 2021). The evaluation reflects the quality of the studies and critical

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research areas, predicting the focus of future examinations. All essential works (articles) are available on online databases like the Web of Science, Scopus, Dimensions, Lens and PubMed, involving visual analytical tools for representing numerical data. VOSviewer software analyses the imported input, creating maps containing items (points of interest) such as publications, keywords, authors, etc. The connection or relationship between any pair of components forges a link, including related links between publications. The map usually contains only one type of item and references. An intensity expressed in positive numbers determines the relation between the pairs, growing closer with higher values. The links and items form a network comprising clusters on the map. One article relates only to one assemblage, marked Cluster 1, 2, 3, etc. The items may have different features, including weight or score expressed in numerals. The item weight refers to significance (the weight scales with the item's significance), and the score represents the year of publication and citation rate. Essential items (according to the weight) stand over the less significant (lower weight) (Van Eck & Waltman, 2022). The size of 'hubs' suggests the occurrence frequency, while curves show the joint occurrence of both words in the same publication, growing with the shorter distance between the hubs (Donthu et al., 2020).

The one-factor analysis of variance (ANOVA) is another method for finding two significant dependent variables, including their intensity. The ANOVA mathematical model explores the relationship between dependent ratios of the interval variable and other variables (factors). We distinguish between one-factor and multi-factor analysis of variance containing more determinants. The one-factor examination tests hypotheses on the equality of means for more than two samples, surveying whether the differences in multiple selection groups are statistically significant or random. The analysis of variance provides an ANOVA table informing on the p-value. We accept the hypothesis if the significance level exceeds 0.5 (p-value > 0.05), which means no significant difference. On the other hand, we reject the theory if the significance is lower or equal to 0.05 (p-value ≤ 0.05), which indicates a huge difference.

Dimensional analysis

Dimensional analysis (Dimensional analysis - Scale reliability) involves analysing problems to explore more viewpoints, including the heart of the matter, the circumstances and dimensions. Its implementation tackles questions representing individual dimensions (Texocotitla et al., 2020). The reliability coefficient ranges from 0 to 1 with no fixed bottom limit, presuming that the closer the coefficient alfa is to 1.0, the higher consistency of the items we achieve (Gliem & Gliem, 2003). Bathgate et al., 2015; Shemwell, Chase & Schwartz, 2015; Wild, 2015; Griethuijsen, 2014; Plummer & Tanis Ozcelik, 2015 use multiple qualitative descriptors for interpreting calculated alfa values. Taber (2017) considers ($\alpha \geq 0.9$) excellent, ($0.9 > \alpha \geq 0.8$) good, ($0.8 > \alpha \geq 0.7$) acceptable ($0.7 > \alpha \geq 0.6$) questionable, ($0.6 > \alpha \geq 0.5$) poor and ($0.5 > \alpha$) unacceptable. The general rule states that α (0.6-0.7) indicates an acceptable confidence level and 0.8 and better or excellent levels. Values higher than 0.95 do not always have to be favourable as they may suggest redundancies (Hulin, Netemeyer and Cudeck, 2001) Alfa coefficient comprises an essential and decisive statistic factor in V&V, including its construction and use (Cortina, 1993), (Schmitt, 1996).

Correlation analysis

Correlation analysis involves the last research method, comprising a background for the ANOVA technique, which specified the previous results. The correlation analysis explores the intensity of interrelationships between selected random variables of the statistical dataset calculated by various correlation coefficients. We generally use two of them: the Pearson and Spearman Correlation Coefficient. Our article applies the Pearson coefficient using R Software (Senthilnathan, 2019) to measure the relationships between X and Y variables. The formula is as follows:

$$R = \frac{n \cdot (\sum X \cdot Y) - (\sum X) \cdot (\sum Y)}{\sqrt{\mathrm{n} \cdot (\sum X^2) - (\sum X)^2} \cdot \sqrt{\mathrm{n} \cdot (\sum Y^2) - (\sum Y)^2}}$$

where: n = number of observations; X = measures of Variable 1; y = portions of Variable 2; ΣX·Y = Sum of the product of respective variable quotas; ΣX= Sum of the scopes of Variable 1; ΣY = Sum of the parts of Variable 2; ΣX2 = Sum of squared values of the measures of Variable 1; ΣY2 = Sum of squared values of the portions of Variable 2. The Pearson correlation coefficient ratio (r or R) measures the intensity of linear relationships between variables. Correlation coefficients (rP) acquire values, while X and Y variables are entirely independent.

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According to the measured magnitude, the interpretation of the correlation coefficient may be as follows:

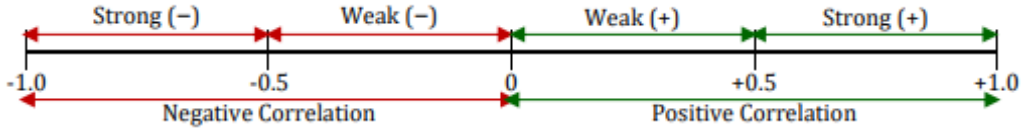


Figure 1. Interpretation of correlation coefficient
Source: Gogtay & Thatte (2017)

Levels of significance in a range of -3.5≤R≤+3.5 find use in social sciences, indicating high statistical significance.

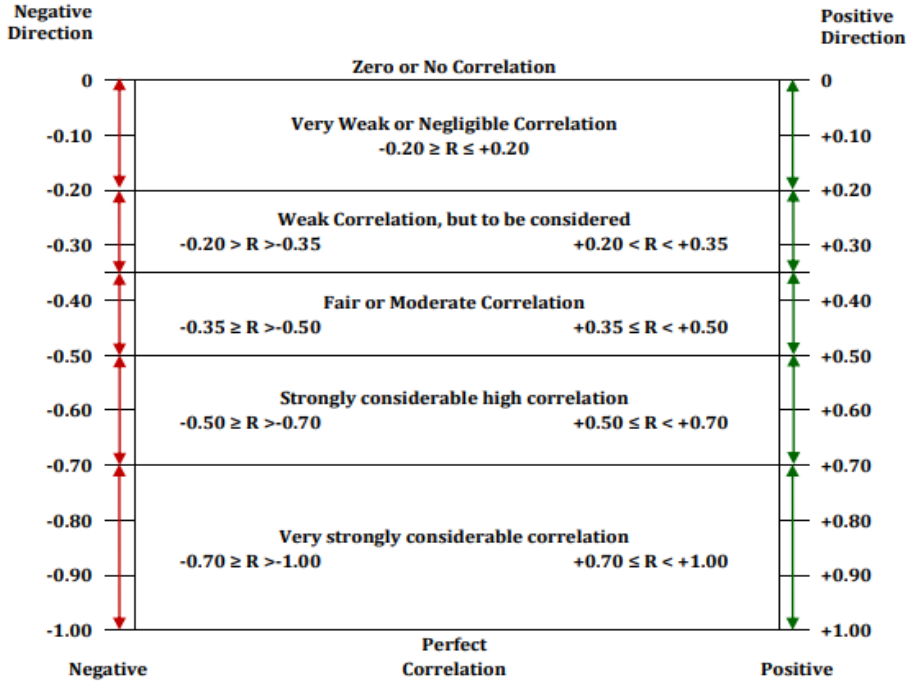


Figure 2. Interpretation of the correlation coefficient in social sciences
Source: Senthilnathan (2019)

Given the inconsistency of observed parameters, Senthilnathan (2019) suggested an innovative scale, giving a new interpretation of the correlation coefficient for social sciences (see Figure 2). The scale will expound upon the dependent variables in the presented study.

3. Results

The global pandemic profoundly affected topics of scientific publication, giving rise to many studies that allow us to conduct bibliometric analysis. We researched worldwide literature published on the Web of Science between 2020 and 2022, using the VOSviewer program to visualise the keywords (see Figure 3). The survey involved 9,825 publications, from which we used only 4,500 pieces. We also included the number of articles published in specific years, including 480 (25%) articles in 2022, 4,554 (46%) articles in 2021 and 2,791 articles (28%) in 2020. Most publications came from the USA (2,258), England (1,100) and China (1,042) from periodicals like the Journal of Asian Finance Economics and Business (299), Journal of Business Research (239) and Journal of Business Ethics (128). The literature explores three widely discussed issues of Economics, Business and Management. The bibliometric analysis involved keywords like 'Home-Office', 'Crisis period', 'SME', 'Organisational changes', 'Pandemic', 'Job positions', 'Workforce', 'Regional development' and 'Employee' comprising all relevant publications. The analysis encompassed all keywords occurring in the articles at least five times, covering only 1,435 from 14,858 words due to the failure to meet the requirements. The term 'Covid-19' showed 5,904 references, indicating the most frequent keyword in the research with a strong relation to the 'performance' and 'impact'. The VOSviewer allowed a survey of the joint occurrence of the

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keywords to reveal the thematic structures of research areas, suggesting intellectual topics and systems of scientific spheres.

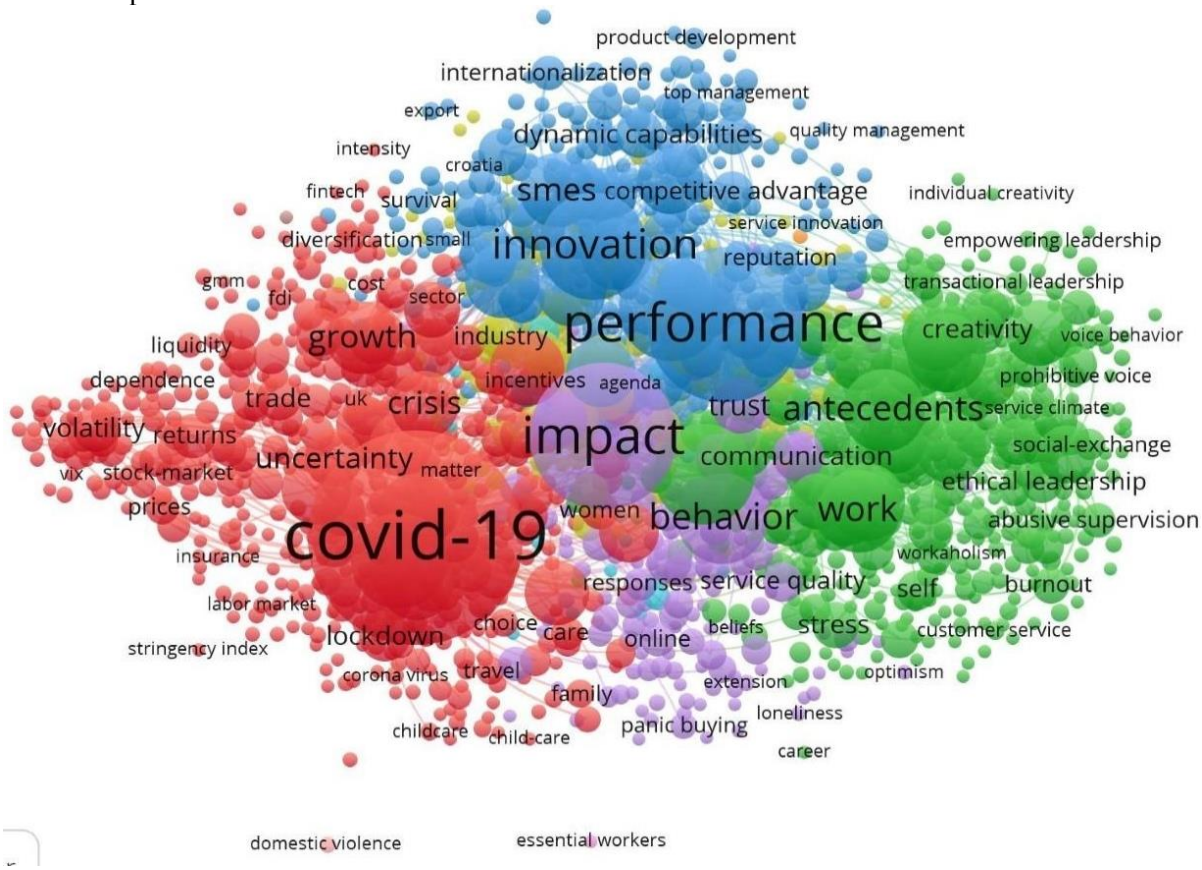


Figure 3. Bibliometric analysis of keywords – Network Visualisation.
Source: the authors

Figure 3 suggests ten analysed clusters. Five of them are dominant, showing great intensity and strong relationships. The remaining five form subgroups of less than 20 items. The separate clusters contain the predominant research category. Cluster (No. 1) 'Business' includes 512 components obtained from 2,439 articles from the WOS database. Its documents focus on the impact of the COVID-19 pandemic on business and its sustainability in various sectors.

Table 1. Results from 4,500 publications from the Web of Science

	COLOUR	ITEMS	FIELD	RECORD COUNT	% OF 4 500
CLUSTER 1	Red	512	Business	2 439	54,20
CLUSTER 2	Green	372	Working Environment	2 288	50,84
CLUSTER 3	Blue	248	Management	913	20,29
CLUSTER 4	Yellow	146	Business Finance	197	4,38
CLUSTER 5	Purple	136	Environmental Studies	172	3,82

Source: the authors

Cluster 2 'Working Environment' encompasses 372 keywords from 50.84% of articles. The studies explore how employees view the working environment. Cluster 3 'Management' embodies 248 keywords from 913 documents, analysing corporate management and its changes in the Covid-19 and the post-Covid-19 era. Clusters 4 and 5 contain 146 and 136 keywords from less than 200 journals, examining impacts, behaviour, sustainability and resistance to adverse effects on subjects.

The achieved outcomes reject H1: ***Addressing impacts of the pandemic on companies, the current scientific community has been using the 'pandemic' and 'impact' with the highest frequency for the last two years.*** Although the sociometric analysis revealed that 'COVID-19' was the most frequent term in the inspected studies,

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the word 'performance' takes second place. The high occurrence of the latter proves that scientists eagerly delved into the corporate behaviour, considering the challenges managers had to face. The term 'impact' ranked third, indicating the current state of the ongoing pandemic crisis where we can monitor, evaluate and quantify its impact on corporate management and its workforce.

Table 2. Results from the correlation matrix

	Field	*Size*	*Relations*	*Age*	*Location*	*Region*	*Position*	*Workload change*	*Remuneration change*	*Members unprovided for*
Field	1									
Size	0.21	1								
Relations	0.13	0.08	1							
Age	0.19	**0.44**	0.14	1						
Location	-0.24	**-0.46**	-0.21	**-0.33**	1					
Region	-0.10	0.26	-0.21	0.24	-0.23	1				
Position	0.13	-0.04	-0.06	-0.05	-0.09	-0.01	1			
Workload change	-0.01	-0.08	0.03	-0.08	0.06	-0.20	0.07	1		
Remuneration change	-0.04	0.06	0.03	0.17	-0.03	0.03	-0.15	0.21	1	
Members unprovided for	0.01	-0.12	-0.11	-0.14	0.15	-0.08	0.06	0.01	-0.14	1

Source: the authors

The outcomes used correlation analysis to answer the second hypothesis H2, ***'The Covid-19 pandemic affected corporate subjects in terms of their market life, the main field of business (NACE), the main scope of the company and the business size'***. Table 2 suggests several significant dependencies between the age and size of the business. The correlation between the size and regions of the province shows an inverse proportion, despite the lack of a broader sense for it in the parametric-categoric data relationship. The age and location also reflect a slight dependence. The table also illustrates a lesser significance between the workload and remuneration changes, indicating a value of 0.21. Answering the third hypothesis, H3, ***'The change in the workload impacted the remuneration'***, involved the one-factor ANOVA analysis depicted in Table 3.

Table 3. Results of the one-factor ANOVA and F-test ANOVA

ANOVA						
Variability source	***SS***	***Difference***	***MS***	***F***	***P value***	***F crit***
Lines	607.9678	248	2.4515	1.3641	**0.00739**	1.232
Columns	160.8213	1	160.8213	89.4897	2.49E-18	3.879
Error	445.6787	248	1.7971			
Total	1214.468	497				
F-test of equality of variances						
	Workload changes		*Evaluation changes*			
Mean value	1.9194		3.056			
Variance	1.8963		2.361			
Observation	248		248			
Difference	247		247			
F	0.8031					
P(F<=f) (1)	**0.0428**					
F crit (1)	0.8108					

Source: the authors

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The research results proved that the change in remuneration impacted the different workloads, indicating the significance level alfa = 0.05. The F-test of equality of variances confirmed the outcome (see Table 3). The current social demand was the impulse for the hypotheses of the collective of authors of this article, observing the topic up-to-dateness regarding the professional experience and consumer use. Considering the pandemic and its repercussions on the corporate environment and workers, we framed several research questions: ***RQ1 'Is there a differentiation by which we can prove that the Covid-19 pandemic affected certain enterprises more than others?'*** This query explored the interrelationship between the Covid-19 pandemic and the differentiation of corporate components, including the market life, main field of business (according to NACE), the main scope of the company and business size. We applied the one-factor ANOVA, testing individual differentiation aspects depending on the identified variable and separate test models (see Table 4).

Table 4. Results of the one-factor ANOVA and F-test ANOVA - research questions

ANOVA – tested RQ1					
Model I.	*RQ1A: Has your remuneration changed during the pandemic period?*				
	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
Market life	2	13.1	6.556	2.825	0.0613
Residuals	246	571.0	2.321		
Model II.	*RQ1B: Has your remuneration changed during the pandemic period?*				
	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
The main field of business	17	71.4	4.197	1.891	**0.0196**
Residuals	231	512.7	2.220		
Model III.	*RQ1C: Has your remuneration changed during the pandemic period?*				
	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
The main scope of the company	2	0.2	0.1189	0.05	0.951
Residuals	246	583.9	2.3734		
Model IV.	*RQ1D: Has your remuneration changed during the pandemic period?*				
	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
Business size	3	19.3	6.445	2.796	**0.0409**
Residuals	245	564.8	2.305		

Source: the authors

*Legend: [Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1" 1]*

Table 4 suggests a profound significance of models II and IV, confirming the research question. The inquiry proved a strong correlation between the sectoral and size differentiation and the Covid-19 pandemic, indicating the P-value >0.05. The dimensional analysis examined parallels between inspected corporate topics and their impact on remuneration and business size, showing great utility for answering the inquiries. We adjusted the dataset to comply with our objectives, forming two groups. We looked for potential changes in remuneration or if wages were the same as before the pandemic (Table 5). We further explored whether there were positive or negative salary alterations (Table 6).

The first research phase dealt with ***RQ2A, 'Which factors mostly contributed to the change in the remuneration regarding the size differentiation?'*** Dimensional analysis - Scale reliability examined a dataset of 78 micro and small, 28 medium-sized and 59 large enterprises, indicating no relationship (or significant correlation) between the observed variables (please be specific) and no change in remuneration related to various business sizes (Table 5).

The second step involved ***RQ2B, 'Which factors mostly contributed to the consistency in the remuneration regarding the size differentiation?'*** Dimensional analysis - Scale reliability again answered our query on a dataset of 78 micro and small, 28 medium-sized and 59 large companies, revealing the remuneration consistency (Table 5).

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Table 5. Results of the Dimensional analysis - Scale reliability: Size differentiation – no changes in remuneration, consistent with the payment before the COVID-19 pandemic.

Model VO2A	Alpha	Stf.Alpha	*Micro & Small enterprises*	*Medium enterprises*	*Large enterprises*
			r(item, total)		
Overall.communication.and. information.to.employees.	0.8421	0.8470	0.6947	**0.8744***	0.6896
The.overall.corporate.strategy.	0.8350	0.8382	**0.7630**	**0.7450**	**0.7467**
Flexibility.and.responsiveness.	0.8374	0.8422	**0.7298**	**0.8807***	**0.7844**
Work organisation.	0.8441	0.8479	0.6917	**0.7014**	**0.7440**
Approach.to.employees..Pay. policy.	0.8600	0.8636	0.5733	0.4681	0.6787
Approach.to.employees. Health.protection.	0.8507	0.8562	0.6330	**0.7783**	**0.7082**
Use.of.digital.technology.for. internal.communication.	0.8752	0.8781	0.4564	0.6654	0.6385

Source: the authors

The analysis showed 'Flexibility and responsiveness' as decisive factors in determining the observed variables (the business size, the consistency in the pandemic and before-pandemic payment), spanning through the business size categories. 'The overall corporate strategy' followed a similar pattern. The issue 'The overall communication and information to employees' stands out only in medium-sized enterprises. These companies apply a traditional organisational structure of effective communication networks. 'Work organisation' and 'Approach to employees and health protection' involve other significant topics discussed in medium and large corporations.

The research question RQ2B, 'Which factors mostly contributed to the remuneration consistency regarding the size differentiation?' used a similar strategy, including dimensional analysis, to evaluate the data. The results showed no change in remuneration during the COVID-19 crisis. Table 6 suggests the distributed dataset using the Data analysis in the MATLAB Program, including 37 micro and small, 24 medium and 22 large firms.

Table 6. Results of the dimensional analysis – testing the factors according to the size differentiation - changes in remuneration

Model VO2B	**Micro & Small enterprises**	**Medium enterprises**	**Large enterprises**
	r(item, total)		
Overall.communication.and.information.to.employees	0.6221	0.5898	0.5304
The.overall.strategy.of.the.company.	0.6561	0.5425	**0.7454**
Flexibility.and.responsiveness.	0.6022	0.5544	**0.7597**
Work organisation.	**0.7207**	0.6272	0.5765
Approach.to.employees.Pay.policy.	0.5773	0.5443	0.5162
Approach.to.employees.Health.protection.	0.5713	0.6086	0.5829
Use.of.digital.technology.for.internal.communication.	0.4871	0.1308	0.3503

Source: the authors

Legend: r-item total > 0.7

Table 6 illustrates three crucial factors affecting size differentiation. Micro and small companies indicated 'work organisation'. Large enterprises included 'the overall corporate strategy' and 'flexibility and responsiveness' as aspects responsible for size differentiation and changes in remuneration.

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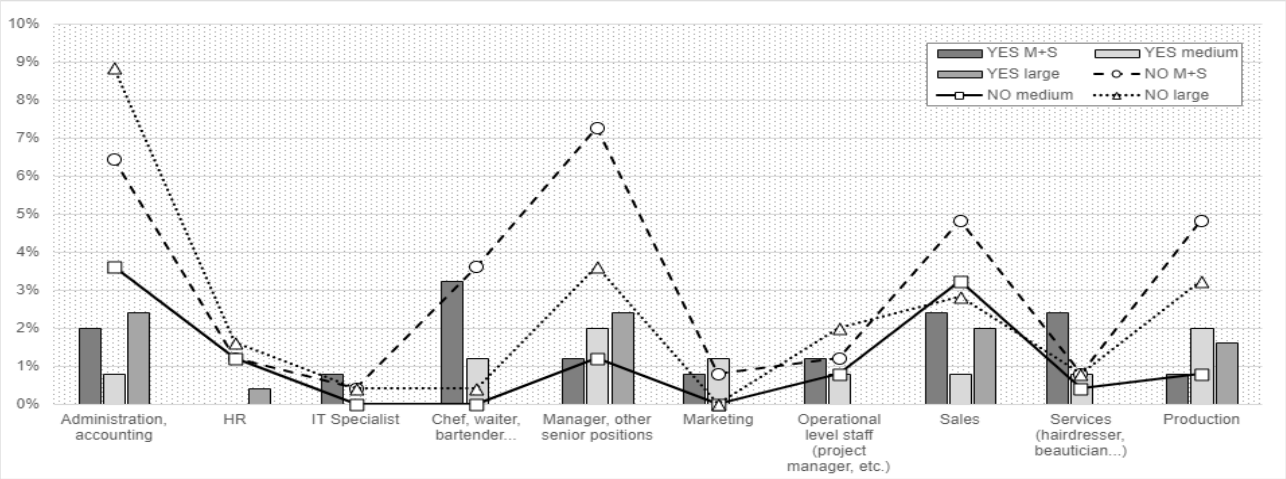


Figure 4. Changes in remuneration per job according to the business size differentiation
Source: the authors

Figure 4 above depicts results suggesting salary alterations per employment according to business size differentiation.

Discussion

The conducted study provided us with the first result approximation, addressing up-to-date and socially significant issues, including the impact of the COVID pandemic on Czech entrepreneurs or the highest business risks during a crisis. We assessed threats to the working conditions of employees who largely contributed to coping with the economic plight and had to respond to the ever-changing situation.

The outcomes involve multiple parts, following the methodology of scientific hypotheses and defining the research questions. The introduction comprises the sociometric evaluation of big data from the WOS database, and the first hypothesis is discussed in the research section. The quantitative analysis encompassed ca 4,500 articles, suggesting the term 'COVID-19' as the most frequent word in the observed field and period. Concepts like 'performance' and 'impact' ranked second and third. Table 1 illustrates the results, containing the relevant cluster, including its interrelation with predominant topics and other keywords. The outcomes prove the significance of the two parameters. The column 'analysed items' shows that the 'performance' cluster double-exceeds the effects of the third cluster 'impact'. The overwhelming dominance of the former might indicate that the social demand aimed to quickly solve or prevent difficulties at the beginning of the crisis, completely overlooking the pandemic consequences. The authors of the presented articles tackled widespread repercussions on the business sector and its employees no sooner than the following year, which corresponds to the findings of Tiutiunyk, Humenna & Flaumer (2021), Belitski et al. (2021), Hamidah, Sriyono & Nur Hudha (2020), Saad et al. (2022), etc. They argue that the COVID-19 pandemic profoundly affected the quality of life and global business activities. The bibliometric analysis explores the relationship between the pandemic and business, confirming the discernible global trends. Individual clusters assess the effects of the Covid-19 crisis on the business sector, define corporate organisational factors, explore the unemployment rate and social aspects and measure impacts on public health.

The following research involves a correlation analysis of interrelationships between the parameters, detecting significant variables with different relation intensities. The method provided data on the impact of the business size (micro and small, medium and large enterprises) on the change in remuneration during the COVID-19 crisis (Hypothesis 2). The outcomes proved no causality in the relationship between the business size and salaries. The enterprises were careful about possible negative scenarios that unfolded later on. Table 2 suggests other analysed relationships, indicating a medium correlation between the corporate size, the company's age and province (local, regional or national). A weaker correlation exists between the company's age and the residence (calculated to NUTS 3 region unit). The findings revealed that the business age, size and expanding, yet limited, globalisation are hastily pushing companies to extend their province. This enormous pressure mounts with massive digitisation, dramatically expanding during the Covid crisis. The coefficient between the workload and

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remuneration changes indicates a weak correlation, requiring a one-factor ANOVA analysis for reliable, detailed information. The F-test of variance confirmed the relationship, reflecting a deliberate national (regional) subsidy policy. Despite the efforts, the subsidy sometimes went to worthless items throughout business sectors, showing unequal and uneven redistribution. Our results correspond to Molina (2021) and Francis-Devine (20220, who point to ambitious support schemes for wage increases despite declining GNP.

Ultimately, we collected answers to research questions involving ***RQ1, 'Is there a differentiation by which we can prove that the Covid-19 pandemic affected certain enterprises more than others?'*** (according to the market life, main field, scope and business size). The one-factor analysis proved a strong dependence on sectoral differentiation, including a specific sector and size. We may confirm that enterprises with an established home office handled the crisis better than vital industries like healthcare, food industry, agriculture, power engineering or cybersecurity, without which the society would collapse. Scientists point to diverse effects throughout the demographic population structure, regarding education (including different sectors) and territory as crucial factors behind the successful surmounting of the crisis (Montenovo et al., 2021; Bloom et al., 2020; Anayi et al., 2021).

The findings provided decisive factors for dimensional analysis, observing two possible scenarios, ***RQ2A, 'Which factors mostly contributed to the change in the remuneration regarding the size differentiation?'*** and ***RQ2B, 'Which factors mostly contributed to the consistency in the remuneration regarding the size differentiation?'*** First, we explored the change in remuneration, incorporating the factors analysed according to size differentiation (RQ2A). The outcomes showed that the work organisation in small enterprises and overall corporate strategy and flexibility and responsiveness in large companies are key determinants behind alterations in remuneration. The final part presents reactions from individual corporate subjects, suggesting jobs affected by radical changes in salaries, including administration, accounting and senior management. Commercial representatives and operatives reflected slight inconsistencies, while the IT sector and marketing spotted no change. Second, we examined remuneration consistency throughout business sectors (RQ2B), involving the overall corporate strategy and flexibility and responsiveness as the crucial factors in dealing with a crisis (Straková et al., 2020; Schoenwaelder et al., 2020; Kazancoglu et al., 2022). Medium and large firms embodied the approach to employees' health protection as major determinants, indicating that personal interest and concern played a vital role during the pandemic.

Conclusion

Czech enterprises have never encountered a crisis of such a magnitude as the COVID-19 pandemic, which radically affected working environments. We foresee that SMEs and large companies will feel economic repercussions and impacts for several years. The presented article explored various hypotheses and research questions, observing decisive factors behind jobs, remuneration and classifying corporate subjects. The results proved a direct correlation between business age, size, salary, and workload changes, considering size and sectoral differentiation. The empirical findings incorporated in this study comply with the suggested theories and sociometric analysis. Although this is only the first approximation of outcomes, we arrived at interesting conclusions using one-factor, correlation and dimensional analysis presented in this article.

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THE COMPETITIVENESS FACTORS OF AGRICULTURAL SUBSECTORS UNDER INNOVATIVE DEVELOPMENT

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Abstract. The current trend in developing global economic processes directly influences the transformation of national economies. A key conceptual element of any socio-economic system has been, and continues to be, the achievement of substantial competitive advantages, the preservation and strengthening of various aspects of security (including food, economic, and national security), the attainment of a high level of socio-political stability, and improvements in both quality of life and population well-being. An efficiently organised and structurally coherent food market is crucial in realising these strategic objectives. In turn, this market's performance dynamics and development trends are closely correlated with the performance indicators of individual subsectors within the agro-industrial complex (AIC) and the food industry. Among these, the domestic meat production subcomplex plays a pivotal role in shaping structure, ensuring system integrity, maintaining a holistic approach, and supporting sustainable socio-economic growth in the aforementioned sectors.

Keywords: livestock farming; competitiveness; meat products; production; stakeholders; programs; mechanisms; regulations; factors

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JEL Classifications: Q01, Q13

1. Introduction

The current trend in the development of global economic processes directly determines the nature of transformation of the national economy. These processes have specific qualitative and quantitative parameters directly impacting the country's socio-economic development. The conceptual aspect for any form of socio-economic management was, is and remains the provision of highly competitive advantages, preservation and strengthening of security (food, economic, national), achievement of a high level of socio-political stability, growth of the quality of life and well-being of the population. An effectively organised and structurally verified food market is essential in achieving these targets. In turn, the dynamics of its functioning and development trends are closely correlated with the performance of individual sub-sectors of the agro-industrial complex and the food industry. In particular, the domestic meat-product subcomplex plays a key role in structure formation, comprehensiveness, systematicity, and integrity, as well as ensuring a sustainable trend of socio-economic growth in the abovementioned spheres.

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In modern organisation and management, the agricultural sector is paramount in establishing and strengthening the position of the domestic agro-industrial complex both at the national and global levels. In particular, this industry segment from the economic and social points of view is the most important in the system of ensuring food security of the country, as meat and meat products belong to the category of socially significant, and the level of their consumption directly determines the overall indicator of the quality of life of the population. Among Central Asian countries, which are members of the CIS and EAEU, Kazakhstan is the leader in producing livestock and poultry meat, about 1100 thousand tons per year in slaughter weight. This is about 10 times higher than in Armenia, Azerbaijan, Uzbekistan, Kyrgyzstan and Tajikistan. The article presents an overview of the current state of the meat industry in the Republic of Kazakhstan. The industry's achievements are shown, and the problems that have arisen due to the implementation of state programs are noted.

2. Literature review

Competitiveness of agricultural sector is studied internationally by numerous researches (Abad-Segura et al., 2024; Nowak & Zakrzewska, 2024; Tran et al., 2024; Meziani et al., 2024). The problem's relevance prompts domestic researchers to study the development of livestock farming under current conditions. The livestock industry holds a strategic position in the economy of all countries, as it provides the population with affordable food products and thus ensures food security at both national and regional levels.

Issues related to the development of fundamental principles, concepts, and mechanisms, as well as the establishment of state support measures and enhancing the competitiveness of the meat industry, have been addressed in the works of domestic scholars such as Zakshevsky et al. (2020), Kaliev & Moldashev (2021), Kakharmanova (2020), Mukhamedova et al., (2022); Mizanbekova et al. (2022), Mizanbekova et al. (2024), Moldashev et al. (2024), Abildaev et al. (2025), among others.

The study of this topic is especially relevant in addressing the growing demand for environmentally friendly and safe meat products, which necessitates the development of advanced technologies and increased entrepreneurial activity among large, medium, and small agribusinesses (Safta & Popescu, 2024; Al-Amin et al., 2025).

In recent years, the demand for livestock products has increased dramatically due to the global population growth. Consequently, there is a pressing need to develop new approaches to circular economy models and sustainable, environmentally clean production systems. As noted by Kurmanova et al. (2022), Dambaulova et al. (2022), Kydyrbaeva et al. (2024) and Abdikerimova et al. (2024), the application of innovative technologies significantly influences the level of agricultural development, particularly the quantity and quality of farm products, as well as improvements in productivity and labour efficiency — all of which contribute to the resilience of rural areas.

Role of innovations in the meat industry, including technological advancements and use of Artificial Intelligence (AI), is currently studied by many authors (e.g., da Silva & Carrer, 2023; Wang & Li, 2024; McCarthy et al., 2024; Hinrichsen & Stoier, 2024; Chatti & Majeed, 2024; Walden & Stathopoulos, 2024; Lyu et al., 2025). In their research, Issa et al. (2024) and Kolesnikov and Kharina (2025) emphasised that food security, preservation, and healthy nutrition are closely interconnected and mutually reinforcing. Zielinska-Chmielewska (2023) emphasised the importance of economic policy for fostering the environmental efficiency of the meat industry.

3. Research methodology

The study aims to identify the key problems of competitiveness of Kazakhstan's meat industry and justify its development in the conditions of innovative transformations of the agro-industrial complex. To achieve the goal, it is necessary to solve the following tasks:

- To analyse the current state of the meat industry in Kazakhstan;
- To determine the main factors restraining its competitiveness;

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- To consider the possibilities of application of innovative solutions in the industry;
- To offer practical recommendations to improve the efficiency of meat production.

The object of the study is the meat industry of the agro-industrial complex of the Republic of Kazakhstan.
The subject of the study is the economic, organisational, and technological aspects of improving the competitiveness of the meat industry in terms of innovation development. Statistical data of significant meat industry enterprises were collected for the study.

Hypotheses of the study: It is assumed that the growth of domestic meat production in Kazakhstan in 2020-2024 contributes to reducing dependence on imports and forming sustainable export potential of the country in international markets. It is also assumed that the development of the meat industry stabilises prices and improves the country's food security.

Problems constraining the development of competitiveness:
-Technological lag - many meat processing plants operate with outdated equipment, which reduces productivity, increases costs and limits the introduction of modern quality standards;
-Shortage of personnel and weak scientific and educational base;
-Lack of qualified specialists in veterinary medicine, biotechnology, automation and logistics makes it challenging to implement innovations;
-Low level of innovation activity; iinvestments in R&D (research and development) remain limited. The industry has little interaction with scientific institutes and startups;
-Logistical and infrastructural problems: lack of modern cold storage facilities, logistics centres and efficient distribution channels hinders the development of export potential;
-Imperfect regulatory framework, slow certification procedures and differences in international standards hinder access to foreign markets.

4. Results and discussion

The meat industry is considered one of the economy's main branches in the sphere of material production, and its development determines the complete nutrition of the population with such products as meat and dairy products. In Kazakhstan, the production and consumption of meat and dairy products are connected with the ethnic peculiarities of nutrition of the inhabitants. History presents us with a rare opportunity to compare and comprehend the reforms that have taken place in the agricultural sector, taking into account the influence of socio-psychological, organisational-economic, national, environmental factors and introduce new ones.

The increase in consumer demand for meat and meat products, weak investment activity and high rates of dependence of the agricultural market on imports determine the need to develop the meat industry. Over the past period, the meat industry's share in Kazakhstan's GDP amounted to 2.3%, and in the volume of gross agricultural production amounted to 45% (Table 1).

Table 1. Gross Domestic Product for 2022-2024 mln. tenge

Indicators	2022	2023	2024	2024 to 2022	
				+/-	%
GDP total	54 378,9	61 819,5	69 532,6	15 153,7	127,9
agricultural GDP	4 092,3	4 497,6	5 177,9	1 085,6	126,5
Including: livestock breeding	1 810,9	2 050,5	2 319,5	508,6	128,1

Source: Bureau of National Statistics ASPiR RK https://www.gov.kz/memleket/entities/stat?lang=en

Table 1 shows that the GDP of agriculture increased by more than 26.5% in 2024 compared to 2017 and amounted to 5,177.9 billion tenge. In agriculture, the GDP of livestock showed an increase of 28.1% and amounted to 2,319.5 billion tenge. The specificity of meat and meat product manufacturing is directly interconnected with the peculiarities of the livestock industry. Economic growth and an increase in competitiveness of domestic commodity producers in the meat market are associated with the forced development of all types of livestock.

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The main goal of the meat industry development in Kazakhstan is to increase the level of provision of the country's inhabitants with meat and meat products of the current production in accordance with the rational norms of consumption. Rational consumption norms represent a balanced set of products considering the nutritional traditions of the population.

There is economic and physical availability of food. Economic accessibility refers to the purchase of products at existing prices in terms of volume and assortment in accordance with the income level of the population. Physical accessibility refers to the coverage of consumers by the commodity distribution infrastructure (Garcia-Garcia et al., 2021).

According to statistical data from 2024, the state provided the population of Kazakhstan with all types of meat and meat products, despite the price growth of 6% in annual dynamics. In the regional context, prices for meat and meat products rose more strongly in Akmola region: by 11.8% over the year. The top five regions with the highest price increases were East Kazakhstan, Atyrau, Ulytau and Abay. The lowest price growth in the sector was observed in Shymkent, Turkestan, and West Kazakhstan regions. In March 2024, beef was sold at an average of 2.7 thousand tenge per kg, mutton at 2.8 thousand tenge, pork at 2.3 thousand tenge, horse meat at 3 thousand tenge, and chickens at 1.5 thousand tenge.

Table 2. Number of livestock and poultry as of April 1, 2024, thousand heads

Name of livestock	2024/03	2023/03	Year-on-year growth
Cattle	4 710,1	4 502,4	4,6%
Cows	2 365,4	2 118,9	11,6%
Sheep	12 101,6	10 906,7	11,0%
Goats	762,3	767,0	-0,6%
Pigs	310,3	329,0	-5,7%
Horses	2 569,6	2 405,9	6,8%
Camels	156,1	145,0	7,6%
Bird	38 335,0	36 564,7	4,8%

Source: Bureau of National Statistics ASPiR RK https://www.gov.kz/memleket/entities/stat?lang=en

According to the Bureau of National Statistics ASPiR RK, in January-March 2024, Kazakhstan produced 20.3 thousand tons of fresh and chilled meat of cattle, pigs, sheep, goats, horses and animals of the horse family, by 13.9% more than a year earlier. The dynamics and forecast of meat – Gross Production Value is provided below in Figure 1, and Revenue is shown in Figure 2.

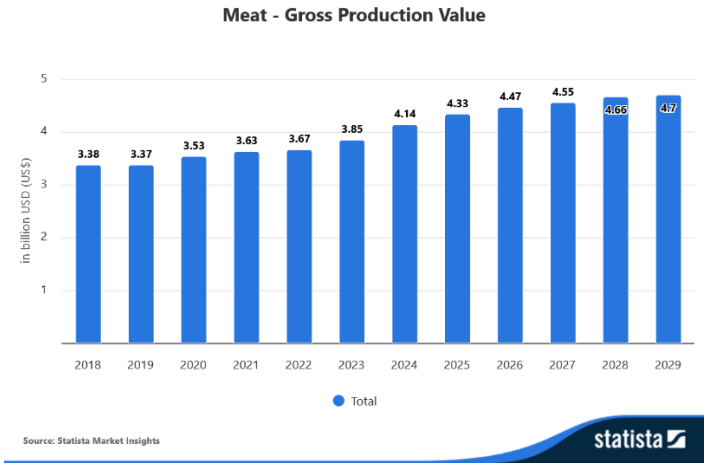


Figure 1. Dynamics and forecast of meat – Gross Production Value.
Source: Statista. (2025). Meat - Kazakhstan. Statista. https://www.statista.com/outlook/emo/food/meat/kazakhstan

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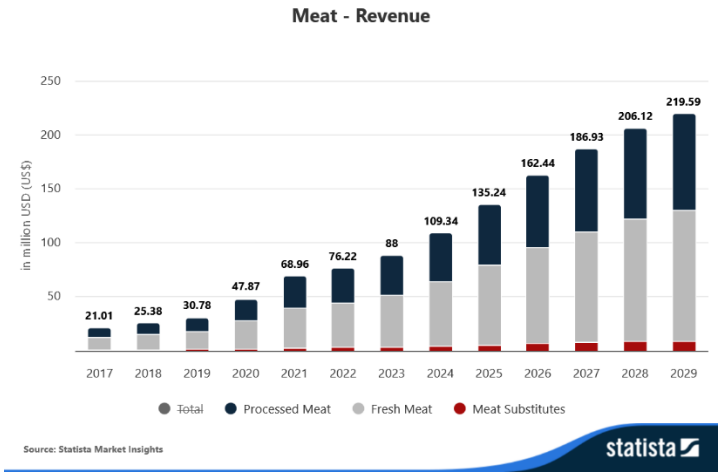


Figure 2. Meat - Revenue
Source: Statista. (2025). Meat - Kazakhstan. Statista. https://www.statista.com/outlook/emo/food/meat/kazakhstan

In the regional context, the most significant production volume fell in the Aktobe region: 3.5 thousand tons, an annual growth of 24.8%. Kostanay region (3.1 th. tons), North-Kazakhstan region (2.8 th. tons), Pavlodar region (2.6 th. tons), and Akmola region (1.8 th. tons) were also among the five leading regions.

Table 3. Production of certain types of livestock products

Product Name	2024/03	2023/03	Year-on-year growth
Livestock and poultry slaughtered on the farm or sold for slaughter in live weight (thousand tons)	235,1	219,0	7,3%
Livestock and poultry slaughtered on the farm or sold for slaughter in slaughter weight (thousand tons)	154,9	143,3	8,1%
For reference:			
Cow's milk (thousand tons)	347,2	316,8	9,6%
Chicken eggs (mln. pcs.)	935,4	322,3	1,4%
Large hides (thousand pieces)	227,4	219,1	3,8%
Small hides (thousand pieces)	348,4	334,0	4,3%

Source: Bureau of National Statistics ASPiR RK https://www.gov.kz/memleket/entities/stat?lang=en

In general, the production of livestock products from January to March of this year is in luce. For example, the output of hen's eggs increased by 1.4% over the year, to 935.4 million pieces. Cow milk yields in farms amounted to 347.2 thousand tons, 9.6% more than a year earlier. Production of large hides increased by 3.8% over the year to 227.4 thousand pieces, and small hides by 4.3% to 348.4 thousand pieces. Based on system analysis using economic and statistical data, the priority directions for increasing the country's meat industry's competitiveness are determined.

In the accepted world norms for ensuring food security, it is considered that imported food products brought into the country should not exceed 15% of the total volume of its consumption (Golovatiuk et al., 2022). To date, there is an increase in consumer demand for meat and meat products. In the development of the meat industry of the agricultural sector, the import indicators are over 19%, which exceeds the security threshold.

Kazakhstan provided the population with all types of meat and meat products at the level of 78.3 kg per capita, with the share of imports amounting to 19.2%. In 2022, the provision was 73.6 kg per capita, and the share of imports reached 20.3%. Thus, at the moment, the volume of production of meat and meat products has almost reached the annual rational consumption norm and amounts to 78.3 kg per capita (Kaliev & Moldashev, 2021). At the same time, the physiological norm of consumption of meat and meat products is on average 84 kg per capita.

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The state is working on withdrawing irrationally used land and simplifying access to it for all those wishing to open their own business and engage in farming (Kalmus et al., 2024). The existing meat-processing enterprises are being re-equipped at a good pace. At LLP "Semipalatinsk meat processing plant", the latest equipment and automation of technological processes were introduced, which contributes to improving the organisation of service workplaces, significantly increasing the level of technical equipment of the enterprise. The enterprise is reconstructing production shops, and new equipment from world leaders (Russia, Germany, Italy and France) for production, packing, and packaging of sausage and meat products has been installed. Among other things, the newest technological line for meat processing and production of meat products has been launched. The latest technological line is equipped with 22 units of modern equipment from the Austrian company "Schaller" worth 1.3 million dollars. The uniqueness of the equipment lies in automatic sensor execution, ease of operation, quality development of raw materials and finished products, speed and high productivity.

The meat processing plant is a specialised enterprise that processes all types of livestock and produces meat, sausage, and canned goods. The plant's production site is equipped with convenient automobile and railway entrances, which reduces transportation costs. All products have a wide range, about 200 types of meat products. The products undergo veterinary control at all stages of the technological process (from the moment of delivery of raw materials, processing, production and ending with their sale). This plant produces: 35 thousand cans of canned meat per shift; 10 tons of sausage products, minced meat and dumplings; 24 tons of products sold daily (Kalpakpaeva et al., 2022).

Ordabasy Kus LLP is the largest poultry complex in South Kazakhstan for cultivating and processing turkey meat. This company began to export 35% of the total volume of products to the countries of the Customs Union (EAEU), producing about 8 thousand tons of finished products. The company plans to reach full production capacity in the coming year, expand the range to 100 items, and increase exports to 50%. (Kydyrbaeva et al., 2024). Representatives of the Meat Union of Kazakhstan believe that the growth of meat exports is the result of the systematic development of the industry, which by the end of 2023 will almost close domestic consumption. Every inhabitant of the republic consumes an average of 72.9 kilograms of meat and meat products annually. This allows us to increase sales abroad.

Over the past five years, the Republic of Kazakhstan has opened international markets for domestic meat, including China, Iran, the United Arab Emirates, Saudi Arabia and Oman. It has also increased supplies to CIS countries such as Russia, Uzbekistan, Kyrgyzstan, Tajikistan, etc. Kazakhstan currently ranks 17th with a share of 0.01% among meat-exporting countries (Kalmus et al., 2024). However, the growth of production and exports (see Figure 3) and imports (Figure 4) could not create a solvent consumption of meat in the country, so the product became less accessible to a broad population segment.

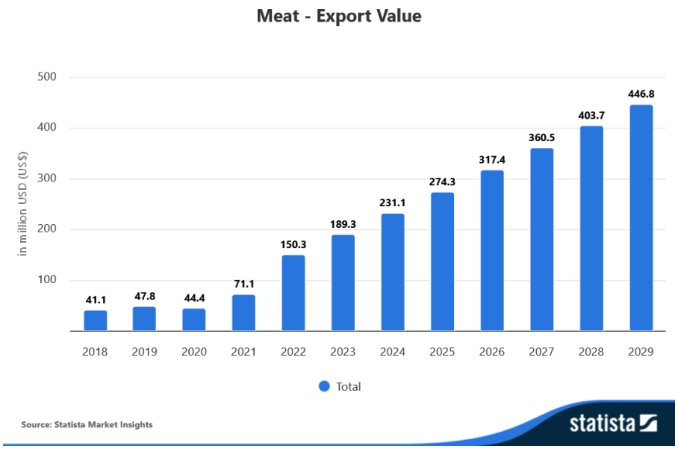


Figure 3. Meat – Export Value
Source: Statista. (2025). Meat - Kazakhstan. Statista. https://www.statista.com/outlook/emo/food/meat/kazakhstan

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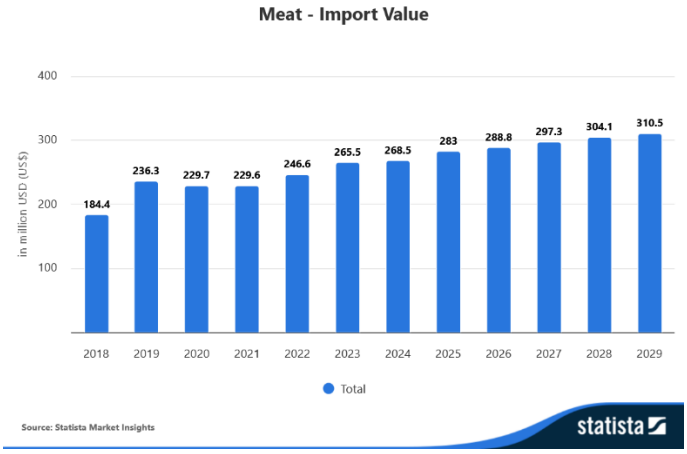


Figure 2. Meat – Import Value
Source: Statista. (2025). Meat - Kazakhstan. Statista. https://www.statista.com/outlook/emo/food/meat/kazakhstan

The gross meat production in slaughter weight covers 87% of the domestic market. The market share of exports is 14.5%, which is only 2% of the domestic output. The meat industry's position in Kazakhstan is even weaker in the deeper processing of raw materials. For example, imported sausages occupy 38% of the market. Meat processing and storage facilities are idle. Specialised storage facilities for meat are loaded by only 38.7%, and degradation is observed for food by-products from farm animal meat.

The heads of processing enterprises point out the existing obstacles to their further development. First, there is a shortage of working capital and raw materials for processing. Moreover, these problems are interrelated: no money, no raw materials, and vice versa. All this translates into the issue of insufficient workload for enterprises. On average, the workload of enterprises in the industry ranges from 30 to 40%. Adding to the complexity is the massive purchase of live cattle by entrepreneurs from Uzbekistan, who export, process and sell high-quality Kazakh meat to foreign countries under the guise of their own. Processors see the solution to the issue in investment subsidies for processing enterprises (Uspambayeva et al., 2020; Kurmanova et al., 2022).

In recent years, the implemented programs within the agroindustrial complex for animal husbandry and meat processing have been characterised by experts as a period of missed opportunities. With significant government support, the qualitative indicators of market positions in the domestic market are modest. Regarding gross meat production by slaughter weight, the share of local producers in the domestic market increased from 85% to only 87%. Kazakhstan is still a net importer of meat (Nurakhova et al., 2023; Kolesnikov, 2025).

About two trillion tenge was spent on subsidies within the framework of three state programs for developing the agro-industrial complex. However, at the same time, the industry's indicators have not grown and are seriously lagging behind world records. Experts believe that, as a result, the operators of development programs lacked the competence to monetise public financing resources into quality. Moreover, state support for agriculture in the meat industry has passed professional business by. Thus, the availability of developed government programs and financing is not always the key to successfully implementing the goals.

The analysis and the results of the study show that meat processing enterprises are at the initial stage of their development, do not have high results, it is difficult for them to develop independently, and the conclusion is that only with the participation of government agencies, the livestock industry and related sectors of the economy can they achieve the desired result.

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Conclusions

According to research, the current investment and technological activity of the country's meat industry enterprises do not contribute to increasing the competitiveness of enterprises due to a lack of funds, high cost of modernisation, long payback period, and insufficient government support. In this regard, domestic timber companies suffer heavy losses, which do not allow them to conduct expanded production.

To solve the issues of improving the quality of primary raw materials, it is necessary to apply methods and new forms of organisation of preparation with acceptable functional and technological characteristics of raw materials, allowing the achievement of the assigned quality of the final product and to improve the legislative sphere of the meat industry development. Financing should be increased to partially cover the cost of buying feed and breeding cattle, which will reduce the cost of meat by 10%, increase profitability by 7%, and lower the threshold for loan rates.

Due to the construction of high-tech and modernisation of existing enterprises, it is necessary to increase production capacities for the slaughter and processing of livestock and the production of meat products. To increase profitability and occupational safety, achieving a high level of integrated production process automation and reducing the proportion of manual labour is necessary.

Due to the optimal and integrated use of the meat industry's primary and secondary raw materials, it is necessary to increase the processing volume. This will improve environmental safety and increase the production of a marketable product.

It is necessary to modernise a multi-stage logistics structure, where there should be integrated wholesale distribution centres, warehouses, refrigerating and freezing chambers, specialised vehicles for servicing enterprises in a specific regional area, which will reduce the shelf life of meat raw materials and energy costs, including transport.

Solving the problems of the meat industry will make it possible to fill the domestic market with a wide range of domestically produced meat products, improve product quality, increase the profitability of existing enterprises, create more high-tech, export-oriented productions, and open new jobs.

Increasing the competitiveness and efficiency of meat processing enterprises will allow them to take an active part in the international agricultural market in the future.

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SUSTAINABILITY AWARENESS: EVIDENCE FROM JAPAN

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Abstract. This article aims to assess sustainability awareness among the Japanese and the commitment of governments and civil society. The study delves into Japan's historical and cultural background, exploring the interplay between these factors and the natural environment. Original research was conducted through a survey questionnaire administered to native Japanese people and residents of Japan. The key findings indicate a correlation between the historical and cultural origins of the Japanese and their relationship with nature, which influences the current specificity of environmental policies in Japan. An assessment of the implemented actions confirms these initiatives encompass all pillars of sustainability: environment, society, and economy. However, Japanese society's sustainability awareness and knowledge level fall below the global average. The data also reveal a gradual improvement over the years. The study concludes that Japan faces significant challenges and risks to sustainable development, particularly those arising from climate change, which are anticipated to become increasingly severe.

Keywords: sustainability; SDGs; Japan; Tokyo; Mottainai; Satoyama; local development

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1. Introduction

Sustainable development has been receiving increasing attention over the past years. It was recognised globally in the 1970s, which might seem like a long time ago, but on the other hand, it is a very short time considering all the aspects and frameworks behind this topic. It is crucial now, as climate change and global warming have made people realise that society must abandon the standard economic model based solely on economic growth and strive for more sustainable, environmentally friendly, and socially responsible growth and development. Therefore, raising awareness of these problems among citizens and determining the optimal involvement of stakeholders and decision-makers in activities to address these challenges is a critical issue today. Therefore, this study addresses the research subject of assessing sustainability awareness in the chosen society, specifically among the Japanese.

Japan is one of the world's most significant and most developed economies, and Tokyo is the world's largest and most populous city. Japan's approach to sustainability is comprehensive, addressing financial, industrial, agricultural, and social dimensions. The country's policies and initiatives are committed to balancing economic growth, environmental protection, and social well-being. Japan's global position in sustainable development is characterised by its commitment to health as a fundamental aspect of human security, its

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translation of sustainable development into international cooperation, and its proactive role in global health and environmental sustainability. Based on the example of Japan (especially its capital, Tokyo), this study focuses on analysing the practical implementations of sustainable development. It explores the unique characteristics of the mentioned Asian area. Such an example enables the exploration of the transformation process of an economically prosperous country, which is also exotic in its location and cultural aspects compared to the Western world.

The study aims to examine Japan's cultural aspects related to sustainability and explore the relationship between these two issues. Moreover, this paper seeks to assess the governmental commitment to sustainability at both local and national levels and evaluate society's knowledge and involvement in achieving sustainable goals.

The primary focus of this research is Tokyo as a metropolitan area. The time frame analysed from the perspective of the implemented actions focuses on years after 2000. However, the theoretical background of sustainability and the cultural aspects of Japanese society include information dating back to the 8th century. In addition to the secondary research, this study incorporates the authors' research on sustainability awareness in Japanese society, which was conducted using a survey questionnaire (CAWI method). Additionally, benchmarking analysis evaluated Tokyo's sustainable performance based on specific indicators and its position among sustainable cities. Finally, the study described the most significant challenges that might hinder sustainable development in Japan and potential future scenarios.

2. Literature review

Sustainability and sustainable development have gained significant attention in environmental science, policy, and global governance. While closely related, these terms have distinct meanings, histories, and implications. This literature review limits itself to establishing the article-relevant framework for their definitions, historical evolution, conceptual frameworks, and key differences only in the light of this research.

Since the term "sustainability" was first used in 1713 (Wilderer, 2007), it was primarily referred to as the responsible use of natural resources for a considerable period. Since then, numerous definitions of sustainability have been proposed, and the term has evolved, sparking a debate about the concept's scope (Borusiak, 2021). Despite various definitions of sustainability widely covered in the literature (Chang et al., 2017), the typical elements of the concept include human adaptation, change, maintenance, resource scarcity, and environmental, economic, and social factors. The first three factors can be found in almost all of them, implying that humans should be able to adapt to the changes that occur while searching for a balance between using resources today and in the future. (Smith, 2015) The core assumption of sustainability is that "current decisions should not impair the prospects for maintaining or improving future living standards. This implies that our economic systems should be managed so that we can live off the dividends of our resources" (Rogers et al., 2008). This broader concept of sustainability roots back to the United Nations Conference on the Human Environment in 1972, which focused on human interactions with the environment and resulted in the Stockholm Declaration (United Nations, 1972), later from 2015 adapted into the United Nations 2030 Global Agenda (United Nations, 2022), and European Union agenda (European Union, 2020) which define the 17 sustainable development goals (SDGs). In scientific literature today (Mensah, 2019; Ruggerio, 2021; Sakalasooriya, 2021), sustainability is often referred to as a process rather than an end state, emphasising adaptability, resilience, and the maintenance of ecological and social systems for current and future generations.

The concept gets more complicated when we assess its relation to another term, "sustainable development", and differentiate the latter from sustainability. The reason is that many sources use these two terms interchangeably and similarly interpret them. (Dixon & Fallon, 1989; Borusiak, 2021; Mazza, 2021) The Brundtland Report defined the most common definition of sustainable development in 1987, which also refers to it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). It can be noticed that while those terms represent common pillars and share principal values, they differ in purpose (Table 1). Sustainability is the leading, long-

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term goal. At the same time, sustainable development refers primarily to a growth strategy, representing the process by which sustainability is achieved.

Sustainability vs Sustainable Development	
Similarities	**Differences**
Importance of environmental, economic, and social factors	Sustainability's primary goal is to achieve and maintain balance (between the three factors)
Acting for future generations' needs	Sustainable development focuses on improving everyone's well-being and quality of life
Responsible resource management and nature maintenance	Sustainable development primarily aims to create growth vs Sustainability aims for self-sufficiency and maintenance

Table 1. Sustainability vs Sustainable Development Comparison Chart
Source: authors' elaboration based on Rogers et al., 2008; Christiansen, 2016; Mensah, 2019; Ruggerio, 2021; Sakalasooriya, 2021; Stefańska, 2021

This difference is a crucial consideration when interpreting the current research results, as respondents typically refer to sustainability from an ecological perspective, particularly in light of the local values that shape the societal context (Kaze et al., 2022). Consequently, this interpretation determines the economic development and priorities of the societies (Schwartz, 2004; Kaze et al., 2011), including the business environment (Sceulovs et al., 2011; Czupryna & Schaff, 2024) and behavioural choices (Kaze & Bolinskis, 2011). Values influence proenvironmental behaviour and are linked to cultural relevance (Primc et al., 2021), while cultural differences may affect the interpretation of the sustainability context. This might lead to a loop where customer demands, priorities and lifestyle are influenced by changes in the external environment arising from the transformation of the economic structure (Kaze et al., 2007), facilitating an awareness of new needs for the society in an ever-changing economic and social environment of modern societies. In this context, Japanese society has traditionally been more concerned about environmental preservation (Bichler, 2023), which may be reflected in consumer behaviour (Hiratsuka et al., 2018) and, consequently, sustainability issues.

Sustainable interactions between nature and people – Satoyama and Mottainai concepts

Japan's culture deeply values the concept of harmony between nature and humanity. One such concept is Satoyama, a rural area comprising different ecosystem types, including secondary forests, agricultural lands, irrigation ponds, grasslands and human settlements (Dublin & Tanaka, 2014). It is said that Satoyama agricultural land systems were created at least 3000 years ago, and their role was to benefit people in harmony with nature, supporting high biodiversity and ecosystem services (Takeuchi et al., 2008; Jiao et al., 2019). Satoyama serves as a model of sustainability, and its areas are currently estimated to cover between 18% and 67% of Japan's national land, depending on the definition (Berglund, 2014; Hiratsuka et al., 2020; Iwachido et al., 2020). Although most traditional Satoyama landscapes have been abandoned, monitoring studies have shown that the remaining Satoyama areas continue to contribute to the proper functioning of the ecosystem. For example, traditional woodland management in Satoyama, such as coppicing, can absorb significantly more carbon than modern forestry systems, which often involve intensive thinning activities. Additionally, high connectivity within forests, croplands, and water sources of conserved Satoyama provides a place for the nesting and foraging of birds and habitats for the entire lifecycle of insects (Kim et al., 2017). In brief, the Satoyama model offers solutions for nature conservation, disaster prevention, and even encourages innovation.

Another crucial aspect of the Japanese connection between nature and people is the concept of Mottainai. Its primary roots lie in the Shinto ("the way of the gods") tradition, a native religion in Japan (Olejarz, 2011; Lee, 2018), where it conveyed the meaning of gratitude and shame for receiving a more excellent favour than one deserved (Suzuki, 2017). Mottainai was also commonly used by Buddhists who regretted the waste or improper use of something sacred or highly respected, such as religious objects or teachings (Suzuki, 2017).

According to the modern dictionary, the meaning behind the word 'mottainai' is "wastefulness" or "a sense of regret concerning waste when the intrinsic value of an object or resource is not properly utilised" (Jisho, n.d.). It is commonly used in the Japanese language and refers not only to material goods but can also express time,

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effort, feelings, and even human relationships. By saying "Mottainai!" (carrying a meaning of words like "What a waste!"), Japanese people denote their regret, for example, when something useful, such as food or time, is wasted (Sirola et al., 2019; Suzuki, 2017). "Mottainai" is used in environmental protection to refer to the improper use of resources or waste (Olejarz, 2011). The Mottainai mindset is commonly handed down to the next generations. One of the examples of actions aimed at the youngest ones is the "Mottainai Grandma" campaign stretching for a few decades already, which was initially coined back in 2005 (Shinju, 2005) in a picture book which funnily and easily conveys the meaning and importance of the word 'mottainai' to children, teaching them how to stop wasting resources such as food, water or paper and how to respect the environment.

Although many scientific studies focus on specific relevant topics, such as flora and fauna (Kuo et al., 2025; Kobayashi & Abe, 2023; Xu et al., 2024; Kovács et al., 2022), tourism (Tsuge et al., 2023), environmental perception and feeling (Wuyts, 2024; Sato, 2017; Xiang et al., 2022), ecosystem management policy (Hasegawa et al., 2024; Sato et al., 2023; Sirola et al., 2022; Uchiyama et al., 2022), these studies are fragmented and do not reflect the attitude of modern Japanese people to the problem of traditions in the context of environmental transformation, these studies do not answer the question of whether the perception of contemporary Japanese people coincides with global trends. The authors try to fill this gap in this article.

Sustainable initiatives in Japan

According to the online “Survey on SDGs” conducted by Rakuten Insight, Inc. in 2020, 50% of Japanese recognise the Sustainable Development Goals (SDG) (Matsuoka, 2021). Moreover, data from the Carter Japanese Sentiment Survey from March 2022 shows that only 10% of all respondents understand and can explain the goals (Carter, 2022). At first glance, these data resemble the global average; however, some unique characteristics distinguish Japanese society.

The primary sources of information on SDGs in Japan are TV, online sources and newspapers. (Carter, 2022; Dentsu, 2023). Those already aware of the SDGs and have some knowledge tend not to expand on them; instead, they gather additional information. Only around 30% of Japanese people consciously seek out more information about the SDGs. Regarding the importance of specific goals, women care more about climate change, whereas men prioritise clean and affordable energy. Moreover, people in their 60s were the ones for whom climate actions were the most important, while only 4% of young adults in their 20s chose it as the most crucial issue to address (Carter, 2022; United Nations, 2023a). In contrast, global trends are the opposite, with Climate Action (SDG 13) as the highest priority for young people up to 29 years old (Schlange, 2023). Overall, the most significant SDGs for Japanese people are good health and well-being (SDG3), climate action (SDG13), work and economic growth (SDG8) (Carter, 2022), but also sustainable cities and communities (SDG11) (United Nations, 2023b).

On the other hand, Japanese people are less aware of ethical consumption. According to a survey by ASMARQ (ASMARQ, 2023), nearly 55% of people in Japan are unaware of it. Among people aged 10-19, the recognition rate is 61%, whereas, in the Rakuten Insight survey referred to earlier, the recognition rate was only 24.5%. Japanese people's consumption decisions are based mainly on the price and quality of the product, with factors such as the place of production or environmental friendliness taking a lower priority. Other SDG-related actions that Japanese people are willing to take are mainly limited to avoiding throwing away items and giving them a second life, as well as buying quality products that last longer and can be sold when not needed anymore (Dentsu 2023).

Regarding sustainable initiatives on the national scale, Japan’s overall strategy and instruments are mainly based on voluntary agreements and regulatory measures. They focus on setting limits on pollutant emissions, prohibiting specific actions, and introducing necessary permits to ensure compliance with environmental standards. In most cases, authorities first seek voluntary compliance by issuing administrative advice or non-binding requests for compliance. One of the reasons behind voluntary compliance practices is the lack of a legally binding national law, as seen in CO_2 emission regulations, where private enterprises cannot be compelled to reduce emissions from their operations.

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Apart from obligations targeting enterprises, there are initiatives, including those for individual households, such as the Tax for Climate Change Mitigation, which addresses CO_2 emissions related to fossil fuels. Such initiatives include the Feed-in Tariff Scheme, targeted at investing (Kastratović et al, 2024) in renewable energy, to make investments more appealing, or Act of the Rational Use of Energy and the Act on the Improvement of Energy Consumption Performance of Buildings, which promote practical and rational use of energy, set energy reduction targets for enterprises, and even serve as the benchmark policy (Kanagawa et al., 2021).

An interesting example of a local initiative in Japan is the "Future Tokyo: Tokyo's Long-Term Strategy", formulated in 2021 by the Tokyo Metropolitan Government (TMG). The strategy aims to create a sustainable Tokyo by integrating three dimensions of sustainability (economic, social and environmental) and achieving a balance between maturity and ongoing growth (Tokyo Metropolitan Government, 2021). The core project, called the Tokyo Bay eSG Project, attempts to create a sustainable city in the Tokyo Bay area by utilising its potential and promoting urban development. This long-term plan (50 to 100 years into the future) is divided into more specific, short-term strategies designed to be achieved by exploiting digital technology and innovation, developing transportation networks, implementing green finance projects (Miszczak et al., 2024), reaching net zero and creating an entire city of green scenery and water, which also expresses the overall goal of the future Tokyo. This project is also said to target 7 Sustainable Development Goals, which are affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, sustainable cities and communities, climate action, life below water, and life on land.

Non-governmental institutions also support sustainable transformation, and while many NGOs address environmental protection in Japan, they are generally small-scale, poorly funded, and have limited influence (Kanagawa et al., 2021). One NGO concerned with the SDGs in Japan is the SDGs Civil Society Network (SDGs Japan), which offers a membership system that brings together other organisations, enabling them to collaborate in implementing effective SDGs. Its actions mainly take the form of policy proposals and advocacy activities for the realisation of SDGs from the perspective of civil society. Another example is the Japan Centre for a Sustainable Environment and Society (JACSES), which is dedicated to achieving sustainable development and social justice. The organisation engages the public and experts in research, policy advocacy, and awareness-raising by promoting environmental taxes and green tax reforms.

Worth mentioning is an example of the University of Tokyo, apparently the first university in the world to take initiatives for sustainability since 1994 (University of Tokyo, 2023). Since then, the university has implemented numerous projects, focusing on sustainability science, designing a sustainable campus, and promoting a healthy and resilient recovery with zero-carbon emissions. One of the most recent undertakings is its Green Transformation (GX) initiative, launched in 2022, which aims to transition to a sustainable and inclusive society. The initiative considers carbon neutrality, a circular economy, and living in harmony with nature as its core pillars.

The proof of the complexity of sustainable initiatives in Japan can be seen in the Tokyo Skytree, whose primary role is to transmit digital terrestrial broadcasting. Nevertheless, it also has another function, aiming to realise the Sustainable Development Goals through its business activities (Tokyo Skytree, 2023). It created three corporate philosophies of providing thrilling space for visitors, transmitting Japanese culture worldwide, and delivering security (Krivins et al., 2021; Raistenskis et al., 2023; Krivins et al., 2023; Vilks et al., 2024) and safety. Concerning the last ones, the Tokyo Skytree is expected to fulfil a role as a disaster-prevention centre. The duplicated power system can continue operating as a broadcasting tower even during a major disaster. This is especially relevant, considering Japan's vulnerability to natural hazards. It is even more critical now, as climate change, extreme weather, and natural disasters (e.g., heatwaves, droughts, fires, floods, or storms) are predicted to occur more often and be more severe.

3. Methodological approach

This study aims to investigate the subject of sustainability and its connections with Japanese culture, society, and economy, as well as the interdependency between these factors in the past and present. The primary

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research question is: Is Tokyo on a sustainable development path, and can it continue to be so? Considering the main problem, this study also tries to answer more specific questions:

- What is sustainability, and how does it affect people's lives?
- What are the connections between sustainable assumptions and Japanese culture?
- To what extent is Japanese legislation targeting sustainability and sustainable development?
- What is the level of awareness of sustainable development in Japanese society?

The research mainly takes a bottom-up approach. The conclusions are drawn after specific observations and data analysis; therefore, the paper has an exploratory character, investigating the chosen topic. The study used the triangulation of research methods (quantitative and qualitative methods) and data (both primary and secondary data). Such an approach enabled gathering necessary information, expressed as measurable indicators and descriptive data background, such as cultural roots. This paper's sources of information are secondary data obtained from books, articles, journals, webpages, reports, policy documents, action plans, and statistical analysis and research conducted by organisations and statistical offices. The table and figures included in this work were personally analysed and created by the authors, based on their research conducted in a survey questionnaire.

The survey was conducted among native Japanese people and residents of Japan, which was crucial for acquiring reliable data needed to perform research analysis. It was quantitative research using computer-assisted web interviewing (CAWI), and the analysis results are provided in figures and tables, but also take a descriptive form. The survey questionnaire was conducted between February 22, 2023, and May 15, 2023, and was dedicated to Japanese people, including non-Japanese individuals living in Japan. The authors used private connections to reach the respondents and contacted them through email or social media. The respondents represent a diverse range of occupations and backgrounds. Among them are Japanese language teachers and Takasaki City University of Economics students. Additionally, the survey was anonymous, and no other personal data was collected beyond what was necessary for the survey.

4. Conducting research and results

After the survey, the questionnaire was completed by 90 people representing age groups ranging from 10 to 70 years old. Most respondents were men, comprising a total of 53 individuals. Women counted for 37 respondents. In the case of living arrangements, the situation is more balanced, with varied habitats - 42 people from urban areas and 48 from rural areas, respectively.

This questionnaire aimed to collect additional insights into common topics related to sustainability and questions previously explored in published survey research results (presented above). Moreover, the questions included topics crucial to Japan. They were chosen based on the outcomes of the literature reviews and data analysis, which were also conducted during the preparation of this study. An example of such a question is the subject of Japan's most urgent issues, and one of the indicators here is a low score on the SDGs. Finally, some questions cover global topics, such as the COVID-19 pandemic and how people perceive its impact on sustainable initiatives, as well as topics that the authors found interesting.

The questionnaire consisted of 14 questions. The first three questions concern the information about the respondents themselves (age, gender, habitat), and the remaining eleven questions ask about their awareness of the chosen sustainability topics, the sustainable practices they might or might not undertake, and their personal feelings about the sustainability movement and their opinions on such transformation in Japan. Most questions have closed-ended character types; however, participants could add their ideas when possible.

Based on the topic of the questions, they can be divided into three main groups. The first concerns overall awareness of sustainability topics and related terms. It also asks about sources of knowledge about the mentioned subjects. The second one asks what is most important for Japanese people and which problems are most significant. Then, questions include topics such as the SDGs' impact on people's lives, the government's role in this process, and the external impacts, such as the pandemic. Lastly, the questionnaire collected

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information about local communities and their commitment to social activities related to sustainability and the sustainable activities people are willing to pursue.

When asked about specific sustainability and sustainable development terminology, phrases such as 'climate change' and the Sustainable Development Goals did not cause much trouble. They were well recognised among most respondents (Figure 1).

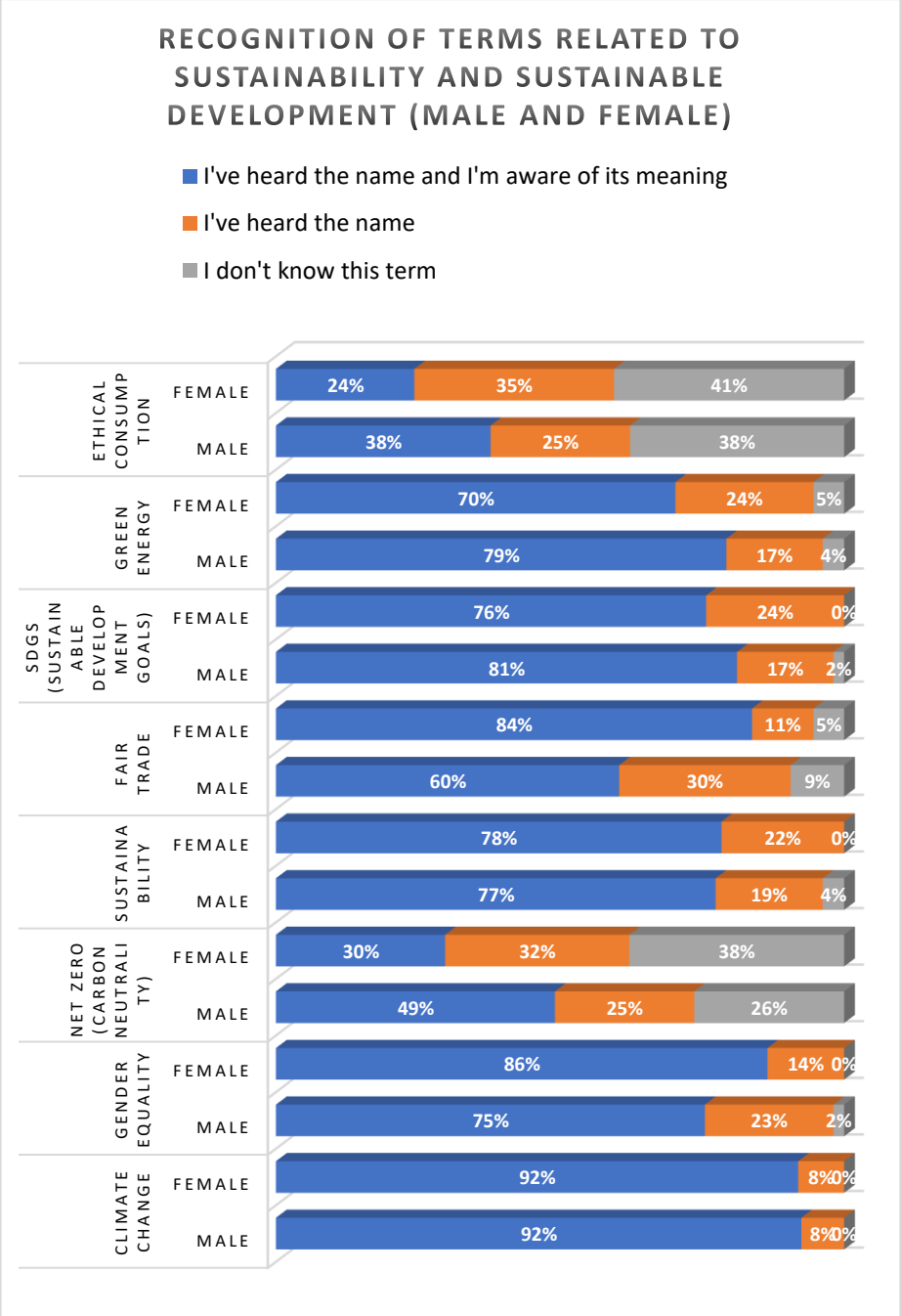


Figure 1. Recognition of terms related to sustainability and sustainable development
Source: authors created based on *their data*

Climate change was the most recognised, with 92% of respondents stating that they had heard the name and knew its meaning. Eighty per cent of the surveyed individuals recognised the term "gender equality," with 86% and 75% identifying it among women and men, respectively. The third most recognised were the Sustainable Development Goals (SDGs), with a total recognition rate of around 79%. The following position was Sustainability and Green energy, with 78% and 76% awareness, respectively. On the other hand, ethical

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consumption was not well recognised, with only a 32% share of awareness of its meaning. Moreover, almost 38% have never heard about it. This term is also the least recognised by both men and women. A slightly better situation is in the case of Net Zero, also referred to as carbon neutrality. Its recognition and understanding of its meaning were claimed by 42%, with 31% stating that they had never heard about it.

Regarding gender-based recognition, the most significant difference in answers between men and women can be observed in their responses to fair trade terms. It was relatively well recognised by 70% of respondents; however, women took the lead, with 84% understanding the topic. 60% of men were aware of the fair-trade meaning.

Concerning the sources of knowledge about sustainability, the most significant share, 31%, declared that they obtained information from the Internet. The second most popular sources were TV or radio, which 23% of respondents chose. One-fifth learn about sustainability at work and school. The newspaper received 10% of all answers; meanwhile, the least popular sources received 5% each were social campaigns and official websites of international organisations. Moreover, only 5% of respondents reported gathering information about sustainability from friends or family. Furthermore, when asked whether students are taught about sustainable development and sustainability at school, 51% said they are. 36% of respondents answered that they did not know, and 13% responded negatively.

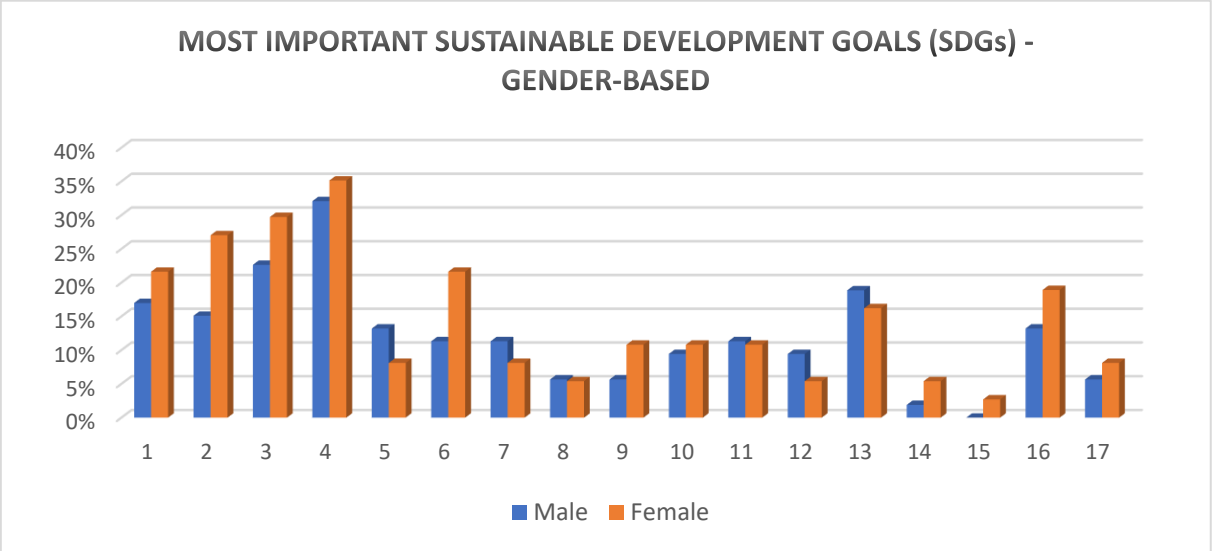


Figure 2. The most important Sustainable Development Goals (SDGs) – gender-based
Source: authors created based on *their data*

The respondents were asked about which SDGs are the most important to them. This question allowed them to check multiple answers; thus, it was not limited to only one SDG per person. Figure 2 above shows the answers based on gender. As can be noticed, the trends are pretty similar, and goals such as SDG4 (Quality Education) and SDG3 (Good Health and Well-being) are equally crucial for both men and women, also taking the highest positions in terms of importance, receiving average support of 33% and 26%, respectively. A similar level of support (in terms of similarities between genders) was received for goals SDG8 (Decent Work and Economic Growth), SDG10 (Reduced Inequality), and SDG11 (Sustainable Cities and Communities). However, those goals were chosen by between 6 to 11% of respondents. The most significant difference can be noticed in the goals SDG2 (Zero Hunger) and SDG6 (Clean Water and Sanitation), both of which are significantly more important for women than for men. The least number of votes received SDG15 (Life On Land) – 1,1%, and SDG14 (Life Below Water) – 3,3%.

The same question was analysed based on age. For this purpose, the age groups were divided into two bigger groups of people aged between 10 and 40 and 50 and 70 and older (Figure 3). That way, we obtained almost equal groups of 46 and 44 people.

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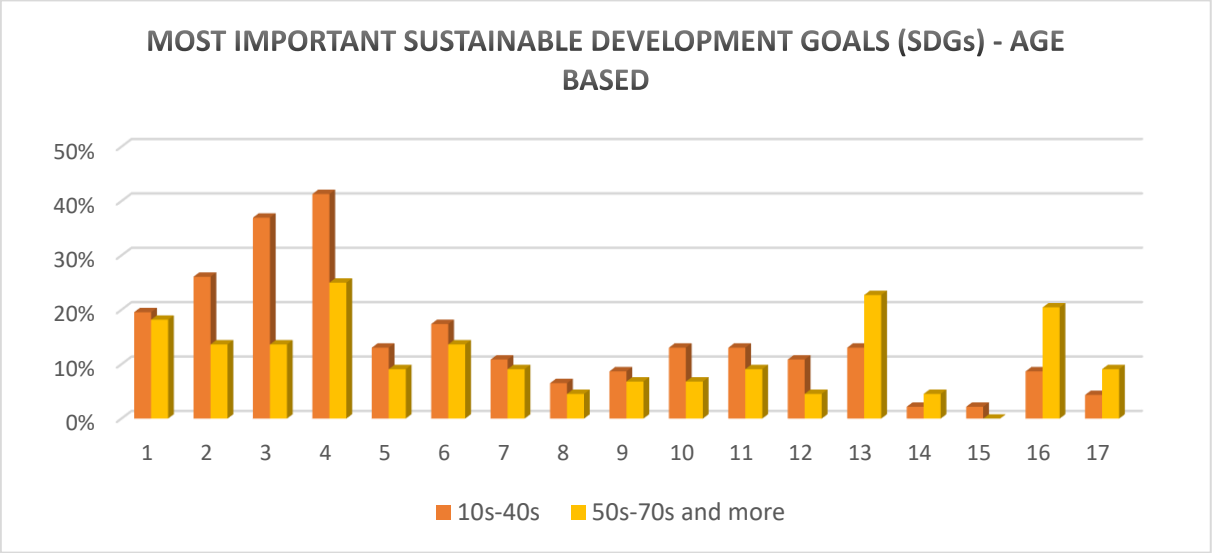


Figure 3. Most important Sustainable Development Goals (SDGs) – age-based
Source: authors created based on *their data*

The first thing that can be noticed is a significant difference in support for goals 2, 3, and 4 (Zero Hunger, Good Health and Well-being, and Quality Education), which are the most important for people aged 10 to 40. These were the most significant goals for this age group, and they received 26%, 37%, and 41% of votes, respectively. In contrast, the most considerable support among those aged 50s to 70s and older was for SDG13 (23% of votes) and SDG16 (20% of votes) (Climate Action, Peace, and Justice Strong Institutions), compared to the younger generation. The goals of SDG13 and SDG16 were also the most important in the mentioned age group, along with SDG4, which received 25% support. The least essential goals for both age groups were SDG14 and SDG15; however, in the case of the age group over 50s, SDG8 (Decent Work and Economic Growth) and SDG12 (Responsible Consumption and Production) were equally less important than the other goals. As presented in the data, climate change is more significant for older generations, opposite to the global trend. Furthermore, the graph appears more balanced from the perspective of people aged 50 and above; most goals receive similar support, with some fluctuations. For those aged 10 to 40, the situation is contrary, as in the case of SDG4, which was recognised as necessary by 41%, whereas six goals did not receive even 10% support.

When asked which problem (among the listed) needs the most urgent actions, 32,2% chose the waste management issue. The second most significant (28,9%) was air pollution, affecting most of Japan. Respondents chose gender inequality as the third option, with 20% of the answers; the last was poor urban planning, with 18,9%. Nevertheless, the answers seem evenly divided, with no considerable difference. A different situation becomes apparent when examining the answer by gender. As for male respondents, the situation looked balanced; women had very different opinions. The most interesting thing is that gender inequality received the fewest points among women – it is the least important to them. Considering that women struggle the most because of the barriers and unfairness in many spheres of life, such a result is unexpected. For women, the most crucial issues were air pollution (41%) and waste management (35%). Slightly more important than gender inequality was urban planning, with 14% of all answers. In the case of men, the most urgent issues were waste management (30%) and gender inequality (26%), which is another surprising result. Urban planning and air pollution received 23% and 21% of votes, respectively. Nevertheless, considering that answers are evenly split among male respondents, there is a possibility that there is no more significant meaning behind that.

The respondents were asked to rate how they would evaluate governmental actions to raise awareness of social and environmental problems. As shown in Figure 4 below, most answers rated the government's role from 1 to 3, and only one out of 90 rated governmental actions as 5. The most significant share of all answers,

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at 42%, received a value of 2, which can be interpreted as somewhat insufficient actions. The second-highest answer was value 3, precisely in the middle, thus not expressing positive or negative opinions.

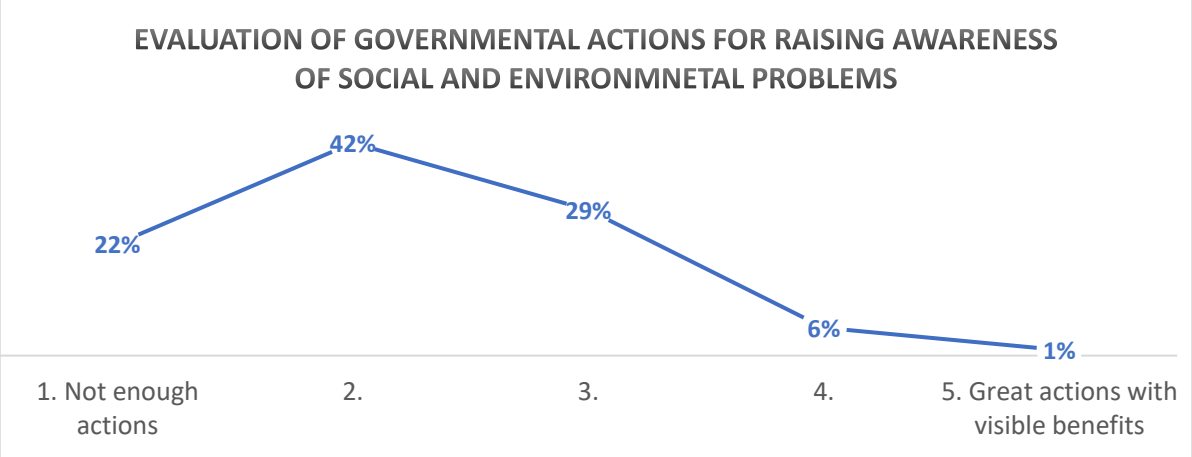


Figure 4. Evaluation of governmental actions for raising awareness of social and environmental problems
Source: authors created based on *their data*

Additionally, when asked whether Japan's climate actions are insufficient (Figure 5), at least 50% agreed. The form of the question was similar to the previous one, where respondents gave answers on a scale from 1 to 5. The most chosen answer was number 4 (28%), which can be translated into "I agree (but not strongly)". The second most significant value of 24% was located at number 3, in the middle; thus, it can be interpreted as "Neither agree nor disagree" or as a neutral answer. Additionally, 22% of respondents fully agree that Japan's climate policy is insufficient. Nonetheless, it can be concluded that the surveyed Japanese people do not think the government is doing enough, especially considering that only 6% strongly disagreed with the insufficiency of the actions undertaken.

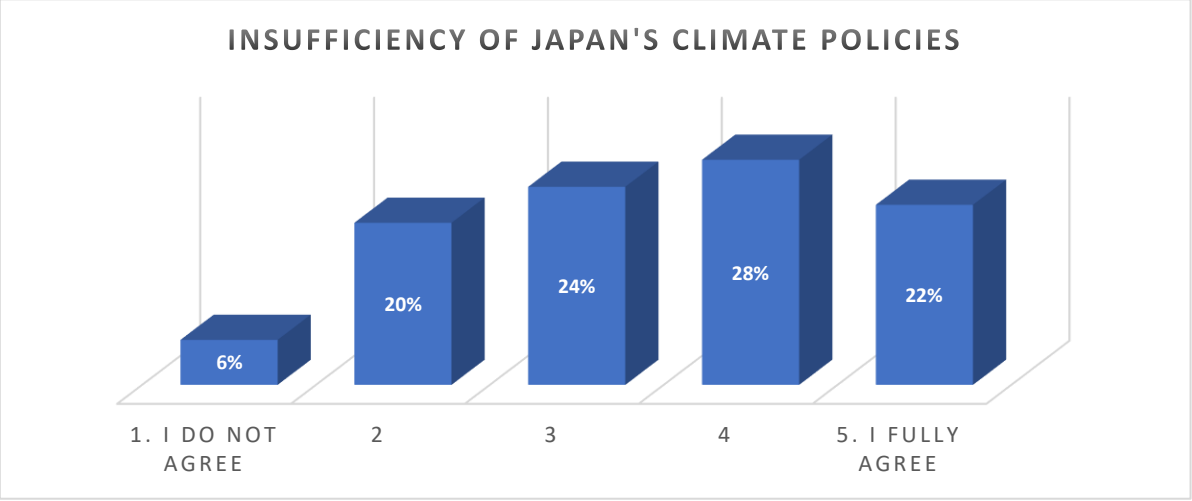


Figure 5. Insufficiency of Japan's climate policies
Source: authors created based on *their data*

Finally, the respondents were asked whether their local communities engage in any activities related to SDGs, such as awareness campaigns, donation programs or neighbourhood clean-up programs. 35% reported that such actions occur, 19% answered "No", and the remaining 46% do not know if such activities occur. The reason behind this might be the lack of proper promotion for such initiatives, but respondents may also not be interested in such projects; thus, they do not pay attention. There is also a possibility that some share of "Maybe (I do not know)" answers should be analysed as the "No" answer. Consequently, regarding the

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reliability of conclusions regarding those answers, it is recommended to interpret them as indicators of awareness of social activities related to the SDGs. The last (multiple-choice) question asked about the actions for climate change that respondents are personally willing to take (Figure 6).

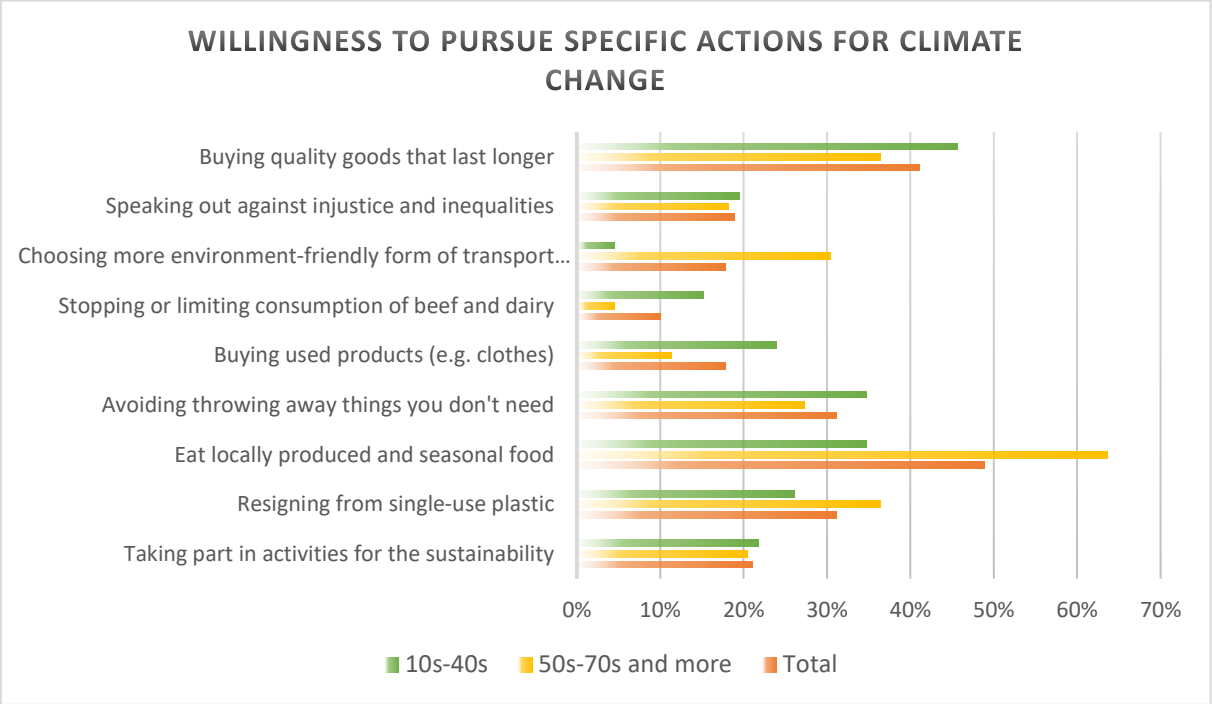


Figure 6. Willingness to pursue specific actions for climate change
Source: authors created based on *their data*

Most people choose to eat locally produced and seasonal food. This option was trendy among people aged 50 to 70 and older, with 64% of votes. Among those aged 10 to 40, the most popular answer was buying quality goods that last longer (46%), which was also popular among the older generation (36%). The next three most popular practices received 31% support from all respondents: resigning from single-use plastic and avoiding throwing away things a person does not need. This can inspire a circular approach to the products we buy and use. Then, taking part in activities for sustainability was chosen by 21% of respondents, just before speaking out against injustice and inequalities in society, which was selected by 19% of those surveyed. Buying used products, such as clothes, was chosen by 18% of all respondents and 24% by those aged 10 to 40, making a visible difference between the older generation, with 11% supporting this action. Another significant disparity between generations can be observed in choosing a more environmentally friendly mode of transportation, such as a train instead of a car or a plane. This action also received 18% support, whereas 30% comes from those aged 10 to 40, and only 5% of those over 50 are willing to implement it. The least appealing idea was to stop or limit beef and dairy consumption (10% of the total), especially among those aged 50 to 70 and older, with only 5% willing to try it. Slightly more popular, with 18% of the votes, was buying used products, such as clothes; again, older respondents were less keen on implementing this practice, with only 11% marking this option. Apart from the answers to the question, two respondents proposed their ideas, such as reducing total energy usage from fossil fuels and switching to renewable energy. The other idea included self-development and learning about the global environment and human society. Both respondents represented the 50s age group.

To conclude, the analysed data and visible trends do not differ much from the secondary data presented. Such similarity can be attributed to a more extensive awareness of sustainability among men; however, the difference is insignificant. The overall knowledge of Japanese people is remarkable. Examples where respondents did not recognise terminology were a rarity. For example, in the secondary data, the primary sources of knowledge on sustainability included TV, online sources (such as the Internet), and newspapers.

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Another common point is that the older generation finds climate change more important (than the younger ones), which both datasets have shown. Moreover, regarding SDG-related activities, respondents chose to buy quality goods and avoid throwing away things, as these are the actions they are willing to pursue, which aligns with the data from the Dentsu survey. It can be observed that the respondents do not have positive feelings towards governmental initiatives and find them insufficient. More severe actions from the authorities are crucial for efficiently implementing sustainable transformation. Nevertheless, it would affect the lives of people who feel that new restrictions and obligations decrease the quality of their lives. Again, due to the small sample size, it is worth noting that the obtained result may vary from the actual state.

5. Conclusions

The subject of sustainability and sustainable development remains relatively new to many; for some, it is even unfamiliar. Apart from the ambitious objectives the 17 Sustainable Development Goals (SDGs) provided, they introduced sustainability to a broader audience, enabling people to understand it more clearly. However, some misunderstandings still arise from interpreting the definitions of these two terms, which are often used interchangeably. It should be remembered that although both terms refer to managing resources for future generations, sustainable development focuses on improving the quality of life and economic well-being; thus, it emphasises economic factors, whereas sustainability encompasses environmental, economic, and social factors. Considering the Sustainable Development Goals (SDGs), the next few years will be crucial for the successful implementation of the 2030 Agenda for Sustainable Development. After this time, we might face new, updated goals and objectives, just like the SDGs replaced the Millennium Development Goals (MDGs).

One of the main findings of this research is the long and deep history of the relationship between Japanese society and nature. The roots of this connection can be traced back to culture, religion, and tradition. Despite their origins and beliefs, it is common for Japanese people to associate natural habitats with holy places and various elements of nature with deities. Throughout the centuries, they have utilised the environment and nature for shelter, food, and places of worship, and have learned how to utilise them most effectively. Furthermore, although many such functions are now unnecessary and people no longer have to fulfil them in the same way, the tradition of living in harmony with nature has evolved and influenced their culture. An example is the expression of Mottainai, which refers to respecting things and not wasting, or the gratitude towards consumed food conveyed in Itadakimasu before a meal.

Moreover, when it comes to legal aspects of sustainability, Japan actively participates in international summits and expresses its commitment to global actions for sustainability. It also aspires to be among the most influential players in shaping the creation of future sustainable initiatives. It also engages with various policies and initiatives within the country's borders, focusing on the most critical matters from the country's perspective and its international commitments. However, it should be noted that a significant share of such actions takes the non-obligatory form, making it difficult for broad transformation. Based on that, governmental actions targeting enterprises are primarily focused on promoting and encouraging sustainable transformation. Nevertheless, the current level of sustainability in Tokyo ranks it among the most sustainable cities in the world, demonstrating that years of effort have paid off, and the future of this city may be even more prosperous.

When we compare Japanese society to the rest of the world, its knowledge of sustainability topics is relatively low. Many people are still unfamiliar with these terms and unaware of their meanings and how they relate to everyday life. Nevertheless, the series of surveys has shown that awareness of the mentioned topic increases yearly. Japanese people learn about sustainability and sustainable development at their own pace and are, in fact, willing to take part in sustainable transformation. Nevertheless, the crucial finding is that Japanese respondents tend to hold a unique perspective on such topics, even one contrary to what is commonly acknowledged globally; thus, general and usual strategies are probably not expected to be effective in Japanese society.

This research highlights the substantial number of local initiatives and the comprehensive approach to sustainable development in Tokyo. However, it also raises the question of the effectiveness of such action. As

was mentioned, the voluntary nature of many policies does not require compliance, making it difficult to evaluate their success. Nevertheless, a crucial fact is that Tokyo has a clear goal for the future, and it knows how to achieve its set objectives. The project for a sustainable future in Tokyo fully utilises all three pillars of sustainability (economic, environmental, and social). It aims to provide citizens with an equal and innovative environment for all. Again, this work evaluates awareness among Japanese society, but this time, it is based on the authors' research.

Regarding the most common terms related to sustainability, most respondents had no difficulty recognising them; only a few were unfamiliar with them. Another important finding is that Japanese people do not feel the government is doing enough for sustainable development. This implies that more decisive actions are expected, especially considering respondents did not perceive any impact on their lives due to implementing sustainable initiatives. Moreover, Japanese society's priorities differ from those observed in Europe or globally, reflecting unique characteristics. Finally, Tokyo is expected to face many external factors, which will significantly affect the sustainable development of Tokyo (and Japan) and the eventual outcome of the transformation. Tokyo must continually focus on and develop its natural risk mitigation and adaptation measures, extending them to policies targeting other issues that, from a sustainability perspective, are not doing well. Nevertheless, considering Tokyo's and Japan's current position and the amount of work the country is doing to commit to sustainable development, the future for Tokyo looks bright.

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VALUE CREATION IN BUSINESS: CURRENT TRENDS AND FUTURE PERSPECTIVES OF ECONOMIC RESEARCH*

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Abstract. This study analyses the current state of value research to identify key themes and their evolution. The method uses VoS Viewer and bibliographic maps from the Web of Science and Scopus databases. Based on the keyword analysis, two models are developed to predict developments up to 2030. The main findings suggest that the first model is suitable for short-term predictions, while the second model is better suited for the long-term outlook. A limitation is the focus on only two academic databases, which may affect the overall representativeness of the results. The study suggests possibilities for extension, including keyword analysis by region and more detailed examination of individual publications using modern technologies such as machine learning or artificial intelligence. The concept of value is examined in its multiple dimensions, including economic, social, and individual perspectives, highlighting its interdisciplinary nature. The analysis shows how the understanding of value has evolved in response to societal and technological change.

Keywords: value; VoS Viewer; total increase; Web of Science; Scopus; innovation

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JEL Classifications: C38, C53, D46

1. Introduction

Comparing academic databases, such as Web of Science (WoS) and Scopus, by creating bibliographic maps using WoS Viewer is essential in scientific research for researchers and academics. These academic databases, specifically WoS and Scopus, represent an indispensable information resource that facilitates access to many scholarly papers, articles, and conference proceedings across various disciplines (Pranckute, 2021). Thus, these databases allow researchers and students to obtain up-to-date and relevant information for their research activities and academic studies. Bibliographic maps, created using VoS Viewer (Visualising Similarities), are a powerful analytical tool for visualising relationships between scholarly articles based on citations. These maps identify key themes, trends, and concepts within a scientific field and help comprehensively understand the structure and content of diverse academic disciplines (Marín-Marín et al., 2021). Several essential aspects can be examined when analysing WoS and Scopus databases using bibliographic maps. The first is the scope of these databases, which includes quantitative aspects such as the number of scientific articles and studies

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included. This indicator provides an overview of each database's overall scope and complexity (Singh et al., 2021; Strakova, 2024).

The second important aspect is the coverage of subject areas. By analytically examining the topics and keywords in the bibliographic maps, we can identify which areas of scientific research are better represented in one database than another. This information offers essential insights for researchers who specialise in particular scientific fields. A third important aspect is the relationships between authors and individual articles. Bibliographic maps make it possible to identify research collaborations and links between scientific papers. This information can be crucial for identifying prominent research groups and networks (López-Belmonte et al., 2023). In the context of strategic management and the concept of value, these data can be used to make informed decisions about which databases bring more value to a particular research project. Choosing the right database for a specific research task can significantly impact achieving positive outcomes from the research process. Strategic management in this context involves careful consideration of the options available for obtaining relevant data and using these data as a key resource for achieving the research project's objectives. The value concept provides a perspective on the effectiveness and benefits that each of these databases can offer to the research team, which can serve as a basis for making informed decisions and optimising the research strategy (Shashi et al., 2020). The literature search focused on this topic will systematically study and analyse the existing academic literature that compares two prominent academic databases, namely WoS and Scopus. It will also evaluate the use of bibliographic maps in analysing these databases. This analysis can potentially be a valuable resource for the research community and the academic sector.

2. Research objective and methodology

VoS Viewer, a sophisticated tool for creating and analysing bibliographic maps, has become indispensable in the comparison of two key academic databases, Web of Science (WoS) and Scopus (Arruda et al., 2022; McAllister et al., 2022). Its use permeates several key sectors of research and information management. At the same time, it is becoming a key element for academics and research institutions engaged in strategic decision-making regarding the selection of relevant resources for research (Nandiyanto et al., 2021; Orduña-Malea & Costas, 2021). VOSviewer is a freely available computer program, first launched in 2009, for constructing and viewing bibliometric maps with the emphasis on graphical representation. The program can also find new trends, keywords and the evolutionary process of the frequency of a particular topic after entering the data (Orduña-Malea & Costas, 2021). VOSviewer has a wide range of applications in all sectors. For example, Einecker and Kirby (2020) used the program in their study on climate change. In ecology, the program has been used in research on lithium-ion battery recycling by Guo et al. (2022). Luckyardi et al. (2022) used it in their study, exploring a wider range of studies on the chemical industry. In industry, VOSviewer was used to examine the evolution of lean manufacturing in the study by Ramkumar et al. (2021), which enabled them to identify changes in trends regarding lean manufacturing. In medicine, VOSviewer can be used to select articles dealing with a given issue, e.g. epilepsy, as done by Manli et al. (2022), and to assess the current state of available information. In the social sphere, Singh, Solkhe and Gautam (2022) have also used the program to research employee productivity in various organisations and companies. Li and Yu (2022) found that the most searched words during the COVID-19 pandemic were associated with this name. With VOSviewer, researchers can determine what impact events can have on people's psyche and overall health.

The first major sector in which VoS Viewer excels is academia and scientific research. This tool supports researchers and academics working in various fields (Kirby, 2023; Apanovych et. al., 2023). Its ability to visualise the complex links between scholarly works enables the identification of key themes and trends in each discipline. This facilitates researchers in understanding the current state of research better and supports the creation of new research projects (Al Husaeni & Al Husaeni, 2021). The other major sector in which VoS Viewer has its application is information management (Ding & Yang, 2020). Organisations that manage large amounts of bibliographic data find this tool valuable for efficient organisation and analysis of this data. VoS Viewer allows them to delve deeper into the structure and meaning of this information, which significantly influences strategic decisions and the optimal use of scientific resources (Soegoto et al., 2022).

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Academic databases are an essential and indispensable source of information for the scientific world and the research community (Gusenbauer & Haddaway, 2020; Vachal & Talir, 2020; Musil & Kocmanova, 2024). The most-used and prestigious academic database has been the Web of Science for many years (Zhu & Liu, 2020). However, the main competition nowadays is the Scopus database from Elsevier Science, which was created in 2004 (Saïd, 2020). These databases provide users access to extensive collections of scientific publications, including articles and conference papers, which provide considerable value to researchers, students and academics (Asubiaro, 2023). Web of Science remains the most extensive database, covering over 75 million records in its Core Collection and up to 155 million records including additional regional and subject citation indexes (Birkle et al., 2020). In her study, Liu (2020) confirmed that information is more accurately retrieved on Web of Science than Scopus. A large comparative study (Visser, van Eck & Waltman, 2020) found that the Web of Science database contains many articles that Scopus does not cover. Still, the same is true in reverse, so each database has advantages and disadvantages. Despite the growth of academic databases in the last decade, both Web of Science and Scopus remain the most extensive and widely used sources of information (Pranckute, 2021).

Strategic management and academic databases are interlinked as these databases serve as a valuable source of information for managers and researchers involved in strategic management (Ragazou et al., 2022; Kollmann et. al., 2024). Strategic management is a pillar of modern business and represents a systematic process to achieve long-term organisational goals and strengthen competitive position in the marketplace (Nicole et al., 2022). The authors Maříková et al. (2022) defined strategic management as a comprehensive methodology that deals with formulating and implementing an organisation's strategies. This process involves analysing the external and internal environment, identifying organisational strengths and weaknesses, setting goals and strategies to achieve them, and implementing them (Mihaylova & Papazov, 2022). Teams specialised in strategic management conduct a thorough analysis of the market environment and competitive situation and evaluate the organisation's internal processes (Alhumeisat, 2023). For an organisation to function effectively, it is necessary to develop rational strategies and ensure cost-effective implementation, such as using an adaptation mechanism (Safonov, Marichereda & Bazhenkov, 2021). Bryson and George (2020) argue that strategic management can help public organisations to achieve important goals and create public value. To implement plans to achieve specific goals, management must be supported with the necessary information and data at different levels to develop strategic, tactical and operational forecasts and plans (Strakova & Talir, 2020). In their study, Oltenau, Drăgan and Stinga (2022) confirmed the relevance of decisions and goals set through strategic management on a specific enterprise. In strategic management, it is also necessary to account for uncertainties that can significantly affect the course of the outlined plan, so it is essential to prepare multiple scenarios and have tools to deal with future problems (Kulinich et al., 2022). Several motivating factors lead organisations to use this approach (Lisnik & Majernik, 2023). The first is the need to ensure the long-term sustainability of an organisation that faces the risk of losing competitiveness or lacking the ability to respond to dynamic market changes (Rao & Shukla, 2022). The second important factor is the efficient allocation of scarce resources, which strategic management enables to decide where to direct investments to maximise value for shareholders, customers and other stakeholders (Fuertes et al., 2020). The practical benefit of strategic management lies in better planning for the organisation's future development, responding to market changes, and achieving the set goals (Barbosa et al., 2020).

Strategic management and value are closely linked in business, as strategic management helps organisations to achieve and deliver value to customers (Pasaribu et al., 2021). Value reflects the importance and usefulness that customers perceive when purchasing a product or service. Customers are willing to pay for what they perceive as valuable; therefore, understanding and delivering value is critical to the success of a business (Zeithaml et al., 2020). According to Mahajan (2020), value can be perceived as a monetary price and a benefit (e.g., emotional value, cultural value, etc.). Breuer, Lüdeke-Freund, and Bessant (2022); Talir and Strakova (2023) argue that values provide desirable outcomes for unintended consequences, and a value-based view facilitates the management of innovation projects, creating and adjusting methods or giving direction, integrating divergent interests. There are different types of values, such as social value, which is measured as the core of business activity through local policy making and social investment activities, i.e. it depends on the geography and the local community (Faludi, 2020). Another value, this time in the economic direction, is market value, which, according to French, Crosby and Thorne (2021), is an estimate of the market price and an exchange

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value. According to Anwer et al. (2020), there is a value match between the people's values at the centre of the purchase and the buying companies' organisational values, influencing companies' decisions to purchase a given product or investment. A significant value is customer-perceived value, which shows how the values offered by companies are perceived by customers in practice (Bocken & Ritala, 2021; Geissdoerfer et al., 2020). In their study, Kusumawati and Rahayu (2020) emphasised the importance of the experience of product and service quality, which influences customer perceived value, customer satisfaction and loyalty. In economics, the product's value is crucial, which according to Guo et al. (2020) is influenced by the set of functions, the degree of realisation of functions and resources, where resources are defined by price, space, time and energy. Customer and supplier value creation is based on operational performance, capabilities, and relationship quality, but secondary factors are dyad-specific (Minerbo, Kleinaltenkamp & Brito, 2020). To sustain value, it is essential to involve third parties that can help create value propositions and embed social value in the service exchange. Strategies for engaging these co-participants must be developed so that each party benefits from the collaboration regarding profitability, value, and sustainability (Brozović, D'Auria & Tregua, 2020).

Based on the information found in the literature search, the following research questions were identified:
RQ1: What is the research direction on value in the economic sector?
RQ2: What topics are most associated with the current state of the literature on value?
RQ3: What are the expected developments in current topics in the coming years?

Web of Science and Scopus academic databases were the data sources for the article analysis. For the WoS database, the parameters Value (All Fields), Business or Management or Economics (Web of Science Categories) were selected, and 256,219 publications were retrieved from 1945 to 2022. For the Scopus database, the parameter Value (All Fields), Business or Management or Accounting and Economics or Econometrics or Finance (Scopus Categories) was also selected, where 838,080 publications were retrieved from 1945 to 2022.

To identify the top 5 strongest keywords, data was collected on the increase in the occurrence of each keyword in the WoS and Scopus databases. For the WoS database, keyword searches in Business, Management and Economics were chosen. In contrast, keyword searches in the categories of Business, Management, Accounting and Economics, Econometrics and Finance were used for the Scopus database. These searches served as the database for the regression analysis.

Bibliographic analysis
To determine the research direction in "value", a bibliometric analysis was conducted using the Vos Viewer program. This analysis was based on available database data, and bibliographic maps were created to highlight the most important keywords based on their frequency and occurrence. Before creating these maps, the type of analysis that would be used was decided. Keywords with the minimum number of occurrences were used using bubbles, grouped into clusters based on similarity and colour, with each cluster symbolising different categories. The spatial frequency of occurrence and the size of each bubble were also important aspects of this analysis, thus denoting the number of occurrences of the keyword in the articles examined.

Keyword analysis
Once the bibliometric analysis was completed, the next step was to analyse the annual growth rate and total number of the top five keywords using Vos Viewer, which allows us to process large amounts of textual data efficiently. This analysis stage was carried out to deepen our understanding and insight into the Web of Science and Scopus databases, which are the sources of information in our research.

Regression analysis
Regression analysis is used to determine the relationship between two or more variables. In most cases, this relationship is expressed by a regression equation that allows the value of the dependent unknown to be predicted using the values of the independent variables (xxx). This statistical method has been used for keyword prediction models, which is the topic of this article. The regression analysis method was applied to 4 selected keywords. The further development of each keyword up to 2030 was determined using the annual increment and the evolution of the total number. This method also includes an R2 index, which determines how accurately

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the predicted curve matches the current state. Second- and third-degree polynomials were used for prediction depending on the complexity of the curve.

3. Results and discussion

Based on the information found in the literature search, this paper will focus on the Web of Science and Scopus databases when using the word value. Searching the Web of Science database with the parameters Value (All Fields), Business or Management or Economics (Web of Science Categories) resulted in 265,219 publications. In contrast, a search in the Scopus database with the parameters Value (All Fields), Business or Management or Accounting and Economics or Econometrics or Finance (Scopus Categories), resulted in 838,080 publications.

VoS analysis of Web of Science **VoS analysis of Scopus**

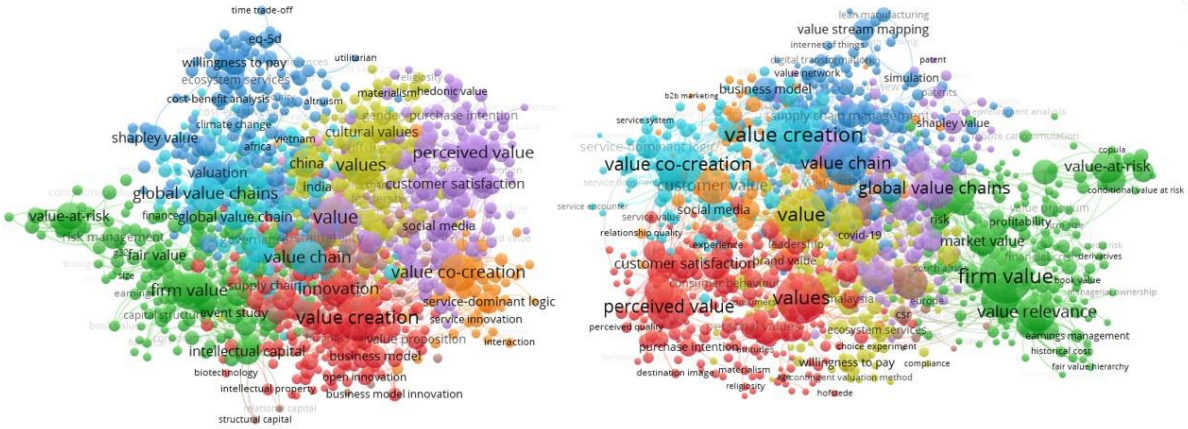


Figure 1. Comparing databases using VoS Viewer
Source: Own (2023)

After each of the database searches described in the previous section, data on 265,219 articles from Web of Science and 838,080 articles from Scopus published between 1945 and 2022 were exported. Bibliographic maps were then created from these data to help illustrate the most frequently used keywords. The results showed that the strongest keyword associated with the search parameters for both databases was "Value Creation". Most of the keywords differ, but at the same time, the distance (keyword linkage) differs in most cases. For this reason, it is recommended to use articles from several databases to find out more.

Comparison of keywords

Table 1. Keyword comparison using VoS Viewer

Web of Science			Scopus		
Keyword	**Occurrences**	**Link strength**	**Keyword**	**Occurrences**	**Link strength**
Value Creation	881	1783	Value Creation	952	1903
Value	859	1770	Value	762	1610
Values	702	1320	Firm value	841	1374
Innovation	472	1106	Values	745	1198
Value co-creation	586	1099	Value co-creation	627	1151
Perceived value	544	969	Perceived value	575	1042
Firm value	569	878	Innovation	412	965
Value chain	515	809	Value chain	541	834
Corporate social responsibility	378	801	Corporate governance	387	760
Global value chains	508	749	Corporate social responsibility	349	746
Sustainability	307	669	Sustainability	337	736
Corporate governance	346	665	Global value chains	490	690
Foreign country	337	650	Value relevance	402	687
Satisfaction	242	635	Customer value	379	674
Customer value	365	611	Customer satisfaction	261	656

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Customer satisfaction	238	600	Satisfaction	247	626
Intellectual capital	249	526	Foreign country	290	570
Trust	197	519	Service-dominant logic	189	476
Culture	222	507	Trust	191	453
Service-dominant logic	183	471	Service quality	169	436

Source: Own (2023)

The assumption that it is desirable to use publications from multiple databases to investigate a search topic in more detail is confirmed by the previous table, which lists the top 20 strongest words according to the Link Strength parameter, which indicates how often a keyword appears in combination with other keywords. Using this parameter, the strongest keyword, for the WoS and Scopus databases, is the word "Value Creation". The analysis performed by Vos Viewer also shows that the most frequently used keyword for both databases is "Value".

Analysis of keyword occurrence

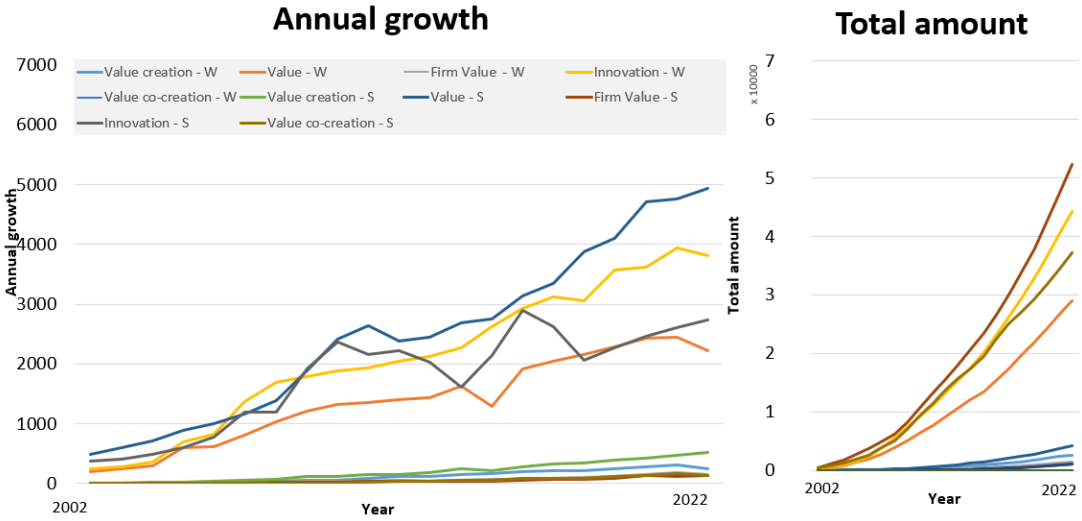


Figure 2: Development of the number of publications
Source: Own (2023)

The keyword occurrence analysis was performed on the keywords Value creation, Value, Firm value, Innovation and Value co-creation in the WoS and Scopus databases for the last 20 years. The results showed that "Value creation" has become the most prominent keyword in both WoS and Scopus databases. The least significant keyword was "Value co-creation".

This indicates that "Value co-creation" is the least published keyword in the context of publications on value. The second most used keyword in the bibliometric analysis for both databases was "Value".

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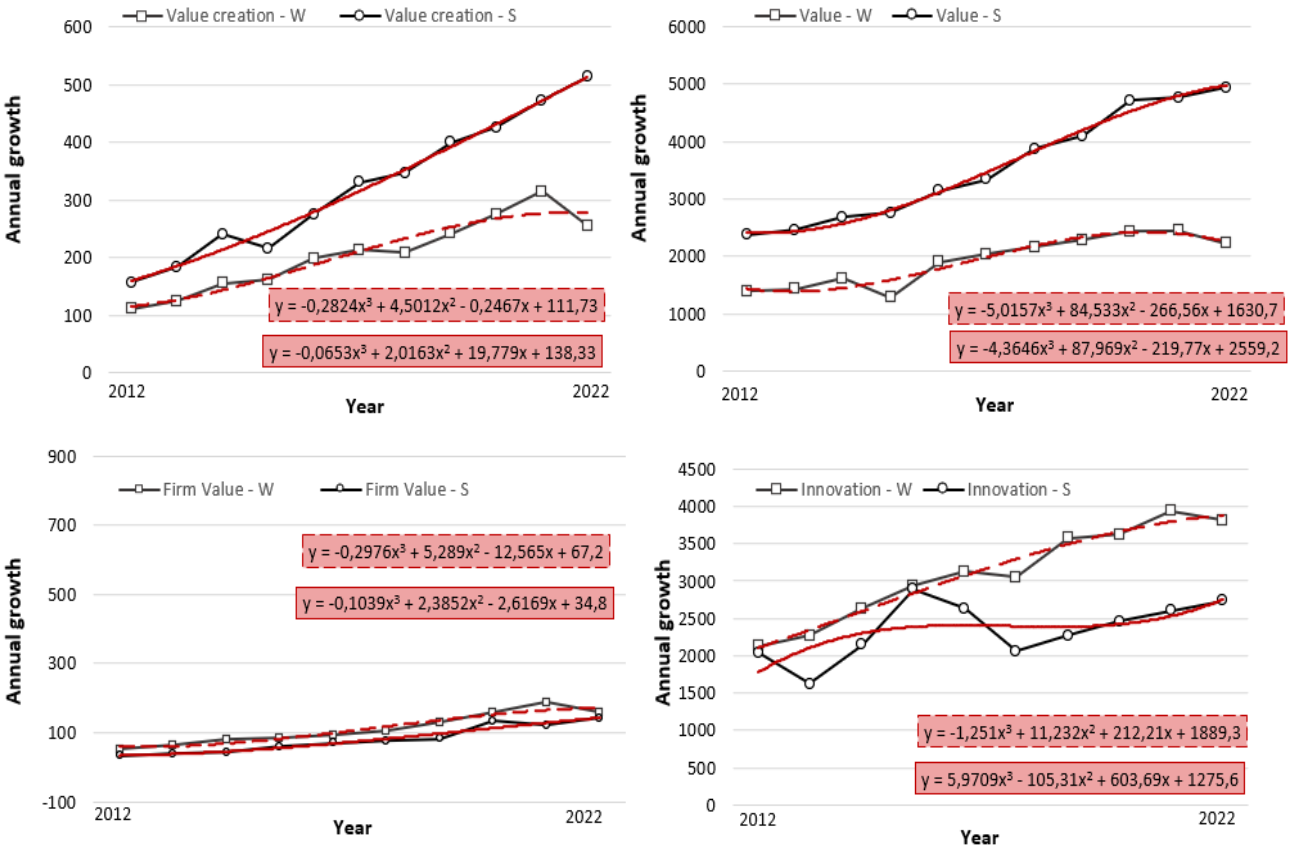


Figure 3. Regression analysis of keywords
Source: Own (2023)

Figure 3 shows the increase in the four strongest keyword-enriched functional dependencies formed by third-degree polynomials. The most prominent keyword identified concerning the search parameters was "Value creation", which was used in 1255 articles in the Web of Science database in the last 11 years, while it was used in 1674 articles in the Scopus database. The second most important keyword was "Value", which appeared in 18,253 articles in the WoS database and 1,333 articles in the Scopus database.

Prediction of keyword occurrence in the following years - Annual growth method

The transcripts of the features that symbolise each keyword were determined by completing the keyword analysis. To ensure the accuracy of the results, third-degree polynomials were used in the analysis, which show an R2 reliability index greater than 90% in most cases. Regarding annual growth, the equations found in Figure 3 were chosen and applied to the following years (2023-2030).

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Table 2. Predicting annual keyword growth

	Value - S		Value - W		Value Creation - S		Value Creation - W	
Year	Result		Result		Result		Result	
2023	5047		1938		553		275	
2024	4980		1432		593		255	
2025	4748		704		631		223	
2026	4325		-276		668		175	
2027	3686		-1538		703		111	
2028	2803		-3113		736		29	
2029	1651		-5030		767		-72	
2030	204	$R^2 = 0,9914$	-7320	$R^2 = 0,9177$	794	$R^2 = 0,9864$	-196	$R^2 = 0,9238$
	Innovation - S		**Innovation - W**		**Firm Value - S**		**Firm Value - W**	
Year	Result		Result		Result		Result	
2023	3673		3892		167		164	
2024	4444		3798		176		144	
2025	5471		3629		181		111	
2026	6788		3378		182		64	
2027	8432		3036		178		1	
2028	10439		2597		169		-80	
2029	12844		2052		155		-181	
2030	15683	$R^2 = 0,4352$	1395	$R^2 = 0,9683$	133	$R^2 = 0,9449$	-303	$R^2 = 0,9369$

Source: Own (2023)

Substituting the order of the years (for 2023, this is 12) into the equations provided gives the predicted usage increases for each keyword. The next parameter is the R2 index, which determines the accuracy of the rewrite function, as defined in Figure 3.

This method shows two major advantages and one disadvantage. The first advantage is the ability to more accurately determine the evolution of keyword occurrence over 2-3 years. The second major advantage is a faster response to changes in keyword evolution, but this advantage also implies a significant disadvantage of using this model. In the event of a rapid, temporary change in the publication of peer-reviewed articles (crisis, change in peer review, etc.), this will be reflected in the curves and, in some cases, may result in negative increment estimates.

Predicting the occurrence of keywords in the following years - Total number method

For the above reasons, a second method of determining the predicted increase in publications on a search topic was also proposed, based on tracking the total number of publications. As in the previous option, a polynomial method was chosen to determine the transcript functions. However, in the case of a more linear increase, a second-degree polynomial could be used, which is simpler to calculate.

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Table 3. Predicting overall keyword growth

	Value - S			Value - W			Value Creation - S			Value Creation - W		
Year	Result	y = 112,45x2 + 80,171x + 473,06	R^2 = 0,9995	Result	y = 57,001x2 + 201,87x - 264,63	R^2 = 0,9996	Result	y = 13,362x2 - 96,629x + 200,7	R^2 = 0,9983	Result	y = 8,7486x2 - 67,116x + 122,63	R^2 = 0,9991
2023	56663			31765			4542			2880		
2024	61803			34532			5047			3207		
2025	67168			37413			5578			3551		
2026	72759			40408			6136			3913		
2027	78574			43517			6721			4292		
2028	84614			46740			7333			4688		
2029	90879			50077			7971			5102		
2030	97368			53527			8636			5534		
	Innovation - S			**Innovation - W**			**Firm Value - S**			**Firm Value - W**		
Year	Result	y = 54,888x2 + 724,99x - 1534,3	R^2 = 0,997	Result	y = 91,946x2 + 194,71x - 371,56	R^2 = 0,9997	Result	y = 3,2808x2 - 28,179x + 66,266	R^2 = 0,9917	Result	y = 4,2484x2 - 27,986x + 70,108	R^2 = 0,9917
2023	40981			48414			1034			1511		
2024	44176			52746			1154			1674		
2025	47481			57262			1280			1846		
2026	50895			61962			1412			2026		
2027	54420			66846			1551			2214		
2028	58054			71914			1697			2412		
2029	61798			77166			1849			2617		
2030	65651			82602			2008			2831		

Source: Own (2023)

From the results of Table 3, it can be observed that, compared to the previous method, the evolution is gradual and does not go into negative numbers. The table contains the transcripts of the individual functions, which reach a significantly larger R2 index than in Table 2. For these reasons, this method is more suitable for predicting longer-term trends than the annual keyword growth method. This method does not respond as quickly to sudden changes in the literature, but this fact prevents the unintended effect on prediction that occurred in the annual increase method.

Comparison of methods

The increment data needed consistency to compare the two keyword prediction methods correctly. For this reason, a table was created to reflect the difference between the keyword usage prediction methods studied.

Table 4. Comparison of prediction methods

	Year	Value - S	Value - W	Innovation - S	Innovation - W	Value Creation - S	Value Creation - W	Firm Value - S	Firm Value - W
Total count method	2023	56663	31765	40981	48414	4542	2880	1034	1511
	2024	61803	34532	44176	52746	5047	3207	1154	1674
	2025	67168	37413	47481	57262	5578	3551	1280	1846
	2026	72759	40408	50895	61962	6136	3913	1412	2026
	2027	78574	43517	54420	66846	6721	4292	1551	2214
	2028	84614	46740	58054	71914	7333	4688	1697	2412
	2029	90879	50077	61798	77166	7971	5102	1849	2617
	2030	97368	53527	65651	82602	8636	5534	2008	2831
Annual growth method	Year	Value - S	Value - W	Innovation - S	Innovation - W	Value Creation - S	Value Creation - W	Firm Value - S	Firm Value - W
	2023	57360	30907	40839	48160	4723	2854	1148	1575
	2024	62340	32339	45283	51957	5316	3109	1324	1719
	2025	67088	33043	50754	55586	5947	3332	1504	1830
	2026	71413	err	57542	58964	6615	3507	1686	1894
	2027	75099	err	65974	62000	7319	3618	1864	1895
	2028	77902	err	76413	64596	8055	3647	2033	err
	2029	79553	err	89257	66649	8822	err	2188	err
	2030	79756	err	104940	68044	9616	err	2321	err

Source: Own (2023)

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From Table 4, we can see that the data in the early years of the assumption for frequently used keywords varies by orders of magnitude, by hundreds of publications. For keywords that are not so frequent in academia, the results of the different methods differ by orders of magnitude and tens of occurrences. The turning point occurs around the 4th-5th year of the assumption, where the error rate for the annual growth method comes to the fore, which is caused by a decrease in publications on the topic in the Web of Science database. Here we can observe that the total number method predicts publications up to 2030, whereas in the annual growth method, we sometimes get a situation where there is no growth after a few years (due to negative annual growth).

According to current trends in the literature, we expect the highest growth in publications to continue to be in the keywords "Value" and "Innovation". These keywords show the highest increases in the analyses performed, while only one of the 8 features tracked shows a downward trend after the 3rd year of the prediction. The remaining keywords no longer show such increases but are areas of great potential and scope for future research.

Current professional publications use VoS Viewer to determine the focus of research in certain specific industries. The research by Nandiyanto et al. (2021) focuses on analysing materials research and its status. Another example is the publication by Orduña-Malea and Costas (2021), who focused on using the VOS Viewer to determine the use of scientific software in the scientific literature. The extent to which the field of remote sensing contributes to the realisation of the SDGs is addressed in Kirby (2023). These publications have inspired the use of the VOS Viewer to determine the research focus within the value framework. This method was subsequently enriched by analysing the current state of development of the literature and identifying future developments according to the two methods discussed in the results section of the research. About the analysis of the value domain, we may encounter more of a literature review focusing on sub-domains of value creation. For example, research by Zeithaml et al. (2020) examines the literature on customer value over 3 decades. As an example of further analysis of the available literature, Ramkumar et al. (2021) focus their study on research on lean manufacturing, to which value is closely related. In contrast, this publication focuses on a broader analysis of the sub-areas of value and related issues.

Within this research, the following research questions were asked to reflect the current state of value research:

RQ1: What is the research direction on value in the economic sector?
Using VoS Viewer analysis, it was determined that the direction of value research today is focused on research on value itself, value creation, and value co-creation. This is due to the increasing focus of companies on optimising their processes and maximising profits. Together with value, the value of the company as a whole and the perceived value from the perspective of the company and the customer are coming to the fore. Within the global focus on sustainability, there is also an increasing focus on corporate social responsibility and the sustainability of the company and its production processes. The final area of research we have mentioned is the focus on customer satisfaction and trust, which nowadays plays an increasing role in sustainable competitiveness.

RQ2: What topics are most often associated with the current state of the literature on value?
4 current topics represented the most frequently published topics in value. The first topic mentioned was value, a broad term encompassing a range of publications. For this reason, it is also the most frequently occurring keyword within our analyses. The second most frequent theme was the area of innovation, which is a slight departure from the theme of value; however, the area of innovation is also closely related to value and innovation is needed largely for proper value creation. Thus, it is unsurprising that value creation was the 3rd most common theme. Indeed, many other aspects are related to value creation, such as the company's production process, competition, sales and distribution. The last topic identified is the company's value, which includes the company's know-how, customer relations or even the company's image, for example.

RQ3: What is the expected development of current topics in the coming years?
Given the current developments in the scientific sphere, the identified topics will continue to develop in the coming years. In view of the analyses carried out, the topics of value and innovation will become increasingly relevant in the coming years. The value creation and enterprise value analyses show that we can expect increased

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publishing activities. Still, these increases will be relatively gradual, and more academic attention can be expected later.

The result of this publication was to identify the key themes that are relevant with regard to research on value within the economy. Future research could build on and expand knowledge by including a more comprehensive data set that would help refine our identified focus of current research or add to other topics discussed. The limitations of this publication are the lack of focus on regional and cultural differences across publications due to the uniform focus of our chosen search.

Conclusions

The paper focused on analysing the current state of development of themes and concentrating on value research. The first part was assessing the current knowledge using the VoS Viewer program to understand the current topics properly. Using the bibliographic map of the selected searches on the Web of Science and Scopus databases, it was possible to determine the different relationships between keywords. Subsequently, the program was used to generate data on the strongest keywords, which include the number of occurrences and the strength of association with other keywords. The strongest keywords were then evaluated for topic relevance by determining the number of publications on each topic. From this data, a transcript of the functions was obtained using regression analysis and second- and third-degree polynomials, which was used to analyse themes of this paper further. Using the equations obtained, two models were used to predict the development of the study areas up to 2030. The first model uses the annual increases in each keyword across the publications under study to predict. This model is more suitable for short-term predictions of topic trends, as in the case of longer-term analysis, the decline heavily influences the curve in publications in academic databases and may result in a pessimistic prediction. For these reasons, a second model was also used to predict and analyse the total number of publications in the areas under study. This model is more suitable for long-term predictions, but it does not respond to rapid changes in publishing like the previous model. By comparing the two methods, it was found that for more accurate analyses, it is necessary to use both available models and compare and evaluate the results between them.

The research covered in this publication has yielded many important insights in value research and in setting out the directions in which current research is moving. However, there are also some limitations and possibilities by which the research conducted can be extended. The main limitation of this publication is the focus on only two academic databases, namely Web of Science and Scopus. Although these are the most used databases in the professional sphere, including only these databases may bias research on value topics. There are several ways in which this publication can be built upon; one way may be to include keyword analysis depending on the region. This perspective would provide a more in-depth view of current topics and help to broaden the understanding of value research in particular areas. It could also form recommendations for relevant new research in each country or region. Another possibility is to include a more detailed analysis of individual publications to help determine a more specific focus for value research. This method could be built on a foundation of data processing using machine learning or current versions of artificial intelligence. In conclusion, future research on value should focus on more detailed research on value to facilitate the identification of current topics within peer-reviewed publications.

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PENSION SYSTEMS IN EUROPEAN COUNTRIES: PECULIARITIES AND CHALLENGES

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Abstract. This study explores the role of pension systems in maintaining the basic living needs of retirees after retirement. As the proportion of elderly populations grows, the burden of the elderly dependency ratio also increases. The article's objective is to ensure the basic living standards of retirees in different European countries in the face of growing population ageing, maintain sustainable development of pension funds, and reduce the government's financial burden. Additionally, the analysis evaluates the impact of government regulation on the lives of people aged 65 and above. Using panel data from Eurostat between 2019 and 2023, we adopt a longitudinal approach to study how long-term commitments to pension fund regulation will influence pension financial sustainability and quality of life after retirement. The analysis provides theoretical insights and tailored managerial policy recommendations.

Keywords: pension systems; retirement; living standards; poverty; population; wages; pension benefits

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JEL Classifications: H55, J26, J14, I38

Additional disciplines: sociology

1. Introduction

One of the most critical components of social security for older people is the pension system. They are intended to give future income to older adults past working age. However, an increasing number of people are at risk of old-age poverty due to the current design of pension systems. The EU's attempts to combat poverty are at odds with this tendency. In the EU, Member States are in charge of pension plans. The EU legal framework covers some aspects of pensions, including the protection of rights in cases of cross-border mobility, consumer protection of pension savings, gender equality to secure equal pension benefits, and the single market for supplemental pensions, even though the EU is unable to regulate the design of pension systems.

Even though EU pension systems vary greatly, they all face the same primary obstacle: figuring out how to maintain pensions' long-term financial viability in the face of an ageing population and a rising proportion of pensioners compared to working-age individuals. While it is unknown how wages and prices will change, Member States are working to guarantee pension adequacy, or an adequate level of pension benefits and protection of older people from poverty. To varying degrees, these concerns are addressed by recent national pension reforms.

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As the population's age distribution shifts and people live longer and have fewer children, the European population is quickly ageing and is predicted to begin declining by 2026. In 2022, 21.1% of EU citizens were 65 or older. By 2070, this percentage will increase to around 30%, along with axe-related public spending on long-term care, healthcare, and pensions. Conversely, the proportion of the working-age population, meaning those aged 20 to 64, would decrease from 59% to 51% of the overall population. With pensions eating up more and more of government money each year, it is imperative to promote long-term savings to lessen the strain on Europe's social security systems.

The number and percentage of senior people in practically every country are on the rise, indicating that the world's population is entering an ageing period (Halliday, 2024). The United Nations World Population Outlook 2024 predicts that the proportion of people 65 and older will increase quickly, almost tripling from 17% to 33% between 2024 and 2054. In the group of nations that have already reached their peak in size, older people may make up 40% of the population by 2100 (with a 95% chance that the proportion of those 65 and over will fall between 33% and 49% in that year) (UN, 2024). As the population ages, several nations may experience pressure to adjust their social security (Petruhhin & Kazjulja, 2025) and pension systems (Sinha & Irala, 2025). The global economic growth rate is also at its lowest point in decades, and as inflation drives up prices and economic growth slows, the cost of living continues to rise. Thus, the issues related to the pension systems occupy an essential place in the EU. To summarise, demographic changes in EU countries, specifically declining birth rates and a rising proportion of older adults, pose a fundamental challenge to pension systems. As the elderly population grows, the ratio between young working individuals who pay into the pension system and retirees who receive pension benefits shifts. In other words, because the proportion of young workers contributing to the pension system is lower than that of the retired elderly population, governments struggle to sustain pension systems. To address the issue, pension system reforms aim to raise the retirement age, reduce the replacement rate of pensions, and increase the roles of private and individual pension systems. However, even private pension systems, in which previous contributions finance current benefits, have been under pressure for decades from the ageing population problem (Ebbinghaus, 2021; Dumiter et al., 2024).

2. System reforms for sustainable pensions in the EU and comparison of Global Pension Index 2024 indicators

In the last decades, EU countries have sought solutions to ensure the sustainability of their pension systems. One such solution is pension system reform, which aims to reduce the benefits provided to retirees to sustain the system. The UK's Thatcher government adopted the Social Security Act in 1986, which expanded individual and private pension accounts while reducing the role of public earnings-related pensions. As a result, between 1986 and 1997, the size of personal pension funds increased by 50% (Professional Pensions, 2019).

Dossinger & Beaver (2025) emphasised that current pension systems face a series of common challenges, which are likely to persist in the future, potentially with more severe consequences. The crisis highlighted the importance of the EU's approach to pension systems and the need for greater efforts to increase the effectiveness and security of pension plans. In Romania, it was suggested that creating quality jobs, promoting legal employment, improving contribution collection, and developing the individual pension system would support the population and the economy through the generated and invested financial resources. While the changes are presented as the employer taking responsibility for workers' future security, an alternative view is that the employer is shifting pension obligations—and the related risks—to employees in pursuit of greater profitability (Vansweevelt et al., 2022; Stiemke, Hess & Pink, 2025).

Hagemann and Scherger (2016), examining pension age increases in Germany and the UK, analysed expert opinions from major political parties, government agencies, employer confederations, trade unions, and interest groups. Despite Germany and the UK having very different pension systems, discussions around similar reforms showed striking similarities. In both countries, reform advocates emphasised fiscal necessity and the ability of older adults to work longer. At the same time, opponents questioned older individuals' capacity to continue working and expressed doubts about the reforms' feasibility. Supporters focused on intergenerational justice and merit-based fairness, while opponents emphasised needs-based justice and social inequalities. The two countries' views differed significantly regarding flexible retirement transitions (Fontana et al., 2024; Vigezzi et

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al., 2025). Olivera (2018), using cross-sectional data from the EU Statistics on Income and Living Conditions (EU-SILC), estimated pension wealth inequality among elderly households in 26 EU countries. To evaluate the role of life expectancy inequality on pension wealth, the study used life tables by educational level to estimate socioeconomic status (SES), also disaggregating mortality estimates by gender, birth cohort, and year. In most countries, this effect declined between 2006 and 2018, indicating that SES-related mortality inequalities have become less significant in explaining current pension wealth disparities. Recentered Influence Function (RIF) regressions confirmed the declining effect of higher education on pension wealth inequality. Chłoń-Domińczak et al. (2017) used age-period-cohort (APC) decomposition to measure cohort effects on pension income profiles of individuals born between 1927 and 1962 in Austria, Germany, Hungary, Poland, and Sweden—countries representing different labour markets and pension systems. The analysis of pension age profiles estimated with the National Transfer Accounts (NTA) approach for 2005–2013 showed that cohort effects have declined for younger cohorts. Increasing age coefficients have offset these adverse effects, reflecting longer working lives and rising retirement ages. Adjustments to pension levels to reflect actual values were more prominent in countries with defined contribution or points-based systems, even before the crisis. Period effects also reflected some reaction to the economic crisis.

Leroux (2019), in his study, showed a close link between payroll taxation and pension benefits as a means to reduce tax evasion. Using a political economy model where institutions may hide part of their income to avoid taxation and where the public sector is more efficient in delivering annual pension entitlements than the private sector, he demonstrated that in the absence of avoidance costs, agents are indifferent to tax rates, as they can perfectly adjust their compliance to match preferred effective tax rates. He found unanimous support for higher tax rates and that public pension systems partially enhance tax compliance and the resources collected, resulting in greater redistribution toward those worst off. The perfect substitution between compliance and taxation breaks down when introducing avoidance costs. In a majority voting equilibrium, a coalition emerges between low-income individuals and those favouring more redistribution to the elderly, opposing middle-income representatives through support for higher tax rates. Beyond the traditional tax base argument, Leroux proposed that the optimal level of the "Bismarckian" pillar is now chosen based on political support. There are also studies criticising pension system reforms for gender discrimination, especially against women. Tabata (2015), analysing the unintended gendered outcomes of seemingly gender-neutral EU policies, examined pension policy reforms that have entered the political agenda due to demographic trends and concerns about the financial sustainability of public pensions. She argued that although EU member states have enacted a series of reforms to reduce state responsibility and increase individual responsibility, these reforms—while appearing gender-neutral—reflect male work models and disadvantage women, who are often removed from the workforce due to caregiving and domestic responsibilities, and who are more likely to work part-time or in temporary jobs.

Given the October 2024 announcement of declining birth rates and rising longevity, the Mercer CFA Institute Global Pension Index 2024 emphasises the necessity of retirement system enhancements. Defined contribution (DC) plans are gradually replacing defined benefit (DB) plans in retirement systems across the globe (CFA Institute, 2024). The study examines the advantages and disadvantages of DC plans for people and pensioners in the continuous transition to defined-contribution pension systems. Retirement is changing, with many people either gradually moving into retirement or returning to work in a different role following their first retirement. Gig and contract workers, frequently excluded from standard DB schemes, can also profit greatly from DC plans.

Restoring stability to retirement systems cannot be accomplished with a single approach. Governments, legislators, the pension industry, and employers must now cooperate to guarantee that older people are treated with respect and can continue living the same way they did during their working years. Forty-eight retirement income systems worldwide are benchmarked by the Mercer CFA Institute Global Pension Index, highlighting potential and concerns in each system. The index compares each retirement income scheme to over 50 indicators and comprises three sub-indices: adequacy, sustainability, and integrity. Overall, ratings were marginally lower this year due to mounting pressure on government resources to sustain pension schemes brought on by rising healthcare expenses, high interest rates, and longer lifespans. In recent years, many systems have implemented pension reforms, including those in China, Mexico, India, and France. Table 1 shows that the Netherlands had the highest results for adequacy (86.3), Iceland for sustainability (84.3), and Finland for integrity (90.8) for each

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sub-index. As the Netherlands transitions from a DB framework to a more individualised DC approach, its pension system remains the best.

Table 1. Measurements of retirement systems by Mercer CFA Institute Global Pension Index

Country	Overal grade	Total	Adequacy	Sustainability	Integrity
Netherlands	A	84,8	86,3	81,7	86,8
Iceland	A	83,4	82,0	84,3	84,4
Denmark	A	81,6	84,0	82,6	76,3
Finland	B+	75,9	77,0	64,2	90,8
Norway	B+	75,2	77,2	63,6	88,3
Sweden	B	74,3	75,2	73,7	73,6
Switzerland	B	71,5	66,0	71,4	80,4
Belgium	B	68,6	81,8	40,1	87,4
Ireland	B	68,1	73,6	52,8	80,5
France	B	68,0	84,8	43,4	75,7
Germany	B	67,3	81,1	45,8	75,3
Portugal	B	66,9	83,4	34,6	85,7
Spain	C+	63,3	82,9	30,7	77,6
Poland	C	56,8	59,2	45,2	69,4
Italy	C	55,4	68,2	25,1	77,2

Source: SFA Institute, 2024

The data in Table 1 also provides participants with guidance regarding their pensions and has strict requirements.

3. Review of pension systems developments in the European Union

The EU, which has the world's largest senior population, is under tremendous strain on social security and the population. Ensuring the sustainable growth of pension funds, guaranteeing the basic living standards of retirees, and lessening the financial burden on the government have progressively grown in importance in social security as the population ages. The duration of statutory social insurance, the amount of contributions, the financing sources, the range of users, the amount of payments they get, and the system's overall viability vary throughout EU nations' pension systems. They are structured around three pillars and comprise both a public and a private section: The first pillar is made up of mandatory public statutory pensions, the second pillar is covered by occupational pensions (quasi-mandatory, earnings-related) and the third, supplementary personal pensions (voluntary, earnings-related).

For those not covered by an earnings-related plan or with limited accrued pension entitlements, most systems offer a minimum guaranteed pension. The state is in charge of pension provision in every EU nation and has the authority to determine the minimum and maximum pension levels.

Different criteria can be used to categorise public pension schemes. Funding sources may be derived from taxes, other non-contributory sources, or contributions (contributory or earnings-related). While some nations have flat-rate pensions that occupational plans can augment, others have public pensions tied to earnings. Concrete pension benefits are calculated using a formula unique to each country. Merit (years worked, payments put into the system) and revenue level are typically combined, along with a baseline pension component that is the same for everyone.

There are three main categories of publicly offered earnings-related pension plans. The primary categories of publicly funded pension plans in the EU countries provide pension benefits that are either benefit-defined or contribution-defined, either as a notional defined contribution or based on a point system (Table 2).

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Table 2. Main types of publicly provided pension schemes in the EU

	Defined Benefit (DB)	**Notional defined contribution (NDC)**	**Point systems (PS)**	**Flat rate + DB**	**Other combination**
Country	Austria, Belgium, Bulgaria, Czechia, Finland, Hungary, Luxembourg, Portugal, Slovenia, Spain	Italy, Latvia, Poland, Sweden	Croatia, Cyprus, Estonia, Germany, Lithuania, Romania, Slovakia	Denmark, Ireland, Malta, Netherlands	Greece: Flat rate + DB + NDC (auxiliary mandatory pension scheme); France: DB + PS (complementary schemes AGIRC and ARRCO)

Source: The 2021 Ageing Report, European Commission, 2021.

For every year of service, a fixed accrual rate is paid under a defined-benefit plan (DB). Benefits are calculated using the average revalued earnings over a lifetime. Wages times the contribution rate is the annual inflow to notional accounts, which is known as the notional defined contribution (NDC). The hypothetical interest rate raises the notional capital annually. The total notional capital is divided by the notional annuity factor at retirement. Contributions made during a person's career are turned into points and accumulated in an account under a points system (PS). The value of a point at the time of retirement then determines the pension payment. There are several methods for funding state pension plans as well. Most public pension plans are supported using the pay-as-you-go (PAYG) model, in which current pension benefits are paid out of current contributions. An alternative is to invest contributions in a special fund, which is subsequently used to pay future pension benefits. Every EU member state has a PAYG-based system complemented by sponsored or required PAYG programs. Old-age and early pensions, disability benefits (not considered pensions in many countries, but health-related payments), survivor and minimum systems, and certain special pensions are among the risks covered (European Parlament, 2023).

Social protection payments, general government revenue (mostly from taxes), and "other receipts" such as transfers from other programs or investment returns are the main funding sources for old-age benefits. The primary source of funding for minimum pensions is general taxation. Employment-related systems typically rely on mandatory contributions from employers and employees, expressed as a proportion of income. Governments frequently support social security programs and earnings-related schemes (either entirely or partially through tax incentives). The primary funding source for old-age benefit programs in the EU is social contributions, primarily from employers. Over the past 20 years, there has been a noticeable movement toward funding from general government revenue as the employer contribution has decreased (European Commission 2021). All pension plans are subject to various hazards, depending on their design, but third-pillar plans are more vulnerable (Brandt, Zanker, & Frommert, 2024; Cumming et al., 2024; Wiman, 2024).

The system's generosity, eligibility conditions, and demography influence the amount and evolution of public pension spending.

In 2020, EU-27 pension spending accounted for 13.6% of GDP. Ireland, Malta, and Lithuania had the lowest levels, while Greece, Italy, and France had the highest (Chen et. al, 2021). Although pensions are taxed in most nations, pensioners sometimes do not make social security contributions.

The tax rate on labour income is typically higher than the average tax rate on pension income. Certain nations provide pensioners with extra tax breaks, and taxes are progressive. People in most nations quit their jobs (and, consequently, their pension contributions) before they reach the legal retirement age, at which point they begin receiving pension benefits (European Parliament, 2023). Although there is still income inequality in old age, it is less severe than in working age in most Member States because of redistribution through pension and tax systems. The gap between people with low incomes and the general population is widening. It's still difficult to maintain acceptable living standards in retirement. For those with modest salaries or brief careers, minimum old-age benefits are considered a crucial sufficiency buffer (European Commission 2024). Growing in popularity are pension credits for taking care of dependent family members, which are an effective way to

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safeguard pension entitlements. At the late-career stage, pension incomes comprise one-third to more than two-thirds of employment incomes.

At the EU level, this replacement ratio has not changed. Older people's income decreases as working-age salaries rise compared to younger generations. This tendency is anticipated to continue as young people's educational attainment increases. It is expected that PAYG public pensions will become less generous in the future due to the ageing population. This has sparked requests for additional opportunities for people to augment their public pensions with safe, well-funded ones, such as occupational programs. Adequate pension indexation and providing services for older adults, particularly long-term care and healthcare, are additional measures to promote living standards throughout retirement. Pensions are a national responsibility of the Member State. Despite this, the EU backs them and aims for higher socioeconomic convergence. On the other hand, EU pension expertise is limited (Eurostat, 2024). Although the EU lacks the authority to enact laws governing pension systems per se, it can enact laws addressing issues that impact the internal market's operation (such as free movement of people, the provision of services, and consumer protection), combat discrimination (including age and gender discrimination), and safeguard workers' rights. The "proportionality measure" was employed by the authors of a 2021 future-focused review of pension systems published by the Centre for Economic Policy Research (CEPR) (European Voices, 2024). to evaluate pension fairness by contrasting contributions made during working life with retirement benefits.

They found that European pension systems, as constructed, are neither egalitarian nor sustainable, and that many require significant state transfers. This was because Europe's average pension system deficit was expected to rise from 2.5% of GDP in 2021 to 4% in 30 years. They believe pension reforms should benefit younger generations and strive for improved sustainability. They also warn against protracted phase-in periods (for changes), which, although they provide people and households time to adjust, exacerbate generational gaps and endanger future implementation of the reforms.

Other experts used two new indicators to analyse the sustainability of the public pension system in a 2023 CEPR discussion paper (European Voices, 2024): the "pension space," which gauges the ability to pay for pension expenditures from labour taxes, and the "pension space exhaustion" probability, which takes demographic uncertainties into account. They discovered that during the next 30 years, most nations will not have much room to increase pension funding through labour income taxes. They estimated that by 2030, France and Italy will run out of pension space, followed by Austria and Finland by 2040, and eventually by most EU nations, excluding Ireland.

The authors recommend lowering pension payouts or raising consumption taxes as preventive measures since they involve less distortionary labour income taxation than raising the retirement age. Key conclusions were drawn from an analysis of eleven European pension systems conducted by the Austrian economic research firm EcoAustria. The ageing of the population forces nations like Austria, which mainly use a pay-as-you-go system to fund their state pensions, to spend a significant portion of their budgets. By 2035, it will account for over 15% of Austria's GDP, up from over 13.7%. Similar circumstances exist in Germany, where a research project projects 12% of GDP by 2035; in Italy, the figure is 18%. However, pension finance expenses are currently lower in the Netherlands, Sweden, and Denmark, at 6.5%, 7.4%, and 8.3% of GDP, respectively (European Voices, 2024). According to the Mercer CFA Institute, the Netherlands has maintained its position as the nation with the best pension system in the world because of its robust asset base and extremely sensible regulation. Forty-eight nations, home to 65% of the world's population, were compared in the analysis.

4. The main challenges of occupational pensions in Europe

Defined Benefit (DB) and Defined Contribution (DC) are the two main types of occupational pension plans, while it is entirely feasible to include aspects of both into "hybrid arrangements." The methods used to calculate pension benefits and who is responsible for the risks involved vary throughout these plans. Most of the risks are borne by employers in traditional DB schemes, where benefits are frequently tied to an employee's ultimate salary. Still, in traditional (or sometimes called pure) DC schemes, the risks are transferred to the individual employees.

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In actuality, several hybrid arrangements fall somewhere between these two extremes. These agreements include varying levels of risk-sharing between employers and employees, often coupled with collective risk-sharing or specific assurances. DC or hybrid plans have replaced traditional DB pension plans in several Member States over the last few decades; EU policymakers have also called attention to this trend (Peyravi, 2015). Several causes have contributed to this transition, such as shifting regulatory environments, economic constraints, and demographic shifts. Stress due to these demographic shifts.

Along with their pension benefits from the first pillar, many European people already rely on workplace and/or occupational DC pension plans, and this number is predicted to increase in the future. Given that the working-age populations of several Member States—including Greece, Lithuania, and Poland—are expected to decline by at least one-third by 2060, structural changes in their populations present difficulties. The current and upcoming pension systems, especially "PayAsYouGo" arrangements, are under challenge.

In certain nations, it is also anticipated that age dependency ratios—the proportion of dependents to working-age individuals—will increase. According to some estimates, by 2060, there would be fewer than two working-aged people for every person over 65 in more than half of the EU's member states. Some governments have created regulations that either mandate or encourage employers to switch to DC schemes in response to these developments. The trend toward DC pension plans is also influenced by the evolving labour market, which includes increased workforce mobility, self-employment, and flexible work schedules. Pension plans that accommodate changing work schedules and offer simple portability when workers quit their jobs or take time off are becoming increasingly popular. Because DC plans provide more control over pension expenses and reduce exposure to the risks and volatility of DB plans, businesses are also selecting them.

Economic pressures: Greece and Italy devote more than 15% of their GDP to pensions, and pension spending as a proportion of GDP has increased in certain European nations. According to Eurostat data, the EU's average pension spending in 2021 was 12.9%. Variations in the labour share of GDP, employment trends, and demographic shifts can all be used to explain this sizeable portion of GDP that goes into pensions. In the second pillar, DB schemes have also found it challenging to produce enough returns to cover their commitments due to falling interest rates, which have been present since the late 1980s. These causes accelerated the trend toward DC (Pensions Europe, 2024). According to the EIOPA Consumer Trends Report from 2020, DC schemes accounted for 55% of active members in 23 Member States. This trend has only gotten stronger since then. According to the 2023 edition of the EIOPA Consumer Trends Report, the number of new members in DC pension plans rose by 115% in 2022 over 2021, with France and Sweden seeing the most significant increases at 61% and 90%, respectively. As a percentage of all active members overall, it translates to an 11% rise in active members in DC schemes in a year (Eurostat, 2024). The number of members and the assets under management of DB and hybrid schemes continue to grow. Regarding absolute numbers, DB pension plans added more members in 2022 (2.1 m for DC and 2.5 m for DB).

As some Member States, like Germany, will continue to offer primarily DB contracts, it is crucial to remember that the trend is not unique to Europe and that DB schemes will continue to be significant. The retirement age in Denmark, which has one of the greatest pension systems, will increase to 67 in 2022. The Netherlands, which is ranked as the best country for retirees, will follow suit in 2024. Germany and Spain will also have a 67-year-old retirement age. Currently, Iceland has the highest retirement age in Europe, at 67. Sailors in this nation are an exception, as they are eligible to retire at age sixty. Iceland has no immediate plans to increase the current cap. There are several exceptions, even though practically every European nation is hiking the retirement age. Norway's retirement age was 67 until recently, but following a reform that increased the pension system's flexibility, citizens can now retire at any age between 62 and 75. Later, people who entered the workforce gained the most from this arrangement, which garnered much praise. As a result, the government rewards Norwegians for working longer hours. By doing this, the detrimental effects of rising life expectancy and falling birth rates are countered, and the strain on the social security system is lessened.

Outside of Europe, the retirement age is typically lower. The retirement age criteria outside of Europe are likewise noticeably lower. For instance, the United Arab Emirates has the lowest retirement age in the world, at just 49. However, this age only applies to citizens physically present in the nation; foreigners who wish to

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earn a pension must be at least 60 years old. Many Asian and African countries also have somewhat lower retirement ages. The retirement age for women is 60 in Egypt, Cameroon, India, and Sri Lanka, while it is even lower in Iran and Vietnam, where it is 55. The issue of an ageing population has been made worse by rising life expectancy and falling fertility rates. Many nations have addressed these problems, including extending pension payment periods and reforming the pension benefit adjustment mechanism to address the adverse effects of growing fiscal costs, ensuring that retired workers benefit from socioeconomic development (European Central Bank, 2022). Pension payments might be made easier by making adjustments to benefits. Scientists and policymakers are now concentrating on assessing the efficacy of pension insurance benefits adjustment plans due to the acceleration of population ageing and socioeconomic development. To modify pension benefits, EU nations typically opt for a mixed indexation model that incorporates both the wage and consumer price indexes (European Central Bank, 2022). This adjustment method often comes in two forms: one is based on the pay index multiplied by a specific percentage, and the other is based on the consumer price index multiplied by the total of the two.

For instance, the adjustment index for pension payments in Switzerland combines 50% of the price index and 50% of the wage index (European Central Bank, 2022). Another kind of adjustment is determined by which is higher, the wage growth rate or the consumer price index. For instance, the automatic yearly adjustment in the Czech Republic is predicated on either a one-third increase in average salaries or a 100% increase in the consumer price index (European Central Bank, 2022).

5. Development of demographic indicators of EU countries

5.1. The share of older people continues to increase in EU countries

As of January 1, 2023, an estimated 448.8 million people lived in the EU. The EU's working-age population, which includes those aged 15 to 64, made up 63.8% of the total population, while children aged 0 to 14 made up 14.9%. At 21.3%, the proportion of older adults (65 and older) increased by 0.2 percentage points (pp) from the year before and 3.0 pp from ten years ago. For contrast, the three demographic categories of working age (15–64 years), older persons (65 years and more), and children (0–14 years) made up 15.0%, 63.9%, and 21.1% of the EU population in 2022, respectively (Eurostat, 2024). In 2023, Ireland (19.3%), Sweden (17.4%), and France (17.3%) had the largest proportions of children aged 0 to 14 in their total populations among EU member states, while Italy (12.4%), Malta (12.7%), and Portugal (12.9%) had the lowest proportions.

Compared to 2022, the proportion of children aged 0-14 in the population of only three Member States (the Czech Republic, Portugal, and Germany) increased in 2023. This proportion decreased or remained constant in the other 15 Member States.

In terms of the proportion of the population that is 65 years of age or older, the most significant shares were found in Italy (24.0%), Portugal (24.0%), Bulgaria (23.5%), Finland (23.3%), Greece (22.0%), and Croatia (22.7%). In contrast, the lowest numbers were found in Luxembourg (14.9%) and Ireland (15.2%).

The percentage of adults 65 and older rose in 2023 compared to 2022 and 2021. Still, it fell in Estonia, Czechia, and Malta. It stayed the same in Spain, Lithuania, Hungary, and Germany (Population age structure by major age groups, 2013 – 2023, in % of the total population, Eurostat).

5.2. Life expectancy trend comparing differences between men and women

Life expectancy increased by 3.8 years between 2003 and 2023. One factor contributing to the ageing of the EU population is the rising life expectancy—people are living longer and longer. Due to several causes, including decreased infant mortality, increased living standards, better lifestyles and education, and advancements in healthcare and medicine, life expectancy at birth increased significantly during the past century. The EU's life expectancy at birth was 77.7 years in 2003, rising by 3.6 years to 81.3 years in 2019. Life expectancy dropped to 80.4 years in 2020 and 80.1 years in 2021 after the COVID-19 pandemic. In 2022 and 2023, it recovered to 80.6 and 81.5 years, respectively, 0.2 years longer than the 2019 value before the COVID-19 pandemic. Between 2003 and 2023, life expectancy increased by 3.8 years at the EU level. From 2003 to 2023, all EU nations had increases; Estonia saw the most significant increase (6.9 years, from 71.9 years in 2003 to 78.8 in

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2023), while Greece saw the smallest (2.3 years, from 79.3 to 81.6). In 2023, Bulgaria (75.8) and Latvia (75.9) had the lowest life expectancies at birth, while Spain (84.0) and Italy (83.8) had the highest 75.9.

Significant disparities still exist when comparing men's and women's life expectancy across nations. In 2022, women's life expectancy remained greater than men's, as it had in prior years. In 2022, the gender difference in the EU was 5.4 years, meaning that newborn girls might expect to outlive males. Additionally, there were significant differences in life expectancy between EU Member States based on gender. Latvia had the most critical gender gap in 2022 (10.0 years), while the Netherlands had the smallest (2.9 years). The gender disparity in life expectancy was greater than the EU average in 13 Member States (Life expectancy at birth, gender age, 2022 (years, female expectancy - male life expectancy), Source: Eurostat)

In 2022, the gender gap decreased in 19 Member States and the EU (from 5.7 years in 2021 to 5.4 years in 2022). According to data from 2023, women in the EU had an 84.2-year life expectancy at birth, while men had a 78.9-year life expectancy, a 5.3-year discrepancy. This was the case in every EU nation, with the Netherlands (2.9; 83.4 and 80.5) and Sweden (3.3; 85.0 and 81.7) having the smallest variations and Latvia (10.0 years; women 80.8 and males 70.8) and Lithuania (9.2; 81.7 and 72.5) having the highest. In 2003, the gender gap in life expectancy at birth in the EU was 6.4 years (women 80.8 and males 74.4), which is 1.1 years more than in 2023. Cyprus (4.4; 81.2 and 76.8) and Malta (4.4; 80.8 and 76.4) had the lowest differences among EU nations in 2003, while Lithuania (11.3; 77.7 and 66.4) and Estonia (10.8; 77.2 and 66.4) had the largest. The gender disparity in life expectancy at birth has shrunk in 25 EU nations between 2003 and 2023, with the most significant declines occurring in Luxembourg (−2.6 years; from 6.0 to 3.4) and Lithuania (−2.1; from 11.3 to 9.2). Only Romania (0.2; from 7.4 to 7.6) and Bulgaria (0.6; from 7.0 to 7.6) had increased.

In 2023, Bulgaria (79.6) and Hungary (80.1) had the lowest life expectancies at birth for women, while Spain (86.7) and France (85.7) had the highest. According to estimates, Latvia (70.8) and Bulgaria (72.0) had the lowest life expectancies at birth for men, while Malta (81.8), Italy, Luxembourg, and Sweden (81.7) had the highest. According to Eurostat (Increase in the share of the population aged 65 years and over, 2013-2023), the effects of the EU's ageing population will significantly impact the ensuing decades. Higher life expectancy and consistently low birth rates are changing the shape of the EU's age pyramid. The significant shift toward an older demographic structure—evident in some EU member states - will likely be the most critical adjustment. The proportion of working-age individuals in the EU is declining due to demographic shifts, while the proportion of retired individuals is increasing. The proportion of older persons is anticipated to rise dramatically in the upcoming decades. As a result, working-age people may find it more challenging to cover the social expenditures that the ageing population needs for various associated services. Meanwhile, fewer people in the EU are of working age (Eurostat, 2022).

The EU's working-age population fell from 269 million in 2012 to 264 million in 2021 over the past ten years. Although the situation is common, it is more noticeable in some Member States (such as Latvia, Bulgaria, and Romania) that experience low birth rates and migratory outflows (Eurostat, 2022).

6. Economic indicators' influence on pension adequacy

In addition to expressing the numbers in a common currency, it is preferable to account for variations in price levels when comparing national accounts statistics internationally, such as GDP per capita. If this were not done, the GDP levels of high-price countries would be overestimated in comparison to low-price countries. Table 4 displays the volume indices of GDP per capita for each country from 2013 to 2023. There is a notable disparity in GDP per capita among EU member states. Of all the nations in this comparison, Luxembourg had the greatest GDP per capita, over 2.4 times more in 2023 than the EU average. This is partially explained by the fact that, although they do not reside in Luxembourg, many foreign residents work there and contribute to the GDP. Their consumption expenditures are documented in their home country's national accounts. The national accounts of their home country reflect their consumption expenditures. The existence of major multinational corporations that own intellectual property helps to explain Ireland's high GDP per capita.

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While a significant portion of the revenue generated by this output is given back to the companies' foreign ultimate owners, the contract manufacturing that goes along with these assets also contributes to GDP. Ireland ranked second among EU nations in 2023, with a GDP per capita of 113% higher than the EU average. The Netherlands, Denmark, and Austria were next, all with more than 20% higher GDPs than the norm. The GDP per capita of the EFTA nations of Iceland, Norway, and Switzerland was 35%, 54%, and 71% higher than the EU average. The other EU nations with GDPs per capita higher than the EU average were Belgium, Germany, Sweden, Malta, and Finland. The GDP per capita of France, Italy, Cyprus, Slovenia, Spain, and Czechia was less than 10% lower than the EU average. (Eurostat- Gross Domestic Product (GDP) per capita, 2013-2023, EU=100).

Romania, Poland, Hungary, Croatia, Slovakia, the candidate country of Turkey, and Latvia all had GDPs per capita less than 30% below the national average. The GDP per capita of Greece and Bulgaria was less than 40% lower than the national average. The candidate country, Montenegro, was placed at 49% below the EU average, followed by the candidate countries Serbia, North Macedonia, Albania, and Bosnia and Herzegovina. Between 2013 and 2023, Table 4's ranking of nations by GDP per capita volume index demonstrates a fair amount of stability. Over the entire period, Bulgaria had the lowest volume index and Luxembourg the highest among EU nations.

Nonetheless, the disparity diminishes within this time frame; in 2013, the highest GDP per capita was six times greater than the lowest, but by 2023, it had dropped to nearly four times. The Gini coefficient shows how much a nation's income distribution departs from a perfectly equal distribution. A Gini number of 0 indicates that income is divided evenly among the population, whereas a value of 100 means that a single individual receives all of the nation's income. The EU's Gini coefficient in 2023 was 29.6.

In 2023, Latvia (34.0), Lithuania (35.7), and Bulgaria (37.2) had the highest levels of inequality in the EU regarding disposable income. The European Union's statistical agency, Eurostat, compared the average pension in Figure 5 by dividing the number of old-age pension claimants by the amount spent on old-age pensions. The figures were taken from Eurostat's database. According to a comparison conducted by Eurostat, the statistics office of the European Union, the average old-age pension in Finland is approximately 1,700 euros, as shown in Figure 5 below, where purchasing power is equal to Purchasing Power Standard (PPS)/month. In 2021, purchasing power was around 1,300 euros per month. The average pension in Finland is higher than the average in the EU. The country-by-country difference in pensions, expressed in euros, is substantial. When the difference in price levels is considered, and pensions are valued according to their purchasing power, the disparity becomes equal. However, Finland's average pension, expressed in purchasing power, is higher than the European average (Finnish Centre for Pensions, 2025). The figures are suggestive. Due to the significant variations in pension systems, comparing pension levels between countries is challenging.

Occupational pensions that augment statutory pensions and are provided to wage earners in many countries are not included in the comparison data for all nations. Furthermore, the comparison ignores the impact of taxes on the ultimate pension amount. The occupational pensions that many nations' wage earners are covered by and which augment statutory pensions are not included in the comparative data for all nations. Furthermore, how taxes impact the ultimate pension amount is not taken into consideration in the comparison (Eurostat - Old age pension in EU countries, in euros/month)

7. Research Methods

TOPSIS, as one of the MCDM methods, considers both the distance of each alternative from the positive ideal and the distance of each alternative from the negative ideal point. In other words, the best alternative should have the shortest distance from the positive ideal solution (PIS) and the longest distance from the negative ideal. This study ranks five criteria and 30 countries based on the TOPSIS method. Table 3 describes the criteria.

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Table 3. Characteristics of criteria

	name	type	weight
1	GDP/capita	+	0.2
2	Gini index	-	0.2
3	Labour productivity: unit of measure	+	0.2
4	Unemployment	-	0.2
5	65 years and over population, percentage	-	0.2

Table 4 shows the decision matrix.

Table 4. Decision matrix

	GDP/capita	Gini index	Labour productivity: unit of measure	Unemployment	65 years and over population percentage
Belgium	118	29.6	123.319	5.5	19.7
Bulgaria	64	24.2	168.965	4	23.5
Czechia	90	37.2	148.328	2.8	20.4
Denmark	125	24.4	111.103	6.4	20.5
Germany	116	28.2	124.737	3.5	22.1
Estonia	80	29.4	167.886	7.6	20.2
Ireland	213	31.8	103.789	4.1	15.2
Greece	69	27.4	101.465	9.3	23
Spain	91	31.8	123.636	11.2	20.1
France	99	31.5	116.053	7.6	21.2
Croatia	76	29.7	127.439	4.8	22.7
Italy	98	29.7	110.206	6.1	24
Cyprus	97	31.5	111.182	5	16.6
Latvia	70	29.6	159.557	6.9	21
Lithuania	87	34	173.547	7.9	20
Luxemburg	237	35.7	140.000	5.9	14.9
Hungary	77	30.6	167.022	4.5	20.5
Malta	107	29	124.044	3	18.6
Netherlands	133	33	125.791	3.7	20.2
Austria	120	26.5	126.717	5.5	19.6
Poland	77	28.1	145.377	2.9	19.9
Portugal	81	27	131.937	6.4	24
Romania	78	33.7	187.306	5.5	19.7
Slovenia	92	31	135.096	3.4	21.4
Slovakia	74	23.4	144.45	5.2	17.9
Finland	105	21.6	115.656	8.6	23.3
Sweden	114	26.6	125.674	8.6	20.4
Iceland	135	29.5	146.185	3.4	15
Norway	171	24	127.921	3.58	18.4
Switzerland	154	24.7	104.621	4.05	19.2

The steps of the TOPSIS method

STEP 1. Normalising the decision matrix

The following formula can be used to normalise.

$$r_{ij}(\mathrm{x}) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad i = 1, \dots, m \;\; ; j = 1, \dots \;, n \qquad (1)$$

Table 5 shows the normalised matrix.

Table 5. The normalised matrix

	GDP/capita	Gini index	Labour productivity: unit of measure	Unemployment	65 years and over population percentage
Belgium	0.186	0.184	0.166	0.169	0.178
Bulgaria	0.101	0.15	0.227	0.123	0.212
Czechia	0.142	0.231	0.199	0.086	0.184
Denmark	0.198	0.152	0.149	0.196	0.185
Germany	0.183	0.175	0.168	0.107	0.199
Estonia	0.126	0.183	0.226	0.233	0.182
Ireland	0.337	0.198	0.14	0.126	0.137
Greece	0.109	0.17	0.136	0.285	0.207

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Spain	0.144	0.198	0.166	0.344	0.181
France	0.156	0.196	0.156	0.233	0.191
Croatia	0.12	0.185	0.171	0.147	0.205
Italy	0.155	0.185	0.148	0.187	0.216
Cyprus	0.153	0.196	0.149	0.153	0.15
Latvia	0.111	0.184	0.214	0.212	0.189
Lithuania	0.137	0.211	0.233	0.242	0.18
Luxemburg	0.375	0.222	0.188	0.181	0.134
Hungary	0.122	0.19	0.225	0.138	0.185
Malta	0.169	0.18	0.167	0.092	0.168
Netherlands	0.21	0.205	0.169	0.114	0.182
Austria	0.19	0.165	0.17	0.169	0.177
Poland	0.122	0.175	0.195	0.089	0.179
Portugal	0.128	0.168	0.177	0.196	0.216
Romania	0.123	0.209	0.252	0.169	0.178
Slovenia	0.145	0.193	0.182	0.104	0.193
Slovakia	0.117	0.145	0.194	0.16	0.161
Finland	0.166	0.134	0.155	0.264	0.21
Sweden	0.18	0.165	0.169	0.264	0.184
Iceland	0.213	0.183	0.197	0.104	0.135
Norway	0.27	0.149	0.172	0.11	0.166
Switzerland	0.243	0.154	0.141	0.124	0.173

STEP 2. Calculating the weighted normalised decision matrix

According to the following formula, the normalised matrix is multiplied by the weight of the criteria.

$$v_{ij}(\mathrm{x}) = w_j r_{ij}(x) \quad i = 1, \dots, m \;\; ; j = 1, \dots \;\; , n \qquad (2)$$

Table 6 shows the weighted normalised decision matrix.

Table 6. The weighted normalised matrix

	GDP/capita	Gini index	Labour productivity: unit of measure	Unemployment	65 years and over population percentage
Belgium	0.037	0.037	0.033	0.034	0.036
Bulgaria	0.02	0.03	0.045	0.025	0.042
Czechia	0.028	0.046	0.04	0.017	0.037
Denmark	0.04	0.03	0.03	0.039	0.037
Germany	0.037	0.035	0.034	0.021	0.04
Estonia	0.025	0.037	0.045	0.047	0.036
Ireland	0.067	0.04	0.028	0.025	0.027
Greece	0.022	0.034	0.027	0.057	0.041
Spain	0.029	0.04	0.033	0.069	0.036
France	0.031	0.039	0.031	0.047	0.038
Croatia	0.024	0.037	0.034	0.029	0.041
Italy	0.031	0.037	0.03	0.037	0.043
Cyprus	0.031	0.039	0.03	0.031	0.03
Latvia	0.022	0.037	0.043	0.042	0.038
Lithuania	0.027	0.042	0.047	0.048	0.036
Luxemburg	0.075	0.044	0.038	0.036	0.027
Hungary	0.024	0.038	0.045	0.028	0.037
Malta	0.034	0.036	0.033	0.018	0.034
Netherlands	0.042	0.041	0.034	0.023	0.036
Austria	0.038	0.033	0.034	0.034	0.035
Poland	0.024	0.035	0.039	0.018	0.036
Portugal	0.026	0.034	0.035	0.039	0.043
Romania	0.025	0.042	0.05	0.034	0.036
Slovenia	0.029	0.039	0.036	0.021	0.039
Slovakia	0.023	0.029	0.039	0.032	0.032
Finland	0.033	0.027	0.031	0.053	0.042
Sweden	0.036	0.033	0.034	0.053	0.037
Iceland	0.043	0.037	0.039	0.021	0.027
Norway	0.054	0.03	0.034	0.022	0.033
Switzerland	0.049	0.031	0.028	0.025	0.035

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STEP 3. Determining the positive ideal and negative ideal solutions

The TOPSIS method aims to calculate the degree of distance of each alternative from positive and negative ideals. Therefore, the positive and negative ideal solutions are determined in this step according to the following formulas.

$$A^+ = (v_1^+, v_2^+, \dots, v_n^+) \quad (3)$$

$$A^- = (v_1^-, v_2^-, \dots, v_n^{-+}) \quad (4)$$

So that

$$v_j^+ = \left\{\left(max\ v_{ij}(x)\middle|\ j\epsilon j_1\right), \left(min\ v_{ij}(x)\middle|\ j\epsilon j_2\right)\right\}\ \ i = 1, \dots, m$$

$$v_j^- = \left\{\left(min\ v_{ij}(x)\middle|\ j\epsilon j_1\right), \left(max\ v_{ij}(x)\middle|\ j\epsilon j_2\right)\right\}\ \ i = 1, \dots, m$$

where j1 and j2 denote the negative and positive criteria, respectively.

Table 7 shows both positive and negative ideal values.

Table 7. The positive and negative ideal values

	Positive ideal	Negative ideal
GDP/capita	0.075	0.02
Gini index	0.027	0.046
Labour productivity: unit of measure	0.05	0.027
Unemployment	0.017	0.069
65 years and over population percentage	0.027	0.043

STEP 4. Calculating distance from the positive and negative ideal solutions

The TOPSIS method ranks each alternative based on the relative closeness degree to the positive ideal and distance from the negative ideal. Therefore, the distances between each alternative and the positive and negative ideal solutions are calculated using the following formulas in this step.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}[v_{ij}(x) - v_j^+(x)]^2}\ \ ,\ \ i = 1, \dots, m \quad (5)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}[v_{ij}(x) - v_j^-(x)]^2}\ \ ,\ \ i = 1, \dots, m \quad (6)$$

Table 8 shows the distance between positive and negative ideal solutions.

Table 8. Distance to positive and negative ideal points

	Distance to positive ideal	Distance to negative ideal
Belgium	0.046	0.041
Bulgaria	0.058	0.05
Czechia	0.052	0.054
Denmark	0.048	0.039
Germany	0.045	0.052
Estonia	0.06	0.031
Ireland	0.028	0.066
Greece	0.072	0.017
Spain	0.073	0.014
France	0.058	0.026
Croatia	0.057	0.041
Italy	0.056	0.034
Cyprus	0.052	0.042
Latvia	0.061	0.033
Lithuania	0.06	0.03
Luxemburg	0.029	0.067
Hungary	0.054	0.046
Malta	0.046	0.054
Netherlands	0.041	0.052
Austria	0.045	0.043
Poland	0.053	0.054
Portugal	0.059	0.034
Romania	0.056	0.043
Slovenia	0.051	0.05
Slovakia	0.055	0.044

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Finland	0.06	0.029
Sweden	0.056	0.028
Iceland	0.036	0.057
Norway	0.028	0.061
Switzerland	0.036	0.055

STEP 5. Calculating the relative closeness degree of alternatives to the ideal solution

In this step, the relative closeness degree of each alternative to the ideal solution is obtained by the following formula. Suppose the relative closeness degree has a value close to 1. In that case, the alternative has a shorter distance from the positive ideal solution and a longer distance from the negative ideal solution.

$$C_i = \frac{d_i^-}{(d_i^+ + d_i^-)}, \quad i = 1, \dots, m \qquad (7)$$

Table 9 shows the relative closeness degree of each alternative to the ideal solution and its ranking.

Table 9. The Ci value and ranking

	Ci	rank
Belgium	0.47	13
Bulgaria	0.467	14
Czechia	0.508	9
Denmark	0.451	16
Germany	0.537	8
Estonia	0.344	24
Ireland	0.703	1
Greece	0.191	29
Spain	0.163	30
France	0.312	28
Croatia	0.418	20
Italy	0.381	21
Cyprus	0.448	17
Latvia	0.349	23
Lithuania	0.335	25
Luxemburg	0.698	2
Hungary	0.46	15
Malta	0.542	7
Netherlands	0.56	6
Austria	0.487	12
Poland	0.504	10
Portugal	0.363	22
Romania	0.436	19
Slovenia	0.497	11
Slovakia	0.443	18
Finland	0.322	27
Sweden	0.328	26
Iceland	0.617	4
Norway	0.689	3
Switzerland	0.604	5

Figure 1 shows the Ci values.

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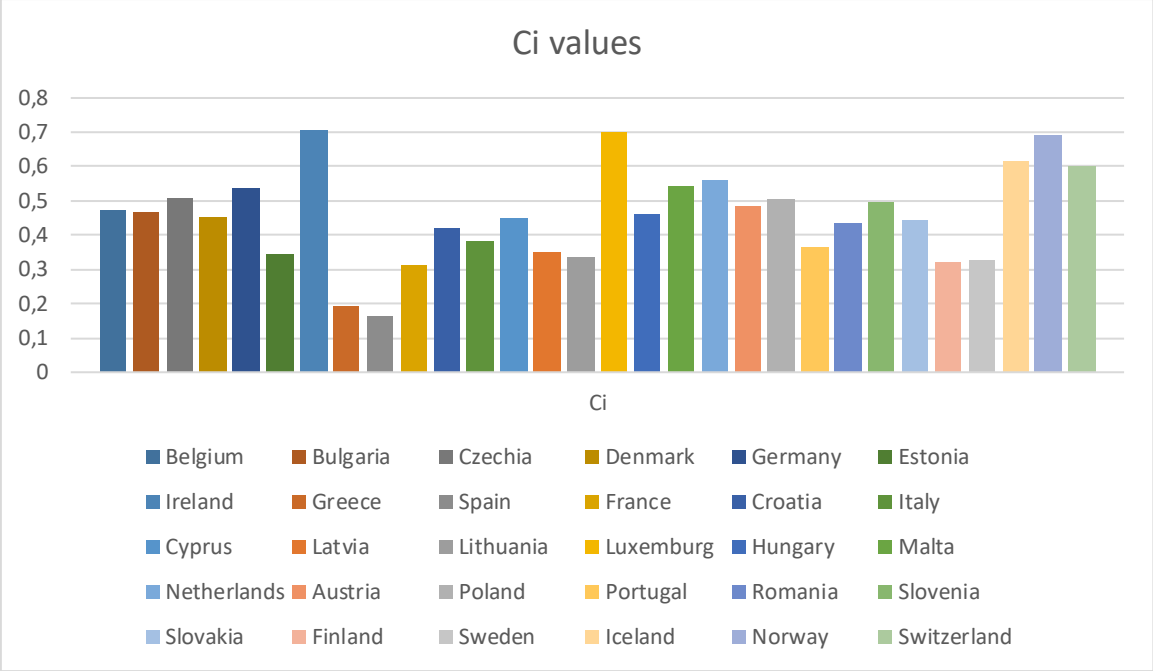


Figure 1. The changes in the CI value of EU countries

Based on the TOPSIS examination, the criteria selected in different EU countries were positioned according to their relative closeness to the ideal arrangement. So, as we can see in Table 11, with the highest relative closeness, Ci*=0.703 was Ireland, with a 2nd ranking with Ci*=0.698 was Luxembourg, and a third ranking with Ci*=0. 689 was in Norway, next was Iceland (Ci*=0,617), and fifth was Switzerland (Ci*=0,604). The TOPSIS analysis has identified the most effective alternatives in managing pension systems. The second group of EU countries can be defined as Sweden (26) - Ci =0,328; Finland (27) - Ci = 0.322; France (28) - Ci = 0.312; Greece (27) - Ci = 0.191. Another group of EU countries is in the middle: Cyprus (17) - Ci=0,448; Denmark (16) - Ci=0,451; Hungary (15) - Ci=0,460; Bulgaria (14) Ci=0,467; Belgium (13) - Ci=0,470.

Conclusions

1. The global population is entering an ageing stage, and the number and proportion of older adults in almost all countries are showing an upward trend. In the process of increasing population ageing, ensuring the basic living standards of retirees, maintaining sustainable development of pension funds, and reducing the government's financial burden have gradually become essential issues in social security.
2. All EU Member States have a system based on a PAYG system, supplemented by mandatory or optional PAYG or funded schemes. The risks covered include old-age and early pensions, disability (some countries do not consider disability benefits as pensions but health-related payments), survivor and minimum schemes, and some special pensions.
3. Analysis of demographic indicators of EU countries shows that the share of older people continues to increase in EU countries, so the governments must analyse how to develop a pension system.
4. Pension systems in Europe, as designed, are neither sustainable nor equitable, and many require substantial state transfers. In their view, pension reforms should aim for greater sustainability and do so not only at the expense of younger generations.
5. Occupational pension schemes take two primary forms: Defined Benefits and defined contributions, and they combine elements of both within ‘‘hybrid arrangements’’.
6. Based on the TOPSIS examination, the selected criteria in different EU countries have been positioned according to their relative closeness to the ideal arrangement. So, as we could notice in Table 11, with the highest relative closeness, Ci*=0,703, was Ireland, with a 2nd ranking, Ci*=0,698, was Luxembourg, and a third ranking, Ci*=0,689, was Norway. Next was Iceland (Ci*=0,617), and fifth was Switzerland (Ci*=0,604). Other countries, such as Sweden, Finland, France, Greece, and Spain, are less close to the ideal arrangement, with a CI interval from 0,328 to 0,163. These results of TOPSIS research provide policymakers and

governments with theoretical insights and tailored managerial policy recommendations to help them maintain financial sustainability and quality of life after retirement.

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ADVERTISING MIX AND MOBILE APP ADOPTION IN EGYPT: THE MODERATING ROLE OF PERCEIVED UTILITY

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Abstract. This study investigates the moderating role of perceived utility on the relationship between the advertising mix and mobile app adoption in Egypt, an emerging market. Drawing on the Unified Theory of Acceptance and Use of Technology (UTAUT), the research explores how perceived utility, defined as the extent to which consumers believe a mobile app enhances their performance or provides value, influences the effectiveness of various advertising mixes in mobile app adoption. Using a quantitative research design, data were collected from 418 Egyptian consumers exposed to mobile app advertisements. The findings reveal that the advertising mix and perceived utility significantly impact mobile app adoption, with perceived utility as a positive moderator. Specifically, the study demonstrates that when consumers perceive higher utility in a mobile app, the effectiveness of the advertising mix in mobile adoption increases. This research contributes to the marketing literature by extending UTAUT to include the advertising mix as a determinant of technology adoption in emerging markets. It also provides actionable insights for marketers and policymakers, emphasising the importance of tailoring advertising strategies to enhance perceived utility and improve adoption rates in culturally and economically diverse contexts.

Keywords: perceived utility; advertising mix; mobile app adoption; UTAUT; Egypt

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JEL Classifications: M31, M37

1. Introduction

Particularly in developed markets where digital adoption is growing, the fast spread of mobile applications (apps) has changed how customers connect with technology (Keith et al., 2015; Mabungela et al., 2025). From financial services to entertainment, mobile applications have become integral to daily life; their adoption is increasingly driven by evolving marketing methods, particularly the advertising mix (Alghazi et al., 2021; Liu et al., 2022). Consumer impressions and behaviours toward mobile applications are shaped by the *advertising mix*, defined as the strategic combination of promotional tools (e.g., digital/social media, TV, print, influencer endorsements) used to communicate app value (Kotler & Keller, 2016; Belch & Belch, 2018; Quyet, 2024). Nevertheless, the success of various promotional techniques in increasing mobile app adoption varies depending on the market, particularly in developing countries where customer behaviour is much influenced by cultural, financial, and infrastructure aspects (Burgess & Steenkamp, 2006; Mugunzva & Manchidi, 2024).

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One crucial aspect that moderates the link between the advertising mix and mobile app uptake is perceived utility (Lin et al., 2016). A central concept in the Technology Acceptance Model (TAM) is perceived utility, which refers to an individual's subjective belief that using a specific technology will improve their performance (Davis, 1989). Although many studies have examined perceived utility in industrialised economies, its function in emerging regions such as Egypt—where digital uptake is still maturing—remains under-explored (Bendary & Al-Sahouly, 2018). Emerging markets provide special difficulties, including lower internet penetration, different degrees of digital literacy, and cultural preferences that might change the efficacy of conventional and digital advertising strategies (El-Gohary, 2012).

The body of current research has concentrated chiefly on the direct impact of advertising on consumer behaviour, paying little attention to the moderating function of perceived value, particularly regarding the acceptance of mobile apps in developing countries. For example, although studies in developed markets have shown that digital advertising and sales promotions greatly affect app adoption (Taylor & Levin, 2014), the same approaches may not produce similar results in emerging markets due to variations in perceived utility and contextual factors. This research gap emphasises the need for a more complex knowledge of how perceived utility interacts with the advertising mix to impact mobile app uptake in developing economies.

This study aims to address this gap by examining the moderating role of perceived utility on the relationship between the advertising mix and mobile app adoption in Egypt, a representative emerging market. The rationale for this research lies in its potential to provide actionable insights for marketers and policymakers in emerging markets. By understanding how perceived utility influences the effectiveness of different advertising strategies, businesses can tailor their marketing efforts to better align with consumer expectations, thereby enhancing app adoption rates. Additionally, this study contributes to the broader academic discourse by extending the Unified Theory of Acceptance and Use of Technology (UTAUT) to include the advertising mix as a key determinant of technology adoption in emerging markets (Venkatesh et al., 2012; Liu et al., 2022).

The study employs a quantitative research design, utilising survey data collected from Egyptian consumers exposed to advertisements promoting mobile apps. The findings will provide a deeper understanding of the interplay between advertising strategies and perceived utility in driving mobile app adoption in emerging markets. The remainder of this study is structured as follows: Section 2 provides a comprehensive review of the literature on advertising mix, perceived utility, and mobile app adoption, focusing on emerging markets. Section 3 outlines the research methodology, including data collection and analysis procedures. Section 4 presents the Conclusion and recommendations.

2. Literature review

Recent studies examine how the advertising mix influences mobile app adoption, especially in developed and digitally transforming markets (Ben Arfi et al., 2021; Andrews et al., 2021). Emerging economies like Egypt, however, have specific characteristics that call for more research on this link, particularly given the moderating influence of perceived utility (Bendary & Al-Sahouly, 2018). Contemporary conceptualisations frame the advertising mix as an integrated bundle of promotional tools—digital, social, traditional and influencer channels—deployed to communicate value propositions (Kotler & Keller, 2022). Rather than a static “4-P” inventory, it is now viewed as a dynamic system that adapts to platform algorithms and consumer journeys in emerging markets (Belch & Belch, 2022; Liu et al., 2022).

Developed by Davis (1989), the Technology Acceptance Model (TAM) offers a theoretical basis for comprehending how perceived utility and simplicity of use affect technology acceptance in the context of mobile app uptake. Key factors of technology adoption, according to TAM, are perceived utility- the degree to which a person feels using a technology would improve their performance - and perceived ease of use - the degree to which a person believes utilising a technology will be free of effort (Ridings & Geffen, 2000). Particularly in developed economies, this model has been extensively used in research on mobile app uptake (Venkatesh et al., 2012; Haurovi & Chilunjika, 2024).

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The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) extends TAM by integrating social influence and facilitating conditions, offering a broader lens for emerging markets (Liu et al., 2022). UTAUT has proved very helpful in elucidating technology adoption in developing countries, where social and infrastructure elements significantly influence (Venkatesh et al., 2012; Liu et al., 2022)

Recent evidence affirms that advertising-mix strategies significantly influence consumer decisions to adopt mobile applications, especially in digitally expanding economies (Alalwan et al., 2017; Bu et al., 2021). Particularly via social media and search engines, digital advertising - especially in developed markets - has been quite successful in increasing app downloads and usage (Taylor & Levin, 2014). For instance, the study by Kim & Han (2014) indicated that focused digital advertising considerably raised the United States' usage of mobile banking apps. Likewise, sales campaigns like free trials and discounts have improved app acceptance by lowering perceived risk and increasing perceived value (Huang &Kuo, 2011).

Empirical comparisons indicate that UTAUT outperforms individual predecessor models in explaining technology-usage behaviour (see meta-analyses by Williams et al., 2015; Venkatesh et al., 2011, 2012) and AbuShanab & Pearson, 2007; Im et al., 2011; Lin et al., 2019; Alghazi et al., 2021; Andrews et al., 2021; Ben Arfi et al., 2021; Bu et al., 2021; Liu et al., 2012). Behavioural intention and use behaviour are investigated using variables including use performance expectations, ease-of-use expectations, social effects, and enabling environments (Wu & Du, 2012). Four additional moderating factors—gender, age, experience, and voluntary use—are also suggested for investigating usage behaviour (Park & Gweon, 2015). This study applied the UTAUT framework to examine the impact of middle-aged PX Mart consumers' behavioural intentions to use PX Pay and related variables since UTAUT has a significant degree of explanatory power for people's intentions and actions in utilising technology (Liu et al., 2012). This study's independent variables include performance expectations, ease-of-use expectations, social effect and enabling circumstances. PX Pay can cause consumers to have distinct behavioural goals and use patterns.

As for the perceived utility of adopting mobile phone applications, the literature has indicated many types, including: performance expectation, effort expectation, social influence, and facilitating conditions. Performance expectancy, a key construct in the UTAUT model, captures an individual's belief that using a system will lead to tangible benefits in their performance (Venkatesh et al., 2003). Previous research has shown that acceptance of technology is much influenced by performance expectations (Davis, 1989; Venkatesh & Davis, 2000; Oechslein et al., 2014). Consumers are more ready to employ information systems when they can use technology to achieve their objectives when their pragmatic and convenient expectations are satisfied (Szajna & Scamell, 1993). Furthermore, performance expectations change based on age and gender (Cabrera et al., 2009; Lian & Yen, 2014; Liu et al., 2012)

Effort expectation (EE) is the degree of simplicity with which the user may use recently developed technology, systems, and applications (Venkatesh et al., 2003). Ease of use expectations change with age and gender (Venkatesh & Davis, 2000). For instance, although women and seniors often pay greater heed to the ease-of-use expectations of information systems, the accumulation of experience still affects their experience. Simultaneously, Maduku et al. (2016) pointed out that consumers do not need extra time and effort if they believe that mobile marketing tools are simple and easy to use; moreover, the tools can help them locate the necessary information, thus enhancing their acceptance .

Social influence is the personal understanding of the user that key others think the user should apply this new technology or system (Venkatesh et al., 2003). Social impact also depends on gender, age, experience, and willingness (Ye et al., 2020). For instance, their colleagues and top managers influence early adopters and .young women

As defined by Venkatesh et al. (2003), facilitating conditions refer to an individual's perception of the organisational and technical resources available to support the use of a system. These conditions encompass the provision of necessary hardware and software tools and the broader organisational support for new technologies

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(Venkatesh et al. 2003). Recent research consistently highlights the critical role of facilitating conditions in influencing technology adoption across various contexts. For instance, studies on educational technology adoption emphasise the importance of adequate infrastructure and support systems (Jarvie-Eggart et al., 2022; Feng et al., 2025). Similarly, in the context of mobile applications, reliable internet access, compatible devices, and technical assistance significantly impact user adoption and continued engagement (Marikyan & Papagiannidis, 2025). Empirical evidence suggests that facilitating conditions directly influence behavioural intention and usage behaviour, potentially moderated by factors such as age and experience (Mensah et al., 2022; Mensah & Khan, 2024).

Behavioural intention, defined as the subjective probability that an individual will perform a specific behaviour (Ajzen & Fishbein, 1975), remains a robust predictor of technology adoption and system utilisation. In the context of mobile app adoption, recent studies consistently demonstrate the significant role of behavioural intention in driving user engagement and continued use (Roy, 2017; Sadiq et al., 2025). For example, research on mobile health services and mobile shopping applications highlights how factors influencing behavioural intention, such as perceived usefulness and social influence, directly translate into adoption behaviours (Popescu et al., 2021; Cao et al., 2024). Venkatesh et al. (2003) established that customers' technology adoption behaviour is contingent upon their behavioural intents, a finding that continues to be validated in contemporary research across various digital platforms and emerging markets (Mahmud et al., 2022; Indiani et al., 2025).

However, the effectiveness of the advertising mix in developing countries remains underexplored (see Figure 1), particularly in contexts like Egypt (Elsafty & Yehia, 2023; Statista, 2023). Furthermore, national culture dimensions shape users' receptivity to new technologies (Hofstede, 1980, as cited in Sheth, 2011, p. 174). Research on collectivist cultures suggests that social influence and interpersonal recommendations can outweigh traditional advertising when consumers decide whether to adopt an app (Burgess & Steenkamp, 2006).

Perceived usefulness is a significant determinant of technology adoption, especially for mobile applications. Davis (1989) claimed that technology acceptance depends mostly on perceived utility, and much research in industrialised and developing economies has confirmed this. For instance, (Venkatesh et al., 2012) research discovered that the acceptance of mobile banking apps in India, a growing market with traits comparable to Egypt, was much impacted by perceived value.

In mature markets, time savings and convenience define perceived usefulness. For example, the study by Kim & Han (2014) revealed that Americans were more inclined to utilise mobile banking applications if they thought they were handy and straightforward. In developing markets, perceived value also includes access to otherwise absent services and cost reductions. For instance, Malaquias and Hwang (2016) discovered that, in Brazil, where access to conventional banking services is restricted, adoption of mobile banking was primarily driven by perceived usefulness.

Empirical research has produced conflicting findings regarding the interaction between advertising mix, perceived usefulness, and mobile app uptake in established and developing economies. With digital advertising and sales promotions especially successful, the advertising mix has been demonstrated in developed countries to directly influence app uptake (Taylor & Levin, 2014). In developing countries, however, the link is sometimes moderated by perceived utility and other contextual elements, including infrastructure and cultural standards (Burgess & Steenkamp, 2006).

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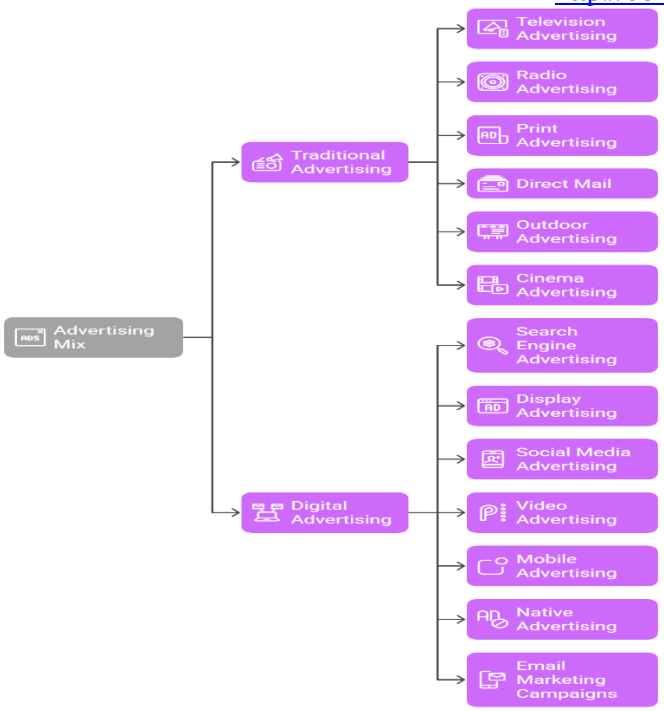


Figure 1. Advertising mix

For instance, El-Gohary's (2012) study indicated that, in Egypt, where internet penetration is somewhat low, conventional advertising media, including TV and radio, were more effective than digital promotion in boosting app use. Likewise, Malaquias and Hwang's (2016) study revealed that, in Brazil rather than in the United States, where infrastructure and access to traditional banking services are more established, perceived usefulness significantly influenced mobile banking uptake. These results imply that although the advertising mix is a major driver of app uptake in developed and developing nations, its efficacy may depend on contextual elements like infrastructure, cultural standards, and perceived usefulness. This emphasises the requirement for a more sophisticated knowledge of the interactions among these elements in diverse marketplaces. Though the literature on the link between advertising mix, perceived usefulness, and mobile app adoption is increasing, an empirical study looking at this link in developing nations such as Egypt is lacking.

3. Study methodology and design

3.1. Hypotheses' development

The advertising mix (comprising traditional advertising and digital methods) is a cornerstone of marketing theory. It has influenced consumer behaviour across various contexts (Belch & Belch, 2018). Mobile app adoption, on the other hand, is a critical area of study in technology acceptance and digital marketing, particularly in emerging markets like Egypt, where digital transformation is accelerating. Still, adoption barriers remain due to economic, cultural, and infrastructural factors (Bendary & Al-Sahouly, 2018). The relationship between the advertising mix and mobile app adoption can be explored through the Technology Acceptance Model (TAM) lens, which posits that perceived usefulness and ease of use are key determinants of technology adoption (Davis, 1989). Advertising plays a pivotal role in shaping these perceptions by communicating the value proposition of mobile apps to potential users. In the Egyptian context, where trust in digital tools and familiarity with mobile apps may vary, understanding how the advertising mix influences adoption behaviours becomes particularly relevant. Then came the emergence of the Unified Theory of Acceptance and Use of Technology (UTAUT), representing the second generation of theories dealing with new technology (Venkatesh et al., 2012). Based on this theoretical foundation, the following hypothesis is proposed:

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Hypothesis no.1: The advertising mix has a positive and significant impact on mobile app adoption in Egypt

On the other hand, mobile app adoption has been studied extensively in technology acceptance models, where perceived utility plays a critical role as a predictor of adoption intention (Davis, 1989; Venkatesh et al., 2003). Perceived utility refers to the extent to which a consumer believes using a particular mobile app will enhance their performance or provide value (Davis, 1989). In the Egyptian context, where digital transformation is accelerating but adoption barriers remain due to cultural and economic factors (Elsafty & Yehia, 2023), understanding how perceived utility moderates the relationship between the advertising mix and mobile app adoption becomes particularly relevant. Based on this theoretical foundation, the following hypothesis is proposed:

Hypothesis no.2: Perceived utility positively moderates the relationship between the advertising mix and mobile app adoption in Egypt.

The advertising mix serves as a strategic framework to communicate the benefits of products or services to consumers. Research shows that a compelling advertising mix can significantly influence consumer attitudes and behaviours of adoption (Kotler & Keller, 2016). For instance, promotional strategies highlighting a mobile app's functional benefits can lead to higher adoption rates (Kim et al., 2015). Similarly, pricing strategies, such as free trials or discounts, have been shown to lower perceived risk and encourage trial behaviours (Alalwan et al., 2017).

In emerging markets like Egypt, mobile app adoption is influenced by unique contextual factors, including economic constraints, cultural preferences, and technological infrastructure (Badran, 2017). Studies suggest that advertising tailored to local contexts, such as emphasising affordability, accessibility, and culturally relevant features, can enhance adoption rates (Venkatesh et al., 2003). For example, apps that address specific needs of Egyptian users, such as financial management tools or localised content, are more likely to succeed when supported by targeted advertising.

Perceived utility - “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989, p. 320) - is central to TAM. In the context of mobile apps, studies have demonstrated that perceived utility directly affects adoption intentions and amplifies the impact of external stimuli, such as advertising efforts (Venkatesh et al., 2003; Alalwan et al., 2017).

In Egypt, where digital literacy and trust in technology may vary across demographics, perceived utility could act as a critical moderator. Chiagouris and Mohr (2004) argue that enhancing the perceived value of digital tools through targeted advertising can overcome scepticism and drive adoption. Therefore, the interaction between the advertising mix and perceived utility is expected to be pivotal in shaping mobile app adoption behaviours in this market.

These hypotheses contribute to the marketing literature by exploring the moderating role of perceived utility in Egypt's unique cultural and economic context. It extends the Unified Theory of Acceptance and Use of Technology (UTAUT) by integrating the concept of the advertising mix. It provides actionable insights for marketers aiming to promote mobile apps in emerging markets. Furthermore, the findings could inform tailored advertising strategies that emphasise utility to enhance adoption rates.

3.2 Measurement of variables

it is divided into three dimensions: Perceived Utility, Advertising Mix, and Mobile App Adoption. Each dimension includes relevant constructs and items measured on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). The study can demonstrate the statements utilised in measuring the study variables, along with the sources of these statements, as illustrated in Table 1.

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Table 1. Sources of Questionnaire

Dimension	Statements	Sources of Questions
Perceived Utility	1-10	Davis, 1989; Venkatesh et al., 2003
Advertising Mix	11-20	Kotler & Keller, 2016; Belch & Belch, 2018
Mobile App Adoption	21-31	Rogers, 2003; Venkatesh et al., 2012; Hayes, 2018; Baron & Kenny, 1986

In addition to the above, the study created a moderating variable based on the interaction between perceived utility and advertising mix. The moderating role is multiplying the value of the perceived benefit dimension by the value of the advertising mix dimension based on the participants' attitudes.

3.3. Collection of data

The proposed hypotheses are designed to be empirically tested using quantitative research methods. A survey-based approach could collect data from Egyptian consumers exposed to advertisements promoting mobile apps. The study population comprises a broad segment of consumers from various parts of Egypt. 418 surveys were distributed via Google Forms using paid advertisements through X (formerly Twitter) and Facebook. Table 2 illustrates the distribution of the study sample based on demographic characteristics.

Table 2. Demographic Characteristics

Demographic Characteristics	Gender		Education				Age		
	Male	Female	diploma	Bachelor's	MBA	PhD	Age 24 years or below	Between 24 and 45 years	Age 45yearsor above
Size	248	170	57	254	75	32	61	283	74
Weight (%)	59.33	40.67	13.64	60.76	17.94	7.65	14.59	67.70	17.70

The study was approved by Helwan University, Egypt, Faculty of Commerce and Business Administration's ethics committee and registered on March 7, 2024 (Ref. No. 61001). Informed consent was collected in written form for the study. The study was approved by the human subjects' research committee of Helwan University, Faculty of Commerce and Business Administration and registered at March 12, 2024

All study participants in the questionnaire-based survey were provided with detailed information about the study's objectives, procedures, and confidentiality protocols. Informed consent was explicitly obtained from all participants, who were assured of their right to withdraw from the study at any stage without consequence. Data collected from participants was anonymised and aggregated to ensure privacy and compliance with data protection regulations.

The study design and implementation aligned with ethical standards to minimise risks to participants, including avoiding harm, coercion, or undue influence. Special care was taken to ensure the questionnaire content did not infringe on personal privacy.

3.4. Reliability statistics

Based on the study variables, which include three variables, the results of the Reliability statistics appear according to three dimensions in Table 3.

Table 3. Reliability Statistics

Cronbach's Alpha	N of Items
0.763	3

Source: Statistical Package for the Social Sciences output.

The surveys received had a Cronbach's alpha coefficient of 0.76377. Thus, this study identified markers of the consistency of the outcomes of the statistical tests.

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3.5. Description analysis

Table 4 presents the descriptive statistics of perceived utility. This table displays values of the mean, standard deviation, and coefficient of variation.

Table 4. Descriptive statistics of perceived utility

No.	Statement	Mean	Std. deviation	Coefficient of variation
S1	Using mobile apps makes it easier to accomplish tasks.	3.6770	0.99084	0.269469
S2	Mobile apps provide useful features that meet my needs.	3.7153	1.00015	0.269196
S3	Mobile apps are beneficial in my daily life.	3.8158	1.02348	0.268223
S4	Mobile apps save me time and effort.	3.7488	0.98017	0.261462
S5	Mobile apps enhance my productivity.	3.7632	1.00544	0.267181
S6	Mobile apps are user-friendly and easy to navigate.	3.7847	1.01384	0.267879
S7	Mobile apps provide accurate and reliable information.	3.7392	0.96532	0.258159
S8	Mobile apps help me achieve my goals more efficiently.	3.7847	0.98505	0.260271
S9	Mobile apps are a valuable tool for managing my daily activities.	3.7632	0.97148	0.258155
S10	Mobile apps improve the quality of my life.	3.7464	0.98322	0.262442
D1	**Perceived Utility**	3.7578	0.65613	0.1746

Source: Statistical Package for the Social Sciences output.

According to Table 4, the participants agreed on the Perceived Utility at a rate of 82.54%. The agreement was highest for ‘Mobile apps provide accurate and reliable information’ but lowest for ‘Using mobile apps makes it easier to accomplish tasks.’

Table 5 presents the descriptive statistics of perceived utility. This table displays values of the mean, standard deviation, and coefficient of variation.

Table 5. Descriptive statistics of the advertising mix

No.	Statement	Mean	Std. deviation	Coefficient of variation
S11	I am exposed to advertisements for mobile apps through social media platforms.	3.4450	1.32784	0.385442
S12	I notice advertisements for mobile apps on television or the radio.	3.5120	1.32350	0.376855
S13	I encounter advertisements for mobile apps in print media (e.g., newspapers, magazines).	3.5742	1.28093	0.358385
S14	I receive recommendations for mobile apps through word-of-mouth or influencer endorsements.	3.6172	1.25306	0.346415
S15	I find advertisements for mobile apps on search engines (e.g., Google).	3.6962	1.23538	0.334233
S16	I see advertisements for mobile apps in public spaces (e.g., billboards, posters).	3.6148	1.23400	0.341371
S17	I receive promotional emails or notifications about mobile apps.	3.6794	1.21644	0.330605
S18	I am influenced by advertisements that highlight the benefits of mobile apps.	3.6459	1.23070	0.337554
S19	I trust advertisements that feature testimonials from real users.	3.6770	1.25750	0.341986
S20	I am more likely to adopt a mobile app if it is advertised through multiple channels.	3.5526	1.27825	0.359803
D2	**Advertising Mix**	**3.5891**	**0.92080**	**0.256553**

Source: Statistical Package for the Social Sciences output.

According to Table 5, the participants agreed on the advertising mix at a rate of 74.34%. The agreement was highest for 'I receive promotional emails or notifications about mobile apps' but lowest for 'I am exposed to advertisements for mobile apps through social media platforms.'

Table 6 presents the descriptive statistics of perceived utility. This table displays values of the mean, standard deviation, and coefficient of variation.

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Table 6. Descriptive statistics of mobile app adoption

No.	Statement	Mean	Std. deviation	Coefficient of variation
S21	I will likely download and use a mobile app if it is recommended.	3.8732	0.90863	0.234594
S22	I frequently try out new mobile apps that are advertised to me.	3.8852	0.86010	0.221382
S23	Adopting new mobile apps improves my productivity or lifestyle.	3.8421	0.83333	0.216893
S24	I will pay for a mobile app if it provides significant value.	3.8971	0.89036	0.228467
S25	I prefer mobile apps that are free to download, even if they include ads.	3.8852	0.88213	0.22705
S26	I am more likely to adopt a mobile app with high ratings and positive reviews.	3.8589	0.86868	0.225114
S27	I adopt mobile apps that align with my interests and needs.	3.8708	0.89097	0.230176
S28	I was influenced by the popularity of a mobile app when I decided to adopt it.	3.9330	0.85400	0.217136
S29	I adopt mobile apps that offer unique features not available in other apps.	3.8995	0.85352	0.218877
S30	I will likely adopt a mobile app if it is compatible with my device and operating system.	3.8301	0.85234	0.222533
S31	The usefulness of a mobile app influences my decision to adopt it, even if I see many advertisements for it.	3.8995	0.92108	0.236204
D3	**Mobile App Adoption**	3.8795	0.41671	0.107413

Source: Statistical Package for the Social Sciences output.

According to Table 6, the participants agreed on the mobile app adoption at a rate of 89.25%. The agreement was highest for 'I believe adopting new mobile apps improves my productivity or lifestyle' but lowest for 'The usefulness of a mobile app influences my decision to adopt it, even if I see many advertisements for it.'

3.6. Testing hypotheses

The following formulation shows the hypothesis in the form of an alternative hypothesis.

The advertising mix positively and significantly impacts mobile app adoption in Egypt.

Through data analysis, the ANOVA table tests the overall significance of the regression model (see Table 7). The F-statistic (48.943) is significant at $p < 0.001$, indicating that the model as a whole is statistically significant in predicting App adoption. Combining Advertising mix and perceived utility significantly explains the variance in the dependent variable (App Adoption).

Table 7. ANOVA tests without the moderating role

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13.820	2	6.910	48.943	.000[b]
	Residual	58.591	415	0.141		
	Total	72.411	417			
a. Dependent Variable: App Adoption						
b. Predictors: (Constant), Advertising Mix, perceived_utility						

Source: Statistical Package for the Social Sciences output.

On the other hand, the coefficients in Table 8 provide insights into the individual contribution of each variable

Table 8. ANOVA tests without the moderating role

Coefficients						
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.432	0.078		44.212	0.000
	perceived utility	0.059	0.010	0.632	5.696	0.000
	Advertising mix	0.101	0.050	0.222	2.004	0.046
a. Dependent Variable: App adoption						

Source: Statistical Package for the Social Sciences output.

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The coefficients table provides insights into each variable's contribution in the app adoption regression model. The perceived utility unstandardised coefficient (B = 0.059) is positive and statistically significant (p < 0.001). This means that for every one-unit increase in perceived utility, there is a 0.059-unit increase in app adoption. Advertising Mix has an unstandardised coefficient of 0.101 that is positive and statistically significant (p = 0.046). This means that for every one unit increase in Advertising Mix, there is a 0.101 increase in App Adoption.

According to Table 9, the regression model explains 19.1% of the variance in App adoption, as indicated by the R Square value of 0.191. The Adjusted R Square value of 0.187 adjusts for the number of predictors in the model, suggesting that the model's explanatory power is relatively modest but statistically significant.

Table 9. Model summary without the moderating variable

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.437[a]	0.191	0.187	0.37574
a. Predictors: (Constant), Advertising mix, perceived utility				

Source: Statistical Package for the Social Sciences output.

The Standard Error of the Estimate (0.37574) reflects the average deviation of the observed values from the regression line, indicating moderate precision in the model's predictions. Thus, the null hypothesis can be rejected and the alternative hypothesis can be accepted.

Hypothesis within the moderating role:

Perceived utility positively moderates the relationship between the advertising mix and mobile app adoption in Egypt.

Through data analysis, the ANOVA tests the overall significance of the regression model (see Table 10). The F-statistic (52.768) is significant at p < 0.001, indicating that the model as a whole is statistically significant in predicting App adoption. This means that the combination of Advertising mix, moderating role, and perceived utility significantly explains the variance in the dependent variable (App adoption).

Table 10. ANOVA tests within the moderating role

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20.029	3	6.676	52.768	.000[b]
	Residual	52.382	414	0.127		
	Total	72.411	417			

a. Dependent Variable: App adoption

b. Predictors: (Constant), Advertising Mix, moderating role, perceived utility

Source: Statistical Package for the Social Sciences output.

In Table 11, the coefficients table provides insights into the individual contribution of each variable.

Table 11. Within the moderating role

Coefficients						
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	1.672	0.262		6.386	0.000
	Perceived utility	0.105	0.025	1.127	4.143	0.000
	Moderating role	0.550	0.079	0.866	7.006	0.000
	Advertising mix	0.441	0.091	0.975	4.861	0.000

a. Dependent Variable: App Adoption

Source: Statistical Package for the Social Sciences output.

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The coefficients table provides insights into the individual contribution of each variable in the regression model, including the moderating role. The unstandardised coefficient of perceived utility (B = 0.105) is positive and statistically significant ($p < 0.001$), meaning that an increase of one unit in perceived utility is linked to an increase of 0.105 units in app adoption. The Advertising Mix unstandardised coefficient (B = 0.441) is positive and statistically significant ($p < 0.001$). This means that for every one-unit increase in advertising mix, there is a 0.441-unit increase in app adoption. The unstandardised moderating role coefficient (B = 0.550) is positive and statistically significant ($p < 0.001$). This means that for every one-unit increase in the moderating role, there is a 0.550-unit increase in App Adoption. According to Coefficient Analysis, all variables have a significance level of 1%. However, Table 12 shows the model and explains the variance in app adoption.

Table 12. Model summary within the moderating variable

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.526[a]	0.277	0.271	0.35570

a. Predictors: (Constant), Advertising Mix, moderating role, perceived utility

Source: Statistical Package for the Social Sciences output

The model explains 27.7% of the variance in App adoption, as indicated by the R Square value of 0.277 (see Table 12). The Adjusted R Square value of 0.271 accounts for the number of predictors in the model, suggesting that the model's explanatory power is modest but statistically significant. The Standard Error of the Estimate (0.35570) indicates the average distance that the observed values fall from the regression line, reflecting a moderate level of precision in the model's predictions. Thus, the null hypothesis can be rejected and the alternative hypothesis can be accepted.

4. Discussion

The advertising mix, which encompasses various promotional tools such as social media, television, print media, and word-of-mouth, is crucial in influencing consumer behaviour. Prior research has demonstrated that a well-executed advertising mix can significantly enhance brand awareness and consumer engagement, driving product adoption (Kotler & Keller, 2016). In the context of mobile apps, the advertising mix has been shown to positively impact adoption rates by increasing visibility and perceived value (Kim et al., 2015). However, the effectiveness of advertising tools may vary across different cultural and economic contexts, particularly in emerging markets where consumer preferences and media consumption patterns differ from those in developed economies (Sheth, 2011). On the other hand, perceived utility, defined as the extent to which consumers believe a product or service will meet their needs and provide value, is a critical factor in adoption decisions. Studies have consistently shown that perceived utility positively influences technology adoption, as consumers are more likely to adopt innovations that offer clear benefits (Davis, 1989; Venkatesh et al., 2003). In the context of mobile apps, perceived utility has been found to mediate the relationship between advertising efforts and adoption, as consumers are more likely to adopt apps that they perceive as useful and relevant to their daily lives (Lu et al., 2011). However, the moderating role of perceived utility in shaping the impact of advertising mix on adoption remains underexplored, particularly in emerging markets.

As an emerging market, Egypt presents a unique context for studying mobile app adoption. With a rapidly growing digital economy and increasing smartphone penetration, Egypt offers a fertile ground for examining the interplay between advertising strategies and consumer behaviour. However, the effectiveness of traditional advertising channels may be influenced by cultural and socioeconomic factors, such as the prevalence of informal communication networks and the importance of word-of-mouth recommendations (El Said & Galal-Edeen, 2017). This study aims to contribute to the literature by exploring how perceived utility moderates the relationship between advertising mix and mobile app adoption in Egypt.

The statistical results of this study reveal several key insights. First, the regression model without the moderating role of perceived utility explains 19.1% of the variance in mobile app adoption, with both advertising mix (B = 0.101, $p = 0.046$) and perceived utility (B = 0.059, $p < 0.001$) exhibiting significant positive effects. These

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findings align with previous research, consistently highlighting the importance of advertising efforts and perceived utility in driving adoption (Lu et al., 2011; Kim et al., 2015). However, including perceived utility as a moderating variable significantly enhances the model's explanatory power, with the R Square value increasing to 27.7%. This suggests that perceived utility directly influences adoption and amplifies the impact of the advertising mix on adoption decisions.

The moderating role of perceived utility is further supported by the positive and statistically significant coefficients for both perceived utility ($B = 0.105$, $p < 0.001$) and the moderating role variable ($B = 0.550$, $p < 0.001$). These findings are consistent with the Technology Acceptance Model (TAM), which posits that perceived usefulness is a key determinant of technology adoption (Davis, 1989). Moreover, the strong positive effect of the advertising mix ($B = 0.441$, $p < 0.001$) in the moderated model underscores the importance of integrated marketing communications in driving adoption, particularly in emerging markets where consumers may rely on multiple channels for information.

This study contributes to the marketing literature by providing empirical evidence of the moderating role of perceived utility in the relationship between advertising mix and mobile app adoption. The findings highlight the importance of tailoring advertising strategies to enhance perceived utility, particularly in emerging markets where unique cultural and socioeconomic factors may influence consumer behaviour. Furthermore, the study underscores the need for marketers to adopt a holistic approach to advertising, leveraging multiple channels to maximise visibility and perceived value.

5. Conclusion and Recommendations

5.1. Conclusion

This study investigated the moderating effect of perceived utility on the relationship between the advertising mix and mobile app adoption in Egypt, an emerging market. The findings consistently demonstrate that the advertising mix significantly influences mobile app adoption, with perceived usefulness as a crucial moderator. Specifically, the study reveals that the effectiveness of advertising strategies in promoting adoption is enhanced when users perceive the mobile application as highly useful. This aligns with contemporary applications of the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM), which continue to underscore the paramount importance of perceived usefulness in technology acceptance across diverse contexts (Jiang and Lau, 2023; Dinh et al., 2025).

The research further highlights the unique opportunities and challenges in developing countries, where cultural preferences, economic constraints, and varying levels of digital literacy shapes consumer behaviour. Recent studies in emerging markets, including those in the Middle East and North Africa, corroborate that while digital advertising approaches must be meticulously tailored to local contexts to optimise perceived usefulness and drive adoption, traditional advertising channels such as television and radio often retain considerable influence (Barquin et al., 2022; Rodríguez-Espíndola et al., 2022). Consequently, the results suggest that marketers should prioritise communicating the pragmatic benefits of mobile applications, such as time-saving and cost-effectiveness, to elevate perceived utility and accelerate adoption rates in these dynamic environments (Lim et al., 2022).

Moreover, the report offers companies and legislators practical advice. To increase customer confidence and improve perceived value, regulatory authorities should demand openness in advertising techniques, support regional content, and tighten data privacy rules (Kotler & Keller, 2016; Venkatesh et al., 2012). Conversely, companies could use influencer marketing to improve user experience and provide incentives such as free trials to drive app acceptance (Rogers, 2003; Nielsen, 2012a).

By extending the UTAUT paradigm to incorporate the advertising mix as a predictor of technology adoption in developing countries, this study finally adds to the scholarly debate. It also offers valuable advice for legislators and marketers trying to increase the acceptance of mobile apps in such surroundings. Future studies may look at cross-cultural comparisons, the function of new technology, and how social media advertising affects uptake and perceived usefulness (Hofstede, 1980; Sheth, 2011)

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5.2. Recommendations

The results of this study underline the vital part that perceived utility plays in controlling the link between mobile app uptake in developing countries like Egypt and the advertising mix. The digital ecosystem is powerfully shaped by regulatory agencies, which also help to guarantee that mobile applications provide real value to consumers and support fair and open advertising policies. Supported by pertinent scholarly material and pragmatic advice, the following are specific suggestions for regulatory authorities:

a. Enforce Transparency in Advertising Practices: Clear, honest, and non-misleading information on the functioning, advantages, and possible constraints of mobile applications should be mandated by regulating authorities for app creators and marketers. Establishing rules requiring marketers to reveal essential characteristics, pricing strategies, and data usage policies will help them to comply. Such steps will improve users' perceived app usefulness, thus raising adoption rates (Davis, 1989; Venkatesh et al., 2012). In developing countries, where consumers may be more dubious of digital platforms owing to prior experiences with false promises, openness in advertising is especially important (Kotler & Keller, 2016).

b. Promote Localised Content and Solutions: Emerging markets like Egypt often present special cultural, financial, and infrastructure issues. Regulatory authorities should encourage the creation of localised applications catering to the particular requirements of different markets. Applications tailored to local languages, payment systems and culturally specific needs tend to be perceived as more useful (Rogers, 2003). Policies supporting local developers and entrepreneurs help to boost creativity in this field even more. For instance, the success of mobile payment systems, as evidenced by Kenya's M-Pesa, illustrates the importance of aligning technology offerings with local context (El-Gohary, 2012).

c. Strengthen Data Privacy and Security Regulations: Users' confidence in mobile applications is intimately related to perceived utility. Strong data privacy and security rules should be set by regulatory bodies to guard consumers' data. These cover giving apps explicit permission for data collecting, guaranteeing safe data storage, and giving consumers easily understandable privacy regulations (Zikmund et al., 2013). Such actions will improve apparent value and foster long-term confidence in digital environments. Emerging markets look to the European Union's General Data Protection Regulation (GDPR) as a model for adopting such systems (Venkatesh et al., 2012).

d. Encourage Digital Literacy Programs: Many consumers in developing countries lack the digital literacy required to completely appreciate the value of mobile apps. Working with corporate sector players and academic institutions, regulatory agencies should start programs to raise digital literacy. These courses may teach consumers how to assess the value of applications, decipher advertising claims, and guard their online privacy (Ajzen, 1991). Through including technology in public services and education, the Indian government’s Digital India initiative has been credited with improving nationwide digital literacy (World Bank, 2023a).

e. Monitor and Regulate In-App Purchases and Subscriptions: Regulatory authorities should set rules for in-app purchases and subscription models to stop user discontent and supposed exploitation. This covers mandating applications to show clear information on expenses, cancellation rules, and the value proposition of premium tools (Kotler & Keller, 2016). Such rules guarantee that users view apps as fair and helpful, promoting greater adoption rates. Similar actions taken by the Federal Trade Commission (FTC) in the United States help to guard customers against misleading in-app purchase policies (Zikmund et al., 2013).

f. Foster Collaboration Between Stakeholders: To produce a fair and user-centric digital environment, regulatory authorities should help cooperation between app developers, marketers, and consumer advocacy organisations. Frequent discussions and feedback systems help spot problems and guarantee that regulatory systems stay relevant and efficient (Rogers, 2003). For example, the cooperation between the Egyptian government and commercial technology firms has produced creative ideas like the "Digital Egypt" platform, which seeks to improve digital inclusion and adoption (World Bank, 2023a).

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Following these suggestions would help regulatory authorities maximise the apparent value of mobile applications, increasing adoption rates and supporting the digital revolution of developing countries like Egypt.

The results of this study underline the vital part that perceived value plays in controlling the link between the advertising mix and mobile app acceptance in developing countries like Egypt. These observations lead to the following suggestions for companies hoping to increase the acceptance of mobile apps using efficient advertising campaigns:

a. Emphasise Perceived Utility in Advertising Campaigns: Companies should create campaigns that effectively convey their mobile apps' usefulness and clear benefits. Emphasising time-saving, cost-effective, and navigational simplicity of use, for instance, can significantly increase apparent value (Davis, 1989; Venkatesh et al., 2012). Showcase in ads how the software addresses specific issues or enhances users' everyday life with case studies, quotes, or demos. This strategy could increase the apparent worth of the app among possible consumers (Kotler and Keller, 2016).
b. Tailor Advertising Mix to Local Preferences: In developing countries like Egypt, consumer behaviour is shaped by cultural, socioeconomic, and economic elements. Companies should match their advertising mix (e.g., social media, TV, influencer marketing) to local tastes and consumption trends (Hofstede, 2011; Statista, 2023). Using well-known social media sites like Facebook and Instagram, which Egypt uses extensively, for example, can help advertising efforts to be more successful and reachable (Smith & Anderson, 2016).
c. Leverage Influencer Marketing and Word-of-Mouth: Working with local opinion leaders and influencers helps make advertising messages more credible and relevant. Target consumers will find the app more enticing if influencers show its value in practical settings (Turban et al., 2018). Encourage happy consumers to spread their good experiences via internet evaluations or word-of-mouth, as, in developing countries, peer recommendations have great power (Rogers, 2003).
d. Optimise User Experience (UX) Design: The software's usability and functionality determine perceived utility. Investing in user-friendly interfaces, simple navigation, and flawless performance can help companies guarantee a favourable user experience (Nielsen, 2012a). Perform frequent user testing and receive comments to find and solve problems so the app satisfies the needs and expectations of its target market (Zikmund et al., 2013).
e. Offer Incentives for Adoption: Companies could provide discounts, free trials, or loyalty prizes to stimulate first adoption. These rewards help users to test the app by lowering their apparent risk (Kotler & Keller, 2016). Offering complimentary premium trials or price reductions can entice users and demonstrate the app’s value proposition (Venkatesh et al., 2012).
f. Monitor and Adapt to Market Trends: Emerging markets are dynamic and reflect fast-changing consumer tastes and technology developments. Companies should closely monitor consumer trends and modify advertising plans (World Bank, 2023b). Tracking the success of advertising campaigns and basing judgments on data analytics can help you to maximise the following initiatives (Zikmund et al., 2013).

Following these suggestions will help companies improve the apparent value of their mobile applications and increase the effect of their advertising mix on adoption rates in developing countries like Egypt.

The results of this study underline the critical role that perceived utility plays in controlling the link between mobile app uptake in developing countries like Egypt and the advertising mix. For customers, these realisations provide practical advice to guide their decisions on using mobile apps:

a. Evaluate Functional Relevance: Users should consider whether the app tools fit their requirements. Consider whether a financial-management app simplifies budgeting, expense tracking and personal financial planning. When the app's capabilities immediately solve the user's problems, perceived value is much higher (Davis, 1989; Venkatesh et al., 2012).
b. Prioritise Ease of Use: The study underlines the relevance of usability in boosting perceived utility. Customers are urged to pick programs with low learning curves, easy navigation, and simple UI.

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Regardless of the degree of promotional activities, apps that demand too much time or effort to grasp are less likely to be accepted (Nielsen, 2012b; Rogers, 2003).

c. Seek Tangible Benefits: Although advertising primarily stresses applications' emotional or aspirational attractiveness, customers should pay more attention to real advantages. A shopping app should provide benefits such as discounts, quick delivery, or an extensive product line. These valuable features significantly increase apparent value and stimulate acceptance (Sheth, 2011; Kotler & Keller, 2016).
d. Leverage Social Proof: In developing markets, perceived utility is much shaped by word-of-mouth and peer recommendations. Before starting an app, consumers should give evaluations, ratings, and quotes from reliable sources some thought. Social proof helps to confirm the app's value and lower the apparent adoption risks (Ajzen, 1991; Statista, 2023).
e. Be Cautious of Over-Advertising: Although advertising can raise awareness, too aggressive or invasive advertising could inspire mistrust. Consumers should cross-check the assertions stated in ads with independent evaluations or app trial runs to be sure they hold. This strategy guarantees that judgments on adoption are grounded in actual value instead of merely compelling advertising itself (Sheth, 2011; Kotler & Keller, 2016).
f. Consider Cultural Fit: Cultural significance strongly influences apparent value in markets like Egypt. Consumers should choose apps honouring regional cultures, linguistic preferences, and social mores. In this environment, national culture dimensions shape users' receptivity to new technologies (Hofstede, 1980, as cited in Sheth, 2011, p. 174).
g. Test Before Committing: Several programs provide limited-feature versions or free trials. Consumers should seize these chances to evaluate the app's value before committing themselves in the long run. This practical knowledge helps one grasp the app's value proposition (Davis, 1989; Venkatesh et al., 2012).

Following these suggestions helps customers in developing countries make better judgments and guarantees that their adoption of mobile apps is motivated by actual value instead of outside pressures like advertising.

6. Directions of further research

Particularly in developing countries, the results of this study open many directions for future studies on the acceptance of mobile apps. Supported by in-text references to pertinent material, these are the leading suggestions for the subsequent research:

a. Cross-Cultural Comparisons: Future studies could investigate the moderating function of perceived utility in other emerging economies, including India, Brazil, or South Africa, to ascertain if cultural variations influence the link between advertising mix and app uptake (Hofstede, 1980; Sheth, 2011). Comparative research might offer a more thorough understanding of how cultural aspects such as individualism versus collectivism shape consumer impressions of utility.
b. Longitudinal Studies: Although this study offers a snapshot of mobile app adoption in Egypt, longitudinal research might examine how perceived usefulness changes over time as users get more experienced with applications (Venkatesh et al., 2012). Research may also investigate how long-term adoption rates are affected by variations in advertising approaches.
c. Role of Emerging Technologies: Future research could examine how perceived usefulness and uptake are influenced by newly developing technologies such as augmented reality (AR) and artificial intelligence (AI). How, for instance, might tailored recommendations driven by artificial intelligence improve the apparent value of shopping apps? (Zhou, 2011; Zhang et al., 2012).
d. Impact of Social Media Advertising: Although this study concentrates on the conventional advertising mix, other studies should investigate how social media advertising influences perceived utility and adoption. Emerging economies are seeing more and more influence from platforms like Instagram and TikTok, which affect customer behaviour, therefore, demand further research (Wang & Sun, 2010).
e. Behavioural Segmentation: Future research might divide customers based on behavioural and psychographic elements, like tech-savviness or risk aversion, to see how these characteristics interact with perceived utility and advertising efficacy (Rogers, 2003; Yousafzai et al., 2003).

f. Quantitative and Qualitative Approaches: Combining quantitative polls with qualitative techniques like focus groups or interviews would help to offer a more complex knowledge of the elements influencing perceived value. Qualitative insights, for example, could highlight why some advertising messages appeal more strongly to particular consumer groups (Davis, 1989; Nielsen, 2012b).
g. Regulatory and Ethical Considerations: Future studies should investigate how ethical issues, including data privacy and legal frameworks, affect apparent value and acceptance. For instance, how would customers in developing countries see the trade-off between usefulness and privacy by utilising mobile apps? (Kotler & Keller, 2016).

By filling these gaps, the following research projects can expand on this work's results and help provide a more complete knowledge of mobile app acceptance in developing nations.

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DISCUSSING EU'S SECURITY IDENTITY: DEFENCE SPENDING, STRATEGIC AUTONOMY AND TRANSITION FROM NORMATIVE AMBITION TO GEOPOLITICAL REALITY

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Abstract. This article examines the evolving nature of the European Union's (EU) security identity, arguing that the traditional perception of the EU as a normative or civilian power is being gradually redefined in light of recent geopolitical challenges. By integrating political analysis with economic data on defence spending and military aid to Ukraine, the study highlights the Union's transition from rhetorical ambition to tangible strategic engagement. Drawing on four comparative graphs that illustrate the increase in defence expenditures, joint EU-level funding, and military assistance provided by member states, the article underscores the growing material basis of the EU's security role. It explores how initiatives aimed at strengthening strategic autonomy—such as PESCO, EDF, and the Strategic Compass—are increasingly complemented by measurable financial commitments and operational capacities. While internal divergences and external dependencies persist, the empirical evidence suggests that the EU is moving beyond symbolic declarations and toward becoming a more cohesive geopolitical actor. The article concludes by outlining key dilemmas and opportunities for the EU as it redefines its role in an era of strategic uncertainty and a dynamically evolving global and regional security environment.

Keywords: European Union; defence spending; strategic autonomy; normative ambition; geopolitical reality.

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1. Introduction

The contemporary international environment is undergoing a profound transformation marked by growing geopolitical instability, strategic fragmentation, and intensified rivalry between democratic and authoritarian systems. The global security architecture, once anchored in multilateralism and a rules-based order, is increasingly challenged by revisionist powers and shifting centres of influence. Within this complex and unpredictable setting, the European Union (EU) is confronted with mounting pressure to redefine its role as a global actor capable of responding to conventional, hybrid, and systemic threats.

The catalyst for this strategic re-evaluation was the Russian Federation's full-scale invasion of Ukraine in February 2022, which not only destabilised the EU's immediate neighbourhood but also exposed structural vulnerabilities in its security and defence architecture. These deficiencies became evident in the form of

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insufficient military readiness, strategic dependence on external actors, and the lack of an integrated response mechanism. Simultaneously, the conflict served as a critical stress test for the EU's political cohesion and defence solidarity, prompting unprecedented decisions in areas such as sanctions, arms transfers, and the mobilisation of financial resources for military support.

In response, the EU has embarked on a multidimensional shift from a primarily normative and civilian power to a more strategic and autonomous actor. This shift is reflected not only in political declarations and strategic documents but also in tangible changes in defence spending and operational engagement. According to the European Defence Agency (EDA) (EDA, 2024a) and Eurostat (2025), defence expenditure by EU member states increased by 16.25% in 2023 and 16.85% in 2024, reaching historically high levels in both relative (as % of GDP) and absolute terms. These figures, documented in the first two graphs of this study, signal a recalibration of political priorities and a recognition of the need for stronger defence capabilities within the Union.

Beyond the quantitative increase in defence spending, a notable qualitative transformation is underway. The EU is no longer merely expanding its budgetary commitments—it is actively redefining the underlying rationale of its security and defence policy. The shift from a declaratory strategic culture to a performance-oriented one is evident in new initiatives such as the European Peace Facility, Permanent Structured Cooperation (PESCO), the European Defence Fund (EDF), and the Strategic Compass (EEAS, 2022), which collectively illustrate the EU's ambition to enhance its strategic autonomy. Furthermore, substantial military assistance provided to Ukraine by individual member states—exceeding tens of billions of euros since 2022 (Figure 4)—has revealed both the limits and the latent potential of European defence coordination.

This evolution poses fundamental questions about the EU's identity as a security actor. The long-dominant notion of the EU as a "normative power" (Manners, 2002, 2006), built on values such as the rule of law, human rights, and multilateral cooperation, is being critically reassessed. Scholars such as Howorth (2019) and Biscop (2022a) have pointed to the growing asymmetry between the EU's declared ambitions and its actual strategic capabilities. Recent developments reinforce the need to bridge this gap through a redefinition of priorities, legal instruments, and institutional mechanisms. The war in Ukraine has not only challenged the normative foundations of EU foreign policy but has also accelerated its transition towards a more interest-driven and geopolitically aware posture.

Simultaneously, the rise of China and other systemic competitors has underscored the broader geopolitical imperative of strategic autonomy. China's model of authoritarian capitalism, its control of technological supply chains, and its assertiveness in international fora pose an alternative to the liberal international order. In this environment, the EU is increasingly vulnerable not only to conventional military risks but also to cyberattacks, economic coercion, energy insecurity, and technological dependency (Bojinović Fenko & Brsakoska-Bazerkoska, 2024; Rieker & Giske, 2024).

In this multidimensional security environment, the EU's internal debates are gradually shifting from idealistic aspirations to pragmatic considerations of power, sovereignty, and operational capability. As highlighted by Akgüç (2021) and Lippert et al. (2019), strategic autonomy encompasses the ability to act independently where necessary, while cooperating with allies where possible. This concept is now increasingly understood not only in political or military terms but also in relation to industrial policy, technological sovereignty, and defence investment patterns. In this regard, recent data on defence-related investments in military defence (new systems, technologies, hardware, etc.) (Figure 3) demonstrate a significant surge in joint procurement, research, and innovation, further embedding the economic dimension into the EU's strategic reorientation.

Against this backdrop, scholarly research is also evolving. While the earlier academic consensus emphasised the EU's civilian character (Majchút, 2024), more recent analyses – such as those by Rieker and Giske (2024), Bojinović Fenko and Brsakoska-Bazerkoska (2024), and Csiki Varga (2024) – highlight the need to view the EU as a complex, multilayered actor operating within a hybrid security environment. In this setting, the boundaries between economic, military, cyber, and legal instruments are increasingly blurred. The EU's security

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identity is no longer based solely on normative declarations but shaped by concrete policies, financial commitments, and industrial capacities.

This article seeks to critically examine the EU's evolving security identity through the lens of its response to contemporary geopolitical challenges. It analyses how increased defence spending, institutional adaptation, and military assistance to Ukraine have influenced the EU's strategic posture, while also assessing the legal and political constraints that continue to shape the contours of European defence integration. By drawing on academic literature, EU policy documents, defence data, and conceptual frameworks, the study aims to contribute to the scholarly debate on the EU's transformation from a normative union into a strategic security actor capable of autonomous action in a multipolar world.

2. The EU as a Security and Geopolitical Actor

For decades, the European Union was primarily perceived as a civilian and normative power, focused on promoting the values of democracy and economic cooperation. Its character was reflected in its orientation towards soft power instruments, such as development aid and diplomatic engagement (Manners, 2002). Although the Treaty of Lisbon strengthened the EU's ambitions as a global actor, its capacities for autonomous action remained limited (Howorth, 2014; Maheshi & Sayuri, 2025).

However, the war in Ukraine represents a fundamental turning point. Russian aggression exposed the limits of a security policy based exclusively on normative power and compelled the EU to reassess its strategic position (Rieker & Giske, 2024). Consequently, the EU is moving towards a transformation from a civilian guarantor of normative order to an active geopolitical actor, capable of independently confronting threats and shaping the security balance. This shift is evidenced in strategic documents such as the EU Strategic Compass (March, 2022), which declares objectives like building a rapid deployment force, increasing defence expenditure, and strengthening cyber resilience (EEAS, 2022). This indicates a shift away from exclusive reliance on NATO for security guarantees.

There is a growing consensus in academic literature that the EU's strategic autonomy is a necessity in an era of multipolar competition (Helwig & Sinkkonen, 2022). This trend is reinforced by changing attitudes within member states, which are moving from passivity to a more active promotion of common defence policies. At a theoretical level, the shift can be understood as a transition from 'soft' power to 'smart power', combining diplomatic and economic tools with military capabilities and innovation (Becker et al., 2025). The EU is becoming a 'multi-level actor', integrating various dimensions of security: traditional, cyber, climate, and technological (Bojinović Fenko & Brsakoska Bazerkoska, 2024; Rieker & Giske, 2024).

Besides internal factors, exogenous determinants are also crucial. The war in Ukraine has shown that the EU cannot rely on multilateral guarantees that fail where rules are systematically violated (Mauro, 2023). The EU is compelled to re-evaluate its own security sovereignty not only in military capabilities but also in energy security (Dirma et al., 2024; Okunevičiūtė Neverauskienė et al., 2025) and technological independence. This development is supported by increasing coordination among member states in identifying threats and formulating common responses, as confirmed by more recent decisions of the EU Council and the European Council.

The full-scale war in Ukraine has reshaped the EU's security environment not only geographically but also paradigmatically. It exposed the absence of operational command and a unified defence culture (Fiott, 2022). In response to these deficits, a rapid series of security and political decisions were made – ranging from unprecedented sanctions against Russia and massive aid to Ukraine (including military assistance via the European Peace Facility) (European Parliament, 2024a; European Council, 2025), to increased investment in defence and resilience against hybrid threats (European Commission, 2025a). A pivotal moment was the adoption of the Strategic Compass in March 2022, which defines the new direction of the CSDP and identifies four pillars: act, invest, partner, and secure (EEAS, 2022).

The war – in addition to a significant increase in defence spending (Figure 1) – accelerated reflection on the need to transform Common Foreign a Security Policy and rebuild the defence potential of member states

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(Genini, 2025). The Commission introduced initiatives like ReArm Europe and Readiness 2030 (European Commission, 2025b). These steps are unfolding in a more complex multipolar environment, where the EU must navigate between value loyalty to the USA and the necessity of preserving strategic autonomy. The EU's actorness is conditioned by its ability to maintain unity among member states and assert itself against global competitors (Bojinović Fenko & Brsakoska Bazerkoska, 2024).

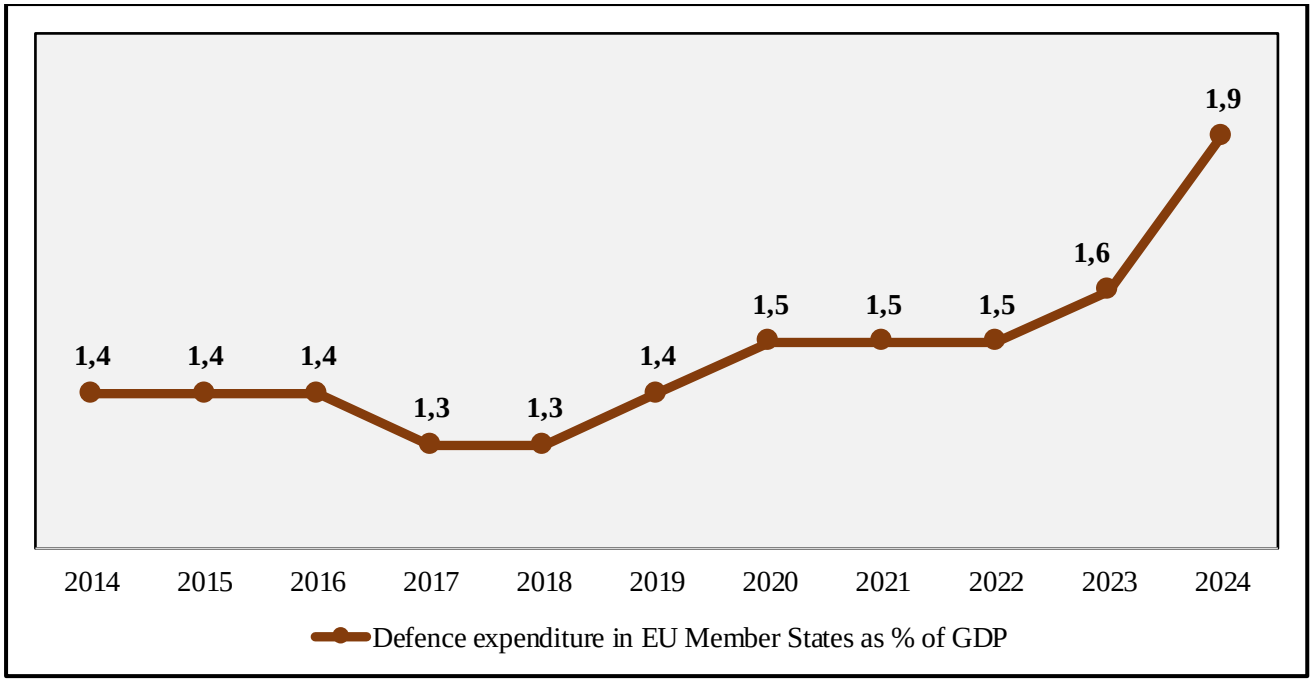


Figure 1. Overview of total defence expenditure in EU Member States (in % of GDP)
Source: EDA, 2024a

The EU is gradually realising that its geopolitical relevance will depend not only on its economic weight but also on its capacity to act as a security guarantor in its immediate neighbourhood and the broader global framework. This paradigm shift is accompanied by a growing recognition of the EU as a defence actor by some partners, although it still faces legitimacy challenges in global security fora. The analysis indicates that the EU is striving to redefine its role and security identity and respond to evolving security threats. This process is profoundly influenced by enduring ties and commitments to NATO and the USA. The following chapter will therefore focus on the intricate balance between the pursuit of EU strategic autonomy and the maintenance of transatlantic cohesion.

3. Strategic Autonomy vs. Transatlantic Linkage: Reality and Ambitions

The concept of EU strategic autonomy first appeared in the conclusions of the European Council in December 2013 (European Council, 2013). Originally, the term applied mainly to the area of security and defence, with an emphasis on the development of European defence capabilities and capacities that would strengthen the EU's ability to act autonomously. And although ideas about greater European autonomy in defence and security policy had appeared earlier (for example, at the St. Malo summit in 1998), 2013 is considered to be the first official appearance of the term "strategic autonomy" itself in EU documents.

However, it only came to the fore after 2016 in connection with the European Global Strategy (EUGS), which declared the need for Europe to take greater responsibility for its security (EEAS, 2016). Strategic autonomy is understood here not as isolationism, but as the ability to act alone when necessary and with partners when possible. This framework was further refined in the Strategic Compass (2022), which emphasizes building the EU's full-spectrum capabilities to respond to crisis situations (Kavan & Dušek, 2022) without exclusive dependence on NATO or the US.

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However, this ambition has provoked critical reactions from some member states (e.g., Poland, the Baltic states) and transatlantic partners (USA), who warned against a possible weakening of NATO unity. The tension between strategic autonomy and transatlantic linkage reveals a dilemma of the EU's security identity: how to ensure its own capacity for action without fragmenting NATO's collective defence (Ossa 2024). While states like France advocate for 'European sovereignty' in defence, Central and Eastern European states perceive the USA and NATO as guarantors of deterrence and fear a weakening of the transatlantic bond (Howorth, 2019; Rieker & Giske, 2024).

The reality of implementing strategic autonomy is asymmetrical. Although instruments such as Permanent Structured Cooperation (PESCO), the Coordinated Annual Review of Defence (CARD) and the European Defence Fund (EDF) have been created, their contribution is still limited, which undermines the goal of creating an integrated European Defence Technological and Industrial Base (EDTIB), key to autonomy in the production of military technologies (Csiki Varga, 2024). On the other hand, due to dramatic changes in the security situation in Europe, as well as the efforts of Member States to strengthen the combat capabilities and capacities of their armed forces, total defence spending has seen a significant increase in 2023 (by 16.25%) and 2024 (by 16.85%) (Figure 2), which will undoubtedly increase the level of ensuring European security and defence.

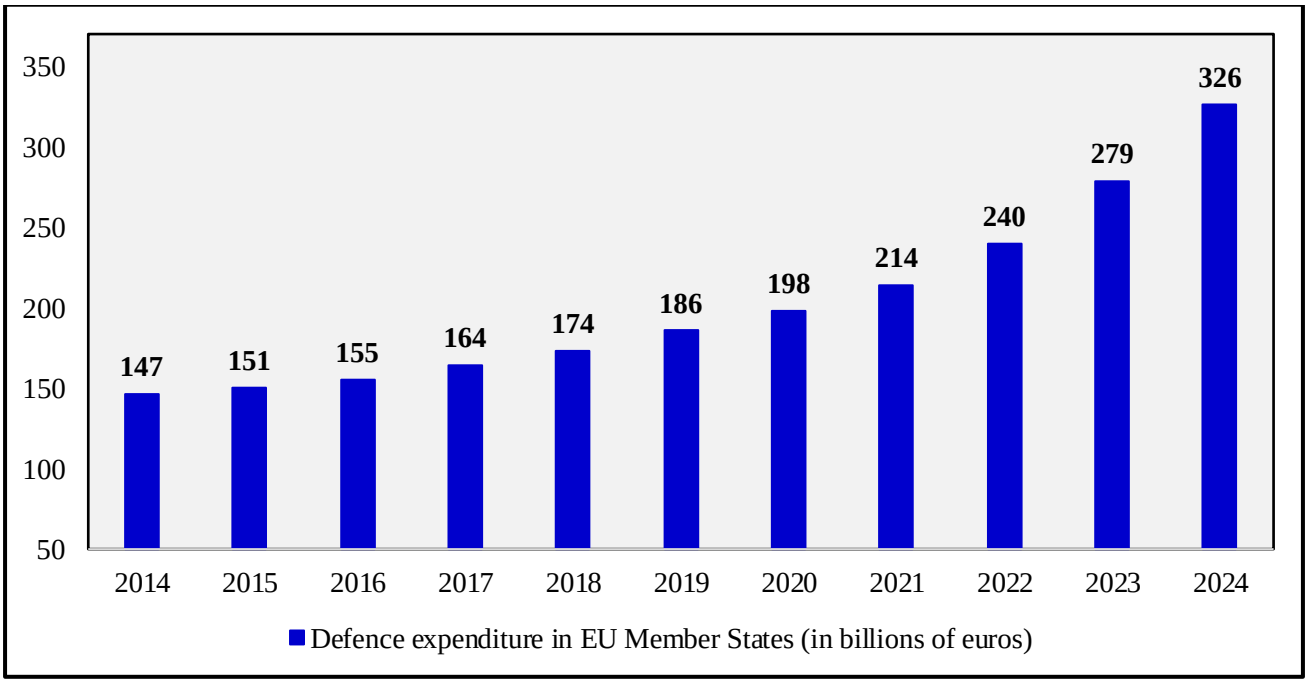


Figure 2. Overview of total defence expenditure in EU Member States (in billions of euros)
Sources: EDA, 2024a; Eurostat, 2025

A key strategic document is the Strategic Compass for Security and Defence, which provides a more concrete operational plan and timelines. It comprises over 80 measures, some of which have already begun implementation, such as the establishment of the EU Rapid Deployment Capacity and the strengthening of joint military exercises (EEAS, 2022). It emphasises the need to reduce operational dependencies, enhance defence research, and build resilience against hybrid and cyber threats.

Another significant instrument is the European Defence Fund (EDF), with €8 billion allocated for 2021–2027 to support research and development of defence technologies (European Commission, 2025c). However, academic literature points to its limited effectiveness due to low participation from all member states and the dominance of a few leading nations (Csiki Varga 2024). Similarly, Permanent Structured Cooperation (PESCO), launched in 2017, has seen over 60 projects, yet few have achieved full operational capability (EDA 2024b). Critics point out the duplication of efforts and the absence of binding control mechanisms in this regard (Fiott, 2023).

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On the other hand, the positive side is the growing investments in the development, research and development of military defence (new systems, technologies, hardware, etc.). These investments have been continuously increasing since 2014, with a sharp increase in 2023, when they reached 72 billion euros (an increase of 24,14 %), and 2024, when they reached even 102 billion euros (an increase of 41,67 % (!)) (Figure 3). In this context, it is clear that the driving force behind the growing volume of investment in defence, military technologies and hardware was mainly the Russian-Ukrainian conflict.

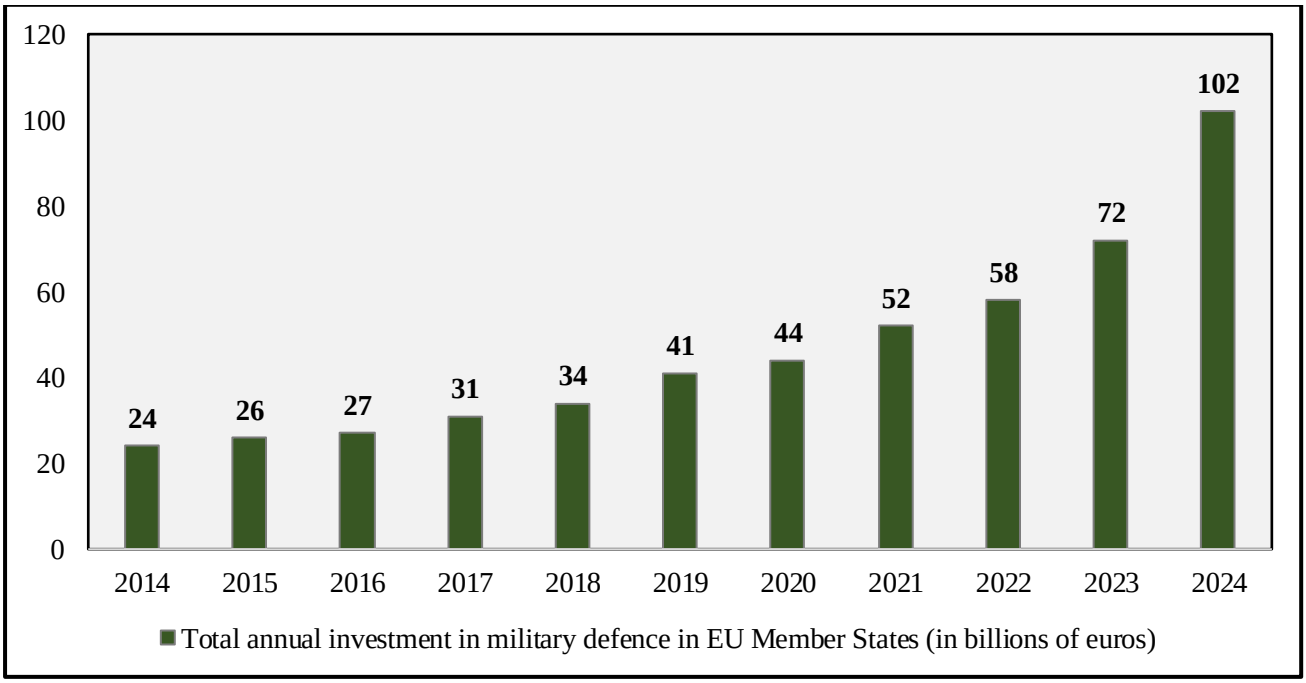


Figure 3. Overview of total annual investment in military defence in EU Member States (in billions of euros)
Sources: EDA, 2024; Statista, 2025

To overcome existing limitations, the Commission introduced the EDIRPA (European Defence Industry Reinforcement through Common Procurement Act) initiative in 2023 to stimulate joint procurement of military equipment. Initiatives like ReArm Europe and Readiness 2030, in turn, focus on increasing the manufacturing capacity of the defence industry, supporting innovation, and accelerating the deployment of technologies (European Commission, 2022).

Despite these initiatives, systemic weaknesses persist, caused by insufficient political integration, uncoordinated national priorities, and member states' caution regarding the transfer of sensitive competencies. European defence cooperation often remains declarative without sufficient performance, which undermines its credibility. Member states, especially those with historical experience of sovereignty protection, perceive defence as the core of national sovereignty and prefer bilateral alliances over firm institutional commitments within the EU. This trend is reinforced by the absence of a common European strategic culture and differing perceptions of threats (Monaghan, 2023; Nikers & Tabuns, 2024).

From a legal standpoint, the EU's institutional capabilities in defence are constrained. Although Article 42 of the Treaty on European Union (TEU) enshrines the Common Security and Defence Policy (CSDP), it explicitly stipulates that *'the implementation of a common defence policy shall be subject to a unanimous decision by the European Council'* and that *'the CSDP shall not affect the specific character of the security and defence policy of certain Member States'* (EU, 2012, Art. 42). This implies that even the most ambitious initiatives must be implemented based on consensus and with due regard for national prerogatives, which represents a structural limitation.

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A further weak point is the absence of a robust executive authority or operational command for coordinating military operations. While the Military Planning and Conduct Capability (MPCC) was established in 2017, its mandate remains limited, and its operational scope is restricted to non-executive missions. Without such a vertical command structure, the EU's capacity for action is contingent upon the assent of its member states.

Despite these limitations, there is potential for synergy among the various CSDP instruments. The Strategic Compass provides the political-strategic framework, the European Defence Fund (EDF) furnishes resources for research and development, PESCO offers a platform for collaborative projects, and EDIRPA addresses acute capability requirements. If existing gaps can be eliminated through increased defence spending, simplified decision-making processes, enhanced transparency, and more effective coordination, the EU could achieve the 'critical mass' necessary for effective autonomous action in crisis situations (Csiki Varga, 2024).

From the perspective of transatlantic relations, strategic autonomy need not imply competition with or a weakening of NATO; rather, it can contribute to a greater balance and strengthen joint capabilities. A more robust EU could complement NATO's activities in regions where the EU possesses unique instruments (e.g., the Western Balkans, Africa) and provide an independent response where the USA lacks the interest or capacity to intervene. As Josep Borrell (2022) observed, *'strategic autonomy is not independence from partners – but independence from vulnerabilities'*.

The analysis of the tension between the ambitions of strategic autonomy and the transatlantic linkage has highlighted the necessity of a more in-depth examination of internal conditions, particularly the legal and institutional framework of the CSDP. The subsequent chapter will therefore focus on legal restrictions, institutional fragmentation, competence tensions, and novel legislative initiatives that hold the potential to reinforce the integrative character of European defence policy.

4. Legal and Institutional Framework of the CSDP and Strengthening the EU's Defence Industry

The legal framework for the European Union's security and defence policy has evolved gradually, respecting the sensitivity of member states regarding the transfer of sovereign powers. Although the Treaty on European Union (Lisbon Treaty), in Articles 42 to 46, establishes the basis for the Common Security and Defence Policy (CSDP) as an integral part of the Common Foreign and Security Policy (CFSP), it simultaneously explicitly preserves the decisive role of member states (EU, 2012). This means that the EU can only conduct military operations based on the unanimous consent of member states within the Council, with neither the Commission nor the Parliament having the authority to directly initiate or control military decisions.

This model of 'intergovernmental governance', while ensuring national sovereignty, leads to an institutional dispersion of powers, legal ambiguity, and limited executive capacity. For instance, the European External Action Service (EEAS), including its military structures (EUMS, MPCC), has a restricted mandate and does not fulfil the function of a full-fledged operational command, unlike NATO (Vimont, 2021; Fiott & Zeiss, 2021). The absence of a centralised command means that the EU is reliant on ad hoc coalitions of member states or cooperation with NATO for larger missions. From a legal perspective, there is thus a tension between the ambition to build an autonomous European security policy and the restrictions stemming from primary EU law, which weakens decision-making coherence (Blockmans, 2017). A competence conflict also persists between national and European policies, particularly concerning the financing and development of defence capabilities.

An important issue is also the legal stability of financial instruments such as the European Defence Fund (EDF) and the European Peace Facility (EPF). The EDF, although falling under the multiannual financial framework, is not explicitly defined in the treaties, which creates legal tension when extending its mandate to defence matters. More controversial is the EPF, an off-budget instrument allowing for the financing of military equipment for third countries, including lethal weapons. While it possesses its own legal basis, questions persist regarding its legal accountability and democratic oversight (Portela, 2021).

In the domain of industrial policy, the EU faces the challenge of a lack of harmonisation in legal regulations among member states. Despite efforts to create a European Defence Technological and Industrial Base

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(EDTIB), the legal framework for cross-border projects remains disjointed, and defence procurement rules often defer to national exemptions. The consequence is market fragmentation, low interoperability, and weak competitiveness among European manufacturers.

In recent years, the European Commission and the European Defence Agency (EDA) have introduced new legislative initiatives to bolster the legal basis of the defence industry. Among the most significant is the proposed EDIRPA Regulation (European Defence Industry Reinforcement through Common Procurement Act), which aims to increase the level of common procurement among member states, reduce costs, and improve interoperability (Clapp, 2023). EDIRPA is underpinned by TFEU articles relating to the internal market and provides a legal framework for joint procurement of military equipment in response to urgent needs arising from the war in Ukraine.

Building on EDIRPA, the Commission in 2024 prepared the draft European Defence Investment Programme (EDIP). EDIP is intended to be a stable legislative instrument for joint investments in defence research, development, and production, representing a shift from a temporary to a systemic mechanism for industrial support (European Commission, 2025d).

At the level of secondary EU law, Council directives and decisions in the field of defence procurement are important. Directive 2009/81/EC establishes a framework for transparency, but its application is uneven. Many states utilise exemptions based on national security (Article 346 TFEU), thereby weakening the single market and the effectiveness of common instruments (Koutrakos, 2013; Trybus, 2014).

With the aim of streamlining the legal environment for defence and strengthening the EU's strategic autonomy, calls for the adoption of a so-called European Defence Strategy are increasingly frequent. This strategy should unify legal, institutional, and political instruments under one coherent framework, build upon the Strategic Compass, and reinforce the nexus between the industrial and operational dimensions of defence (Blockmans, 2017).

From a legal perspective, the issue of democratic legitimacy and oversight of decision-making within the CSDP also remains a challenge. The European Parliament holds only a consultative role, although it has intensified its activities through resolutions concerning defence expenditure and arms exports. There is also pressure to strengthen judicial scrutiny over EU defence decisions, particularly regarding arms exports to third countries, where the EPF pushes the boundaries of existing legal mechanisms (Vroege, 2024).

Looking ahead, the crucial aspect is linking the legal framework with practical defence needs. This necessitates not only institutional innovations but also the political will of member states to accept an increased defence spending and higher degree of integration. If the EU succeeds in overcoming existing legal and competence barriers, it can establish a stable and predictable framework for the development of European defence capabilities, able to confront the challenges of a multipolar and conflict-ridden environment.

In parallel, calls are emerging for improved judicial oversight of EU decisions in the defence domain, particularly in relation to the functioning of the European Peace Facility (EPF). The EPF funds the supply of military equipment, including lethal weapons, thereby exceeding the traditional normative boundaries of EU foreign policy. This shift raises questions about the EU's legal accountability as a subject of international law and the scope of the Court of Justice of the EU's jurisdiction in cases of breaches of international humanitarian law (Genini, 2025).

From a long-term perspective, the strategic imperative is to link he EU's legal framework with the practical demands of defence. This requires not only the harmonisation of rules but also a fundamental change in member states' approach to sovereignty in defence matters. If the EU is to be capable of confronting the challenges of an unstable world, it must overcome the current model of 'voluntary fragmentation' and establish conditions for rapid, coordinated, and legally sustainable decision-making. Such a reform should encompass new mechanisms for fund control, assessment of compliance with international law, and an enhanced oversight role for the European Parliament (Kilic, 2024; European Commission, 2025e).

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The future of European defence policy will hinge on the EU's ability to transform its legal framework from an instrument of restriction into one of strategic support. By removing legal, competence, and institutional barriers, the EU can acquire a stable and predictable framework for developing its own defence capabilities, thereby strengthening its position in the global security architecture.

However, the legal and institutional architecture of defence constitutes merely one pillar of strategic capability. Genuine autonomy also necessitates material, technological, and industrial preparedness. Therefore, the following chapter analyses the status and prospects of the European Defence Technological and Industrial Base (EDTIB), addressing mechanisms such as the EDF, EDIRPA, Readiness 2030, and joint procurements.

5. Development of the European Defence Industry and Technological Base

The European Union entered the 21st century with a fragmented, underfunded, and strategically uncoordinated defence industry. This state was a consequence of historical, economic, and political factors, such as the end of the Cold War, reduced defence spending, and a strong orientation towards NATO (Fiott, 2022). Consequently, the EU lost a significant strategic lead over the USA and China in defence research, development, and production.

This structural deficit is evident in manufacturing capacities, interoperability, technological dependence, and insufficient interconnectivity among member states. In 2021, only approximately 11% of EU member states' defence acquisition expenditure was executed collaboratively, with only a small proportion pertaining to strategic technologies (EDA, 2023). The European Defence Technological and Industrial Base (EDTIB) thus remained fragmented, and a large proportion of modern technologies were imported from non-European sources (Andersson & Britz, 2025).

Following the outbreak of the war in Ukraine, the situation changed dynamically. Massive deliveries of military materiel to Kyiv (Figure 4) led to the depletion of stocks in EU member states, exposing logistical and capacity weaknesses and the absence of a collectively planned production chain. European states were compelled to replenish stocks on an ad hoc basis and through non-EU purchases, thereby deepening their reliance on external actors (Csiki Varga, 2024).

The Commission responded by declaring a 'defence industrial emergency' and introducing new initiatives. Among the most significant is the EDIRPA proposal – a legislative framework for joint public procurement of defence materiel, aimed at overcoming fragmentation. Concurrently, in 2023, the Readiness 2030 initiative proposal emerged, which aims to increase the capacities of the European defence industry, support innovation, and restore critical capabilities (Vroege, 2024).

From the perspective of strategic autonomy, the European Defence Fund (EDF) plays a pivotal role, co-financing research and development projects to foster a European innovation ecosystem in defence. Supported areas include artificial intelligence, quantum technologies, unmanned systems, and space surveillance. The EDF is becoming a platform for connecting small and medium-sized enterprises, research institutions, and large corporations, thereby accelerating technology transfer into production. Despite bureaucracy and opaque rules, the EDF is gradually shifting the logic of defence investment to a European framework.

The establishment of strategic and technological autonomy is a fundamental pillar of European security policy. While cooperation with NATO has dominated defence thinking, increasing instability and geopolitical pressure have reinforced the demand for a resilient and independent industrial base. The objective is not autarky, but a level of self-sufficiency that enables the EU to act autonomously (Fiott, 2022; Rieker & Giske, 2024).

A fundamental prerequisite is to increase production capacity, particularly in critical areas such as ammunition, missile systems, and air defence. The Commission has urged member states to jointly plan demand, harmonise specifications, and form consortia. The pressure for an integrated industrial base is a response to the disparity between the EU and the USA, where the defence industry benefits from massive public investments and centralised management (Csiki Varga, 2024).

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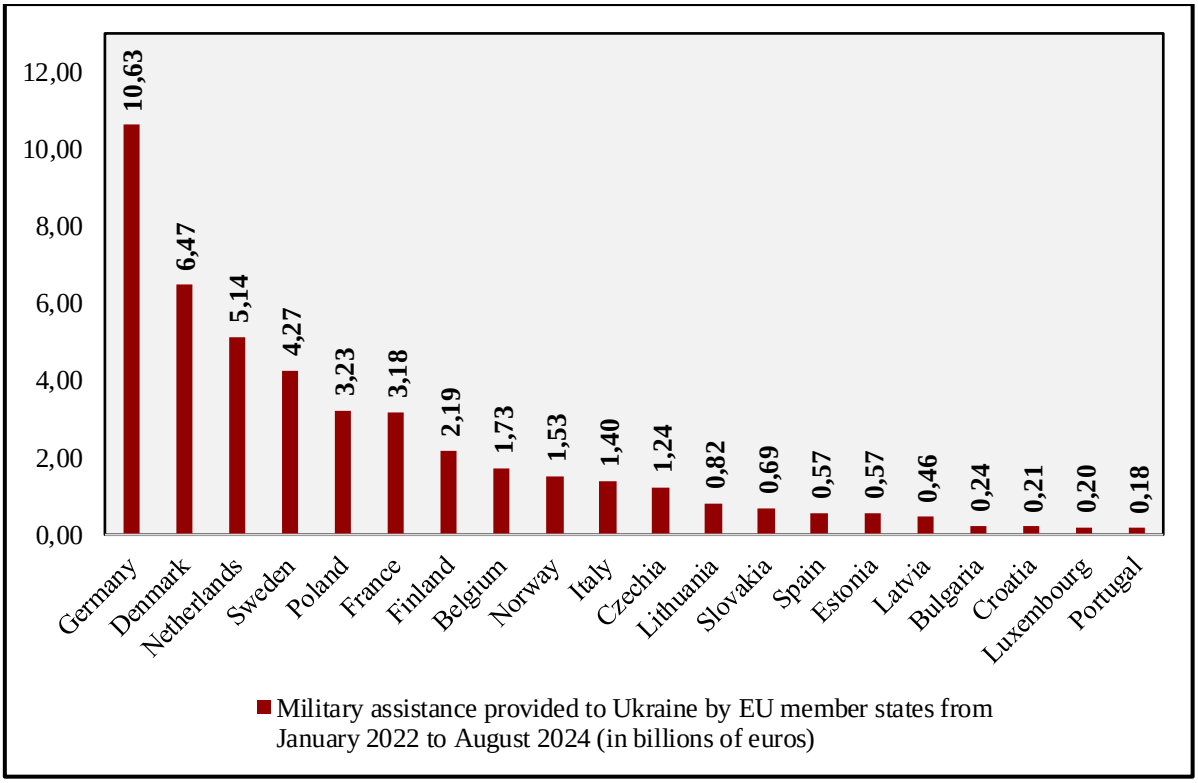


Figure 4. Overview of military assistance provided to Ukraine by EU member states from January 2022 to August 2024 (in billions of euros)
Sources: Statista, 2025

From a long-term perspective, it is essential for the European Union to build a robust, flexible, and technologically advanced European Defence Technological and Industrial Base (EDTIB). This is a strategic objective that extends beyond merely overcoming short-term shortfalls and aims towards constructing a sustainable defence ecosystem with a high degree of adaptability and innovation potential (European Commission, 2024, 2025a).

Achieving such an objective necessitates fulfilling several key conditions:

- Coordinated Investments and Predictable Demand Planning: The absence of common, long-term demand planning leads to project duplication and weakened investment certainty. Joint planning will ensure efficient resource allocation, stability for manufacturers, and improved interoperability. Predictable demand is a prerequisite for competitiveness against American and Asian firms.

- Balanced Involvement of All EU Countries: The development of the EDTIB must align with the objective of territorial cohesion, implying the active inclusion of smaller member states. Programmes such as the EDF or EDIRPA must support regional clusters and technology transfer, enabling smaller actors to acquire know-how and build capabilities. This will foster a truly European defence industry.

- Increased Transparency and Reduced Bureaucracy: Despite the positive impact of the EDF, the process of drawing on funds is bureaucratically demanding. Simplifying procedures and enhancing transparency will contribute to greater participation from SMEs, research centres, and academia, thereby broadening the innovation base and accelerating technology transfer.

- Support for Export Opportunities: For long-term competitiveness, it is essential to increase access to foreign markets. This requires a coherent export policy that respects ethical, legal, and political constraints. Political support and joint guarantees for export agreements are also crucial.

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- Implementation of Mechanisms for Resilience Against Economic Coercion: The EU's industrial base must withstand geopolitical blackmail, disruptions to supply chains, and cyber-attacks. This necessitates technical protection, diversification of suppliers, strategic reserves, control over component exports, and strengthened legal guarantees for investments in the defence sector (Aerospace, Security and Defence Industries Association of Europe, 2023; European Commision, 2024; European Parliament, 2024b; Blockmans, 2024; Aerospace, Security and Defence Industries Association of Europe, 2025; Kollias & Tzeremes, 2025).

If the European Union succeeds in fulfilling these prerequisites, it can build a strategically autonomous, technologically advanced, and globally competitive defence industrial base by 2035. This base will not merely be a response to short-term challenges but also a long-term asset for European security and strategic sovereignty. Indeed, in an environment of great power rivalry and geopolitical fragmentation, the question of defence industrial potential becomes a crucial pillar of both national and collective security (Biscop, 2022b; Balfour & Baroncelli et al., 2024).

From the analysed factors, it can be concluded that the EU has made significant progress in developing defence instruments, yet it continues to face limitations that hinder its geopolitical establishment. The combination of legal obstacles, political disunity, and a fragmented defence industry represents a fundamental challenge to its capacity for action. The concluding chapter will therefore present a synthesis of findings, strategic recommendations, and an outlook on the evolution of European security and defence policy, thereby concluding the presented study.

Conclusions

The European Union’s security identity is undergoing a profound transformation. What once appeared as a largely declaratory and normatively defined actor is increasingly responding to hard security imperatives through tangible policy measures, defence investments, and operational commitments. The war in Ukraine has acted as a catalyst for this transition, forcing the EU to reconsider not only its geopolitical environment but also its internal coherence, strategic ambitions, and practical capabilities. The volume and structure of military assistance to Ukraine, alongside a notable rise in defence spending across member states, indicate that the EU is taking incremental but significant steps toward assuming greater strategic responsibility.

This evolution, however, does not imply a complete rupture with the EU’s foundational principles. Rather, it suggests a recalibration of its identity—one that integrates normative aspirations with pragmatic security considerations. As defence budgets expand (Figure 1) and strategic instruments such as the European Peace Facility are operationalised, the EU is acquiring new tools to assert its presence in a volatile security environment. The creation of shared procurement mechanisms and investments in new defence systems, technologies etc. (Figure 3) also marks a shift toward the development of credible capabilities, which are essential to underpin any vision of strategic autonomy.

At the same time, this transition is riddled with tensions. Despite rhetorical commitments to act more cohesively, intra-EU divergences in strategic culture, national threat perceptions, and political will remain significant. The normative ambition to be a global peace-promoting actor must now coexist with geopolitical realities that demand power projection, resilience, and deterrence. Bridging this gap between identity and capacity remains a critical challenge for the EU.

The incorporation of economic and military dimensions into the EU’s security posture represents more than a policy adjustment—it signifies a conceptual shift. The figures reflecting growing national and collective defence spending (Figures 1 and 2), along with the scope of assistance to Ukraine (Figure 4), suggest a clear departure from the traditional reluctance to engage in hard power dynamics. Instead, the EU is constructing a hybrid security identity, balancing its normative heritage with emerging operational responsibilities and geopolitical ambitions.

This shift also redefines the meaning of strategic autonomy. No longer an abstract notion confined to policy documents, autonomy is increasingly associated with measurable inputs: financial allocations, defence

procurement, operational capabilities, and institutional adaptability. As shown in recent academic contributions (Rieker and Giske, 2024; Bojinović Fenko and Brsakoska-Bazerkoska, 2024), the ability to act autonomously entails not only the willingness to formulate independent policies but also the material capacity to implement them. Within this context, the EU's recent initiatives—such as increased joint defence investments, operational missions, and rapid reaction forces—demonstrate the emergence of a more assertive and capable European security actor.

Nevertheless, this emerging identity remains contested and incomplete. The EU still lacks a unified threat assessment, common strategic culture, and cohesive decision-making architecture. Fragmentation in national approaches continues to undermine the Union's capacity to respond swiftly and decisively to external crises. Moreover, the EU's dependency on NATO—and particularly the United States—for high-end military capabilities underscores the limits of European strategic sovereignty in the near term.

As the EU's security identity evolves, so too must the academic frameworks through which it is analysed. Traditional dichotomies—such as normative vs. strategic, civilian vs. military, or soft vs. hard power—no longer suffice to explain the complexity of the Union's evolving role. The empirical data now available, including trends in defence spending and external engagements, challenge static conceptualisations and call for more dynamic, multidimensional theories of European actorness and strategic behaviour. The EU's transition from a normative ambition to a geopolitical reality is not linear, nor is it irreversible—but it is unmistakably underway.

For policymakers, this evolution presents both opportunities and dilemmas. The redefinition of the EU's security role offers the chance to build a more resilient, capable, and autonomous actor in global affairs. Yet it also demands a careful balancing act between internal cohesion, democratic accountability, and responsiveness to a rapidly changing threat environment. As the EU continues to navigate the turbulence of strategic transformation, future research should closely examine how defence investments, strategic cultures, institutional mechanisms, and external partnerships interact to shape the Union's security trajectory.

In sum, the EU's security identity is no longer a question of aspiration—it is a matter of empirical development, political will, and strategic necessity. The convergence of ambition and capacity will determine whether the EU can sustain its transition from a civilian power with normative intent to a geopolitical actor equipped for responsibility in an era of strategic uncertainty and a dynamically evolving global and regional security environment.

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SUSTAINABILITY AS PART OF STRATEGIC MANAGEMENT IN THE MANUFACTURING INDUSTRY*

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Abstract. The manufacturing industry is a fundamental pillar of the economy in many developed countries. It is also a key sector in the Czech Republic, significantly contributing to macroeconomic aggregates such as gross domestic product, employment, and exports. The current business environment increases the requirements for companies not only in terms of maintaining competitiveness, but also in terms of a responsible approach to production resources and the environment. Company managers who want to keep their company on the market for a long time should always adapt their corporate and production strategies to current trends and challenges. Sustainability goals should be an integral part of corporate strategies today, as well as measuring and monitoring the carbon footprint and systematically reducing it. The article examines approaches to sustainability and ESG in the Czech Republic's manufacturing industry, especially in the context of large companies. The article is based on the results of a nationwide survey. These results show a statistically significant dependence between the size of the company and the sustainability strategy. It is also confirmed that companies that have implemented the environmental management system standard have a sustainability strategy in place. The results contribute to understanding how large companies in the manufacturing industry approach sustainable development and where SMEs lag.

Keywords: carbon footprint; ESG; manufacturing industry; sustainability; strategy

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1. Introduction

Sustainability and ESG (Environmental, Social, and Governance) are becoming increasingly important for large companies worldwide, including the manufacturing industry. The manufacturing industry in Europe plays a significant role in economic growth and development (Mousa & Bouraoui, 2024). The manufacturing industry is one of the pillars of the Czech economy and contributes significantly to the primary macroeconomic aggregates such as GDP and unemployment. The manufacturing industry includes production activities and operations that transform raw materials and materials into finished products. It plays a key role in resource depletion, the rational use of resources, the circular economy, and sustainability. In general, economic progress should be considered a key factor for success, but today, in addition to it, it is necessary to fulfil social responsibility and comply with environmental regulations through sustainable development (Mayamurugan,

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2016; Zairi & Peters, 2002). As part of industry transformation in several European countries, Industry 4.0 and Industry 5.0 are merging. These new stages include, in particular, elements of resilience, sustainability, and safety. Recently, the manufacturing sector has had a vital influence on environmental, social, and economic aspects of sustainability, owing to its substantial demands on energy, water, materials, and other resources (Harikannan & Vinodh, 2025). Today, mainly large companies already include a sustainable approach and management in their corporate strategies. This article focuses on examining these connections in the manufacturing industry of the Czech Republic, with particular emphasis on the role of company size and the use of environmental management tools, such as the ISO 14001 standard or carbon footprint measurement. The research aims to identify key factors that facilitate the implementation of sustainable strategies, thereby contributing to a deeper understanding of environmentally responsible management processes in large companies.

2. Theoretical Background

Strategic management and a correctly set strategy are essential for any company's long-term growth and competitiveness. One of the most critical business capabilities determining a firm's ability to develop effectively is the competitive business strategy (Taranenko et al., 2024). Working with the strategy, its updating for individual business areas and processes is essential for achieving the organisation's goals. The timing of the update and its rapid integration into business processes is key, as this is the only way to cover current challenges, trends, and threats in the business environment. Strategic management is still relevant for researchers, as it intersects with various fields of thought, including economics, sociology, political science, etc. (Hou & Li, 2024).

Knott's study (2024) presents research on strategic management that considers the conditions resulting from the expected impacts of climate change. As the economy is advancing by leaps and bounds, the top priority has been given to managing a green-oriented enterprise due to its significance in the lasting ability and sustainability of the organisation (Le et al., 2024). Companies struggle to integrate sustainability into their corporate strategy and implement it into business activities (Beush et al., 2022). Although several articles take or promise a strategic approach to sustainability, few clearly define their understanding of strategy regarding sustainability (Farkas & Matolay, 2024).

Companies should strive to integrate different aspects of sustainability, even if they seem to be in conflict. Sustainability should encompass economic, environmental, and social dimensions, and accepting the tensions between them is crucial (Hahn et al., 2015). Sustainability should be embedded within the company's strategy, with specific, measurable objectives set (Sabauri & Kvatashidze, 2023). Sustainability strategy in industrial manufacturing should include both ways to ensure the company's competitiveness and a socially responsible approach to the environment. However, they may also be conflicting objectives. Adolph and Beckmann (2024) state that the corporate sustainability strategy (CSS) concept suffers from considerable definitional ambiguity. Understanding the role of corporate strategies in sustainability has become a hot topic for scholarly research (Zameer et al., 2024; Koe et al., 2024).

Incorporating ESG factors into corporate strategies enhances overall performance. It contributes to sustainable development while revealing various implementation challenges, such as difficulties in quantifying ESG factors and navigating different ESG criteria and rating systems (Liang et al., 2022). Measuring ESG performance has become a key factor for investment decision-making, especially for publicly traded companies. High ESG scores indicate that companies are economically, socially, and environmentally sustainable, which increases their attractiveness to investors (Tsang et al., 2023).

Large companies in the manufacturing industry can play a key role in sustainability by integrating different dimensions of sustainability, focusing on ESG, and actively engaging stakeholders. These approaches improve their economic performance and contribute to the company's sustainability (Tsang et al., 2023; Sedlák & Veber, 2024). According to Calabrese (2021), companies also embed ESG in their strategies to increase commercial attractiveness to investors. Environmental management systems can be a tool to ensure the sustainability of large companies.

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ISO 14001 is an international standard for environmental management that helps organisations develop and implement policies and objectives concerning legal requirements and significant environmental aspects (Mayamurugan, 2016). This standard has become a widely accepted tool for sustainability management in enterprises, with its implementation becoming necessary for large companies (Pakulska & Rutkowska-Podolowska, 2017). There are different views on implementing ISO 14001, with some seeing it as a process with limited value, while others see its potential as a competitive advantage in the supply chain (Curkovic & Sroufe, 2011). Implementing ISO 14001 positively impacts environmental sustainability, although it may not have the same impact on economic and social sustainability. Organisations that apply Total Quality Management (TQM) and ISO 14001 achieve better sustainability performance (Tasleem, 2018). A study by Zimon et al. (2022) shows that implementing ISO 14000 contributes significantly to improving the environmental performance of companies.

Companies adopting this standard show better identification and quantification of costs and benefits associated with environmental issues, leading to better decision-making processes (Zimon et al., 2022). Environmental management systems, which include ISO 14001, are considered a key tool for achieving sustainability in companies. These systems help companies meet legislative requirements and improve their environmental policy (Basovníková et al., 2016). Implementing ISO 14001 can lead to energy savings and cost reductions, contributing to higher profitability for companies. Studies also suggest that these systems promote efficient use of resources and ensure customer satisfaction (Zoubek et al., 2021; Zimon et al., 2022). Any human production activity and product cycle within the life cycle leaves a carbon footprint. The carbon footprint can also be the leading indicator of the environmental friendliness of production. Monitoring the carbon footprint, i.e., the amount of greenhouse gases that escape into the air, is fundamental in identifying sources of emissions and inefficient activities. The quality of business processes in a low-carbon economy is key to achieving sustainability. This includes strategic management and calculation of the carbon footprint, which can affect the reputation of companies as socially responsible entities (Straková & Kostiuk, 2023). As part of the effort to achieve carbon neutrality, companies are trying to integrate the green aspects of Industry 4.0 (Benešová et al., 2021).

The current literature on sustainability and ESG practices in the Czech Republic's manufacturing industry highlights the need for further exploration into various aspects, including the distinct strategies of large companies versus SMEs, the specific effects of environmental management systems, the challenges faced by different manufacturing sectors, and the impact of regional factors. In particular, there is a lack of research examining the direct relationship between ISO 14001 implementation and adopting an ESG strategy. This gap underscores the need to better understand how environmental management systems such as ISO 14001 can influence or support broader ESG initiatives within the specific context of the Czech manufacturing sector. Therefore, this study addresses this research gap and contributes novel empirical evidence that advances theoretical knowledge and offers practical implications for environmental management and sustainable corporate development.

3. Research methodology

Initially, the authors created a theoretical basis based on analysing and synthesising domestic and foreign publications and articles. This theoretical background served as a platform for the determination of hypotheses and the design of questions for the survey. Hypotheses to make further theoretical and practical contributions in strategy, sustainability, and manufacturing were constructed as follows.

H1: Large companies have a sustainability or ESG strategy in place.

H2: Companies that have implemented ISO 14000 have developed a sustainability strategy or ESG.

H3: Companies with a sustainability strategy or ESG have a calculated carbon footprint.

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A quantitative questionnaire survey verified the hypotheses. The questions for the questionnaire survey were constructed to help test the hypotheses and extend the problem under study to include theoretical and practical insights. The questionnaire survey was conducted in January 2025. The contacts of the manufacturing companies were obtained from the database available with the Faculty of Logistics and Crisis Management. Further contacts were then supplemented from the Chamber of Commerce of the Olomouc Region. The questionnaire was created using the software Survio. One thousand one hundred twenty-four (1124) enterprises were contacted, and 170 questionnaires were correctly filled out and returned. The return rate was 15%.

The responding companies represent a cross-section of the Czech manufacturing industry, an essential part of the national economy. The largest sectors covered include the production of metals and metal products, electrical and optical equipment, means of transport, and the food industry. Of the total respondents, 30 were small enterprises, 32 were medium-sized enterprises, and 108 were large enterprises. It is evident that most of the responses came from large companies, indicating that ESG and sustainability issues currently attract greater attention among larger manufacturing firms. As a limitation, it should be noted that the sample covers the manufacturing industry as a whole and does not focus in detail on specific sub-sectors or industries with unique environmental or social impacts. Therefore, the results should be interpreted as generalisable primarily to the Czech manufacturing sector overall, and future research could examine selected industries in more depth. General descriptive statistics, contingency table, and chi-square test of independence were used for data processing.

4. Research results and discussion

This chapter summarises the results of the nationwide survey based on the verification of the hypotheses. The first hypothesis was established as follows:

H1: Large companies have a sustainability or ESG strategy in place.
H_0: There is no relationship between company size and the existence of a sustainability or ESG strategy.
H_A: There is a relationship between company size and the existence of a sustainability or ESG strategy.

Table 1. Relationship between company size and the existence of a sustainability strategy or ESG

	Does your company have a sustainability or ESG strategy in place?				Total
Company size	Yes, we have a CSR strategy (Corporate Social Responsibility)	Yes, we have an ESG strategy	We don't have	We are preparing the strategy	
Small enterprise	0	3	19	8	30
Medium-sized enterprise	4	6	10	12	32
Large enterprise	15	42	14	37	108
Total	19	51	43	57	170

Source: Authors‘ own research, 2025

The chi-square test was used to verify the hypothesis. Of the large enterprises (250 or more employees), 42 out of 108, or 38.9%, have an ESG strategy; for medium-sized enterprises (50-249 employees), 6 out of 32, or 18.8%, have an ESG strategy; and for small enterprises (up to 49 employees), only 3 out of 30, or 10%, have an ESG strategy. These results confirm that larger companies are more likely to have formal ESG strategies ($p < 0.001$). ***H_A was confirmed***. The results show a statistically significant association between company size and the existence of a sustainability or ESG strategy.

These results are to be expected as larger companies usually have more resources, both financial and personnel. There is more pressure on large companies from the public, investors, and stakeholders. Large companies are more likely to be part of international supply chains, which motivates them to implement sustainable strategies. Smaller companies often deal with day-to-day operational issues, and ESG strategies may not be a priority for

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them. This fact is also supported by the study of Hou & Xie (2024), who report that ESG strategy is prevalent among large enterprises, significantly impacting the quantity of green innovation in the Chinese economy. Large companies that integrate ESG strategies report higher financial performance than those that do not (Das, 2024). Balogh et al. (2022) examined the 100 largest Czech firms and showed that stakeholders, including investors and customers, play a key role in pressuring large enterprises to implement sustainable strategies. Decker Ure et al. (2024) add that corporate sustainability measures for large corporations have become part of corporate environmental, social and governance (ESG) programs in recent years. However, ESG strategies and their impacts are only beginning to be understood by large corporations. There are few definitions for how to apply, measure and evaluate the effectiveness of ESG practices. The results of Nováková (2025) study show that there is currently a significant difference in the level of ESG implementation not only between large and medium-sized construction companies, but also between Czech and foreign companies. The research confirms that ESG awareness or activity in this area decreases with company size. Other studies that demonstrate a link with firm size and sustainability strategy are (Ren & Ren, 2024; Xu, 2024; Wang, 2023).

Based on the empirical results, it was also possible to identify other significant relationships between sustainability-related variables. In addition to the company's size, implementing an environmental management system according to ISO 14001 proved to be an important factor. This standard represents a formal commitment to improving the company's environmental performance, and its presence may reflect its overall readiness to integrate sustainability at the strategic management level. For this reason, the author's team formulated the following hypothesis:

H2: Companies that have implemented ISO 14000 have developed a sustainability strategy or ESG.
H_0: There is no relationship between the implementation of the ISO 14001 standard and the existence of a sustainability or ESG strategy.
H_A: There is a relationship between the implementation of the ISO 14001 standard and whether the company has a sustainability or ESG strategy.

Table 2. Link between ISO 14001 certification and a sustainability or ESG strategy.

		ISO 14001:2015 - Environmental Management System (EMS)	ISO 26000:2010 - (Corporate Social Responsibility)	ISO 50001:2018 and 50004:2020 - Energy management systems	ISO 45001:2018 - Occupational Health and Safety Management System (OHES)	SA8000:2014 - Social Accountability Standard	ISO 45001:2018 - Occupational Health and Safety Management System (OHES)	Total
Company size	Small enterprise	3	4	3	6	4	7	30
	Medium-sized enterprise	19	2	6	14	2	12	32
	Large enterprise	83	17	45	57	12	58	108
Total		105	23	54	77	18	77	170

Source: Authors' own research, 2025

The contingency table converted into row percentages looks like this.

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Table 3. The contingency table.

		ISO 14001:2015 - Environmental Management System (EMS)	ISO 26000:2010 - (Corporate Social Responsibility)	ISO 50001:2018 and 50004:2020 - Energy management systems	ISO 45001:2018 - Occupational Health and Safety Management System (OHES)	SA8000:2014 - Social Accountability Standard	ISO 45001:2018 - Occupational Health and Safety Management System (OHES)	Total
Company size	Small enterprise	10,0%	13,3%	10,0%	20,0%	13,3%	23,3%	100,0%
	Medium-sized enterprise	59,4%	6,3%	18,8%	43,8%	6,3%	37,5%	100,0%
	Large enterprise	76,9%	15,7%	41,7%	52,8%	11,1%	53,7%	100,0%
Total		61,8%	13,5%	31,8%	45,3%	10,6%	45,3%	100,0%

Source: Authors‘ own research, 2025

The chi-square test of independence was used to test the hypothesis. Of the companies implementing ISO 14001 (n = 105), 41 have an ESG strategy, representing 39%. On the other hand, among enterprises without this standard (n = 65), only 10 enterprises, or 15.4%, have an ESG strategy. This difference shows that firms implementing ISO 14001 are significantly more likely to implement a sustainability or ESG strategy. Statistical analysis showed a statistically significant association between ISO 14001 implementation and the existence of an ESG or sustainability strategy ($p < 0.001$). ***H_A was confirmed.***

ISO 14001 sets out the requirements for an environmental management system to reduce negative environmental impacts. Businesses that implement this standard have already demonstrated some commitment to environmental principles. Such companies are more likely to take a holistic approach to sustainability and develop an ESG strategy that includes social and governance aspects. This context shows that certification, such as ISO 14001, can indicate a company's overall sustainable direction. Pakulska & Rutkowska-Podolowska (2017) state that it is hard to imagine the functioning of a large company that does not include the management of environmental aspects. Tasleem et al. (2018) published on the ISO 14001 standard for environmental management system (EMS) and its usefulness for addressing sustainability issues in organisations. This study identifies TQM and ISO 14001 as important strategies for examining the impact on sustainable performance, including economic, social, and environmental sustainability. The author's team believes that to date, no foreign expert study has been identified that has analysed the relationship between the implementation of ISO 14001 and the adoption of an ESG strategy. Therefore, the results of this research contribute to the development of theoretical knowledge in the field and provide new insights that can serve as a basis for further academic research. The findings may also be helpful for practical application in environmental management and sustainable corporate development. A detailed search found studies that demonstrate that the implementation of ISO 14000 represents a reduction in the energy intensity of production (Goldar & Goldar, 2024), an increase in export opportunities (Goldar & Majumder, 2022), and has a positive impact on sustainable development (Alhamdi & Al-Kahtani, 2025). ISO 14001 helps companies to build legitimacy and credibility, which is important to meet institutional pressure for a proactive approach to environmental protection. This can be perceived positively in the long run, although the short-term financial benefits may be questionable (Riaz & Saeed, 2020).

While Hypothesis H2 focused on the relationship between the implementation of a certified environmental management system (ISO 14001) and the existence of a corporate sustainability strategy or ESG, Hypothesis H3 extends this perspective to include a specific environmental tool - the calculation of carbon footprint. Carbon footprint measurement is a concrete indicator of environmental performance and can be seen as a step towards systematic sustainability management. It is therefore relevant to examine whether the very companies that track this footprint also have a formal sustainability strategy or ESG in place.

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H3: Companies with a sustainability strategy or ESG have a calculated carbon footprint.
H_0: There is no relationship between whether a company measures its carbon footprint and the existence of a sustainability or ESG strategy.
H_A: There is a relationship between whether a company measures its carbon footprint and whether it has a sustainability or ESG strategy.

Table 4. Relationship between carbon footprint measurement and the existence of a sustainability or ESG strategy.

		Have you calculated your company's carbon footprint?			Total
		Yes	We are working on the calculation method	No	
Does your company have a sustainability or ESG strategy in place?	Yes, we have a CSR strategy	14	4	1	19
	Yes, we have an ESG strategy	41	6	4	51
	We don't have	1	4	38	43
	We are preparing the strategy	23	23	11	57
Total		79	37	54	170

Source: Authors‘ own research, 2025

The chi-square test of independence was again used to test the hypothesis. Of the companies with an ESG strategy, 41 out of 51, or 80.4%, have a calculated carbon footprint. On the other hand, only 1 out of 43 (2.3%) of the enterprises that do not have a strategy have a calculated carbon footprint. Of the enterprises preparing a strategy, 23 out of 57 (40.4%) have a calculated carbon footprint. These results confirm that companies strategically committed to sustainability are more likely to measure their carbon footprint actively. The results are statistically significant ($p < 0.001$), supporting the hypothesis of a link between strategic approaches to sustainability and specific environmental activities. ***H_A was confirmed.***

Carbon footprint measures environmental performance in terms of the amount of greenhouse gases generated (Shabir et al., 2023). Carbon neutrality is part of the sustainability strategy, and the tool to achieve it is to monitor and measure the carbon footprint actively. The relationship between carbon footprint measurement, sustainability strategy, and social responsibility is also illustrated in a study (Saeed et al., 2021).

5. Conclusions

The article focused on approaches to sustainability and ESG in the Czech Republic's manufacturing industry, primarily from the perspective of large companies. The results of the quantitative survey confirmed the expectations of the author team that there is a statistically significant connection between the size of the company and the existence of a sustainability or ESG strategy. This relationship suggests that larger companies have broader capacities for implementing sustainable strategies and stronger external pressure on transparency and social responsibility.

The novelty of this research lies in providing new empirical evidence on the relationship between company size and the adoption of ESG strategies in the Czech manufacturing sector, which has so far received limited attention in the domestic context. The results are in line with findings from other recent studies (e.g., Hou & Xie, 2024; Das, 2024; Balogh et al., 2022; Nováková, 2025) which also confirm that larger enterprises are more

active in the field of ESG due to their greater resources and stakeholder expectations. By adding new data for the Czech manufacturing industry, this research complements existing knowledge and highlights the importance of supporting ESG adoption also among small and medium-sized enterprises.

Confirming the hypothesis about the connection between implementing the ISO 14001 environmental standard and the existence of a sustainability or ESG strategy can also be considered a key finding. The author team perceives this finding as theoretically significant, since no professional foreign study has been identified to date that would analyse this relationship. The research results thus represent not only a theoretical but also a practical benefit. The research was expanded to include a carbon footprint indicator in connection with environmental requirements. The hypothesis that a statistically significant relationship exists between whether a company has a calculated carbon footprint and whether it has a developed sustainability or ESG strategy was also confirmed. This finding highlights the importance of specific environmental tools for systematic sustainability management and underlines the role of measurable data in setting strategic ESG goals.

The novelty of this result lies in providing empirical evidence for this relationship in the context of the Czech manufacturing industry, where existing studies are still scarce. The limited available research (e.g., Saeed et al., 2021; Shabir et al., 2023) suggests that carbon footprint measurement is an integral part of sustainability strategies, but does not analyse this link in detail or for the Czech context. Therefore, this study contributes to filling this gap and confirms the expected connection between carbon footprint calculation and strategic ESG management.

Overall, the article provides important empirical findings on the factors influencing the adoption of sustainability strategies in the manufacturing industry in the Czech Republic. These results can serve as a basis for further research and support for decision-making by corporate and public actors in the field of ESG and environmental policy.

The limitation of the study is the regional limitation, as the research was conducted only in the Czech Republic. In the future, the author's team would like to extend their research abroad, e.g. to the V4. Another challenge is the interaction between different aspects of ESG. The research could further explore how different aspects of ESG (environmental, social and governance) interact and their impact on firm performance. Another limitation is that the sample represents the manufacturing industry as a whole and does not analyse specific sub-sectors. Therefore, the results apply mainly to the Czech manufacturing sector, and future research could focus more deeply on selected industries.

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EMPLOYEE MOTIVATION IN CURRENT LITERATURE: A SYSTEMATIC SEARCH*

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Abstract. The main objective of this article is to systematise approaches to motivation in current professional literature and identify key factors influencing employee motivation, thereby contributing to both theoretical understanding and practical improvement of human resource management in organisations. To this end, a systematic literature review of professional articles published in the Web of Science database in 2024 is conducted, using the VOSviewer programme to analyse and visualise key concepts and the relationships between them. The results show that employee motivation to enhance work performance is mainly influenced by quality support and leadership from direct superiors, autonomy in decision-making, ethical leadership, the integration of environmental values into human resource management (commonly referred to as green HRM), and the effective use of digital tools and technologies. The analysis also confirms that two main theoretical models dominate the current professional literature, namely the AMO (Ability, Motivation, Opportunity) model and Structural Equation Modelling (SEM).

Keywords: motivation; employees; human resources; model AMO; systematic literature search

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JEL Classifications: J24, M12, O15

1. Introduction

In the 21st century, rapid technological developments in various innovations have not diminished the value of human capital. Human capital is considered to be the most valuable capital of companies and acts as a driving force of business activity. The perception of human capital should be vital as it has a real impact on the success of a business. When managing human resources, it is important to bear in mind one of the basic functions of management: motivation, planning and organisation, since an adequately motivated employee is the key to achieving the company's objectives (Machova et al., 2022; Caha & Urban, 2023).

Employee motivation plays a fundamental role in the effective functioning of organisations. As stated by Goel & Rashmi (2023), motivation is a critical factor in employee engagement, and its importance, function and influence can vary significantly depending on the industry or work environment. A well-designed motivational

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system contributes to the creation of positive employee attitudes such as high job performance, job satisfaction or willingness to stay in the organisation (Jarkovska & Jarkovska, 2024).

Although organisations have an interest in maintaining employees motivated at work, they do not always fully understand what really motivates them. While academics agree that monetary factors—including employee wages—significantly affect employee performance and productivity, they do not unanimously rank them among the strongest determinants of employee motivation (Uka & Prendi, 2021). Tamara et al. (2020) argue that employees are motivated by brand management, company vision, owner, employee component, salary, teamwork and promotion.

Employee motivation is essential to employee performance, but organisations often do not understand all the factors that influence it. Soliman & Altabtai (2023) further note that the most important motivational factor is job security, followed by salary and promotion, while taking on responsibility is considered the least motivating. They also found a gender difference in the perception of motivation, with male participants favouring salary and female participants choosing job security. Similarly, Subha & Bhattacharya (2022) confirm that training and incentives positively influence employee efficiency and productivity, which has a major impact on the overall organisational performance.

Nowadays, however, there has been a proliferation of perspectives on how to approach the issue of motivation, and authors have come up with different research approaches, methods and interpretations of motivation itself. Alongside traditional theories, new directions are emerging, such as the emphasis on ethical leadership (Abdi & Rahman, 2024), digital transformation (Stachová et al., 2024), and ecological aspects of human resource management (Alshammari & Asaari, 2024). This makes the topic increasingly broad, diverse and often less clear for practice.

In reality, organisations are challenged with navigating a broad spectrum of information and approaches to select the most suitable way to manage employee motivation that aligns with their specific business style. As pointed out by Xing et al. (2024), supporting employees in developing environmental and digital competencies is an important motivational factor, but it manifests differently across organisations.

Thus, there is a clear societal demand for a deeper anchoring of this issue, a categorization of the different schools of thought, and providing a structured overview of their concepts. This research therefore seeks to provide a better understanding of the issue of employee motivation, to identify the main currents, and to map the ideas that can bring new approaches to human capital management.

In response to societal demand, the aim of this paper is to conduct systematic literature review on the topic of employee motivation. The focus of this study is to systematise the approaches to motivation in the current professional literature and to identify the main factors that influence motivation.
To achieve the objective, the following research questions are set:
RQ1: What factors are repeatedly proven to be crucial for increasing employee motivation and job satisfaction?
RQ2: What theoretical models (methods) appear in the current literature in relation to employee motivation?

2. Theoretical background

Using the right type of motivation is crucial for eliciting positive employee attitudes such as job performance, job satisfaction or voluntary retention, which ultimately leads to greater overall organizational effectiveness. Despite the ongoing academic debate, academics are providing practitioners with mixed findings regarding which motivational factors are relevant for target employee groups whose needs are under economic and socio-psychological pressures of a rapidly evolving environment (Jarkovska & Jarkovska, 2024).

2. 1. Motivation at work

Employee performance and consequently the performance of the business is affected by human resource management. The influence of motivation and the fulfilment of employees' needs is fundamental to improving performance and achieving the desired level of productivity (Hitka et al., 2020). Many factors affect employee

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motivation in a company. Some of them are supported by law, others are the result of voluntary activities of the company and the way to some of them has not been found yet (Vavra et al., 2021).

Leaders motivate employees by setting up structures aimed at harnessing the full potential of employees, organizational resources and providing direction. Conversely, they can pose serious challenges to building trust, embracing corporate goals, fostering alignment, and promoting a collaborative environment (Altheeb, 2020). As stated by Ismail et al. (2024), leadership support and on-the-job training opportunities are key elements in keeping employees motivated.

2. 2. Theoretical models

It is well-known that in order to start and complete a certain work, there must first exist a motive that pushes a person to do something. This motive may be related to the satisfaction that the person feels in doing the work, their desire to act or their expectation of the outcome. All of these are related to the motivation that drives a person to perform in a particular way. The higher the motivation, the better the result of the work done. In this way, motivational theories provide an explanation of how individuals should be motivated to perform better, or how employees in an organization should be motivated so that their work leads to the achievement of organisational goals (Bushi, 2021).

Motivational theories provide a solid foundation for understanding the multifaceted nature of employee motivation (Kharadze et al., 2023).

The first model is Maslow's theory of needs, which divides needs into five categories: physiological, safety, love and belonging, esteem, and self-actualization. Central to Maslow's theory of the hierarchy of needs is the idea of their gradual satisfaction. People only begin to think about satisfying a higher order need when a lower order need is substantially satisfied. The motivational system in Maslow's theory seems to be based on human predispositions: once a need is satisfied, it ceases to be the predominant motivator of human behaviour and the highest need becomes the predominant one (Rojas et al., 2023).

The Ability, Motivation and Opportunity (AMO) framework can be key to identifying what factors can support better project performance. However, despite decades of research, the exact interplay of ability, motivation and opportunity, as well as how they influence behaviour, remains largely unclear (Tuuli & van Rhee, 2021). Benítez-Núñez et al. (2024), Qamar et al. (2024), and Adams et al. (2025) confirm the effectiveness of the AMO model in enhancing employee performance through its comprehensive approach to capabilities, motivation, and organisational opportunities.

3. Research objective and methodology

The aim of this paper is to systematise approaches to motivation in the current literature and to identify the main factors that influence motivation.

In early 2025, a quantitatively oriented literature review will be conducted using the Web of Science database. Relevant publications will be searched using the following search query: (((ALL=(motivation)) AND ALL=(education)) AND ALL=(employee)), with keywords applied across all available categories, including the "Title" and "Abstract" fields.

After the results are downloaded, a multi-stage screening process will follow. In the first stage, all records that are not published in English will be screened out. In the second step, only publications published in 2024 will be included, as the review focuses only on the most recent scholarly production. In the final stage of the selection process, articles that do not fall into the selected subject categories will be excluded from the analysis, namely: management, entrepreneurship, educational research, applied psychology, multidisciplinary psychology, social sciences and economics.

The bibliographic data will then be exported from the Web of Science database in a format compatible with the VOSviewer analysis tool. This software will be used to visualise and analyse the relationships between

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publications by creating network maps. To create these networks, a bibliographic data set will be imported into VOSviewer to serve as input data for the generation of the maps.

Several visualisation maps will be created in VOSviewer. In the initial phase, it will be chosen that the analysis will be based on bibliographic data, with the input information read from a file exported from the Web of Science bibliographic database. Subsequently, individual maps will be generated according to the chosen type of analysis. This research will focus on four types of analysis:

1. Co-authorship – enables the identification of collaborations between authors by creating a network map showing the geographical distribution of authors by country.
2. Co-occurrence – analyses the frequency of occurrence and interconnection of keywords within the examined set of publications.
3. Bibliographic coupling – focuses on measuring the relatedness between scientific articles, authors, institutions or countries based on the number of shared references they cite. Through bibliographic coupling, three separate maps will be created showing papers, research organisations and countries of origin.
4. Co-citation – examines which sources (authors, journals) were most frequently cited together within the set of publications studied, thereby revealing influential authors and key scientific sources.

Following the completion of the visual analysis, an evidence review will be conducted based on a more narrowly defined set of articles, selected on the basis of their high thematic relevance and significant contribution to the research problem addressed.

This review will be systematically presented as a table with three columns, the first column containing the main evidence, i.e. the key findings and common topics identified in each study. The second column will focus on the research methods applied in the studies and the last column will list the authors of the relevant studies whose research contributed to the identified evidence.

4. Results

The search results indicated that a total of 3,047 articles on Web of Science include the keywords "motivation," "education," and "employees." These articles were published between 1984 and 2025.

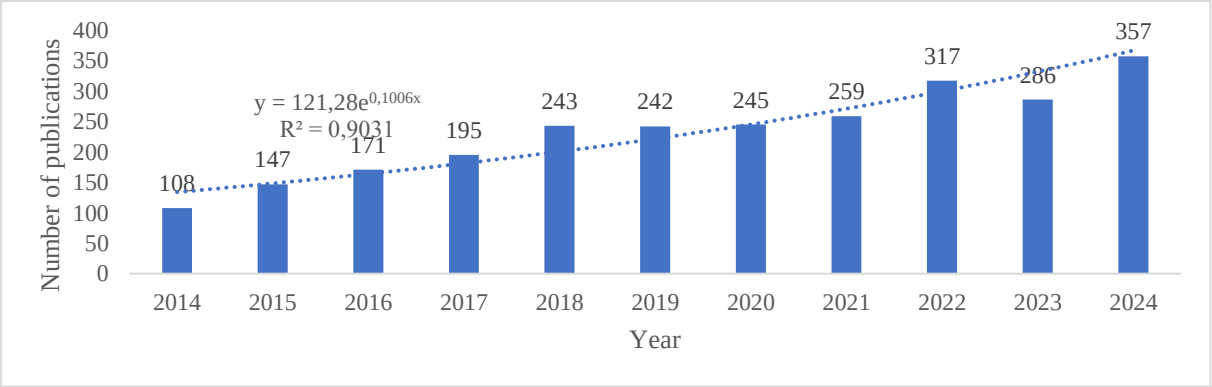


Figure 1. Number of publications from 2014 to 2024
Source: Authors

Figure 1 shows the number of publications published on Web of Science from 2014 to 2024 in all language versions. The graph indicates that the number of publications on employee motivation and training is on an increasing trend, indicating a growing interest of authors in the subject. The aim of the analysis was to identify research publications published in 2024 that relate to the concepts of motivation, education and workers. A total of 3,047 publications were found, but after a screening process (see Figure 1), 193 studies were included in the final set. The higher number of articles at this stage was deliberately retained in order to provide a basis for the

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creation of network maps that allowed for better visual representation and a broader understanding of the issues under investigation.

Table 1. Identified and selected topics and types of scientific products

Topic	Identified publications	Selected publications
Motivation + education + employees	3,047	193
Type of publication		
Article	2,280	146
Article; Book Chapter	19	1
Article; Early Access	85	42
Article; Proceedings Paper	6	0
Article; Retracted Publication	1	0
Correction	2	0
Document Type	3	0
Editorial Material	5	0
Note	1	0
Proceedings Paper	581	2
Review	64	2
Review; Early Access	1	0

Source: Authors

Due to such a large sample of articles, the number of articles was reduced according to the following scheme.

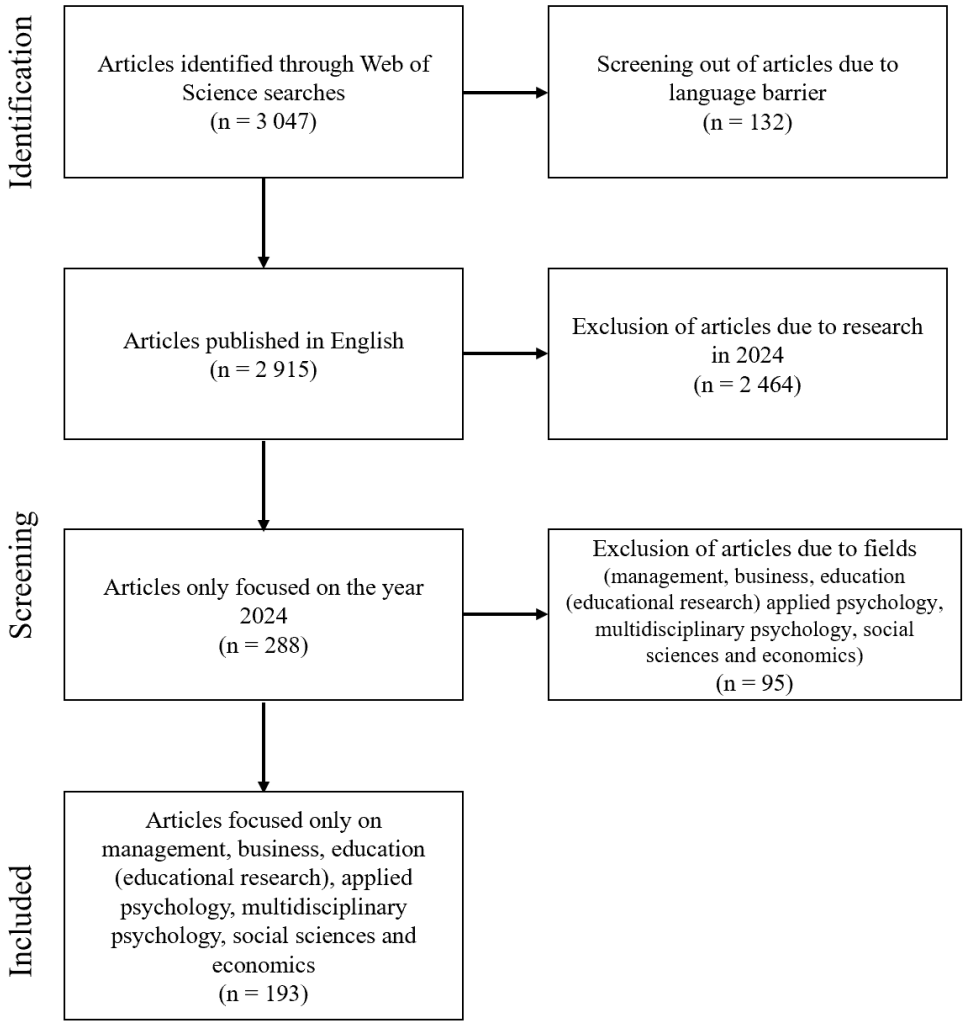


Figure 2. Searching and screening of articles
Source: Authors

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Figure 2 presents the process of selecting research articles from Web of Science. This process is divided into three parts. In the first part, 3,047 articles were identified and then 132 articles were screened out due to language barrier. After the removal of non-English articles, 2,915 articles remained, of which 2,627 publications were subsequently excluded because their research did not fall within the year 2024. Further 95 articles were excluded because they did not relate to the predefined scientific areas. The process resulted in 193 articles that met the criteria and were included in the final analysis.

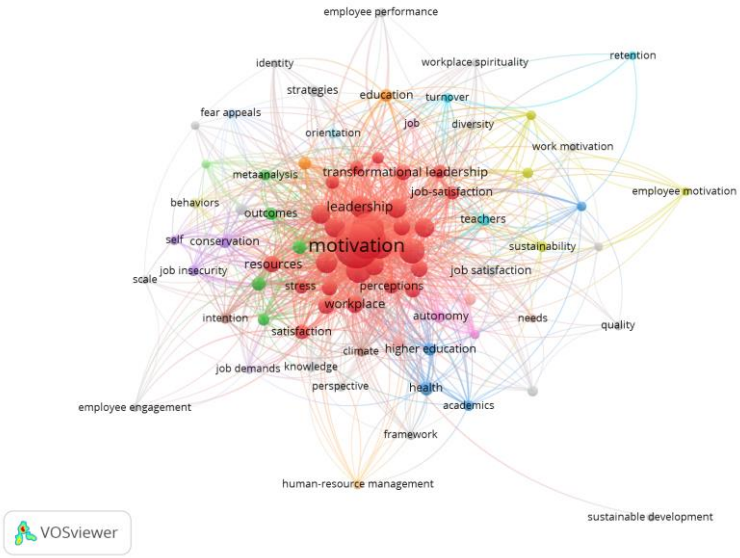


Figure 3. Network map: Co-occurrence – Keywords
Source: Authors

Figure 3 was created in VOSviewer software and shows the relationships between keywords. The map focuses on keywords associated with research on motivation, education and other related topics. The most prominent term is "motivation", which is located in the centre and is connected to other important terms such as "leadership", "job satisfaction", "resources". The coloured links indicate topic areas; the larger and redder the node, the more prominent and frequently mentioned the term is.

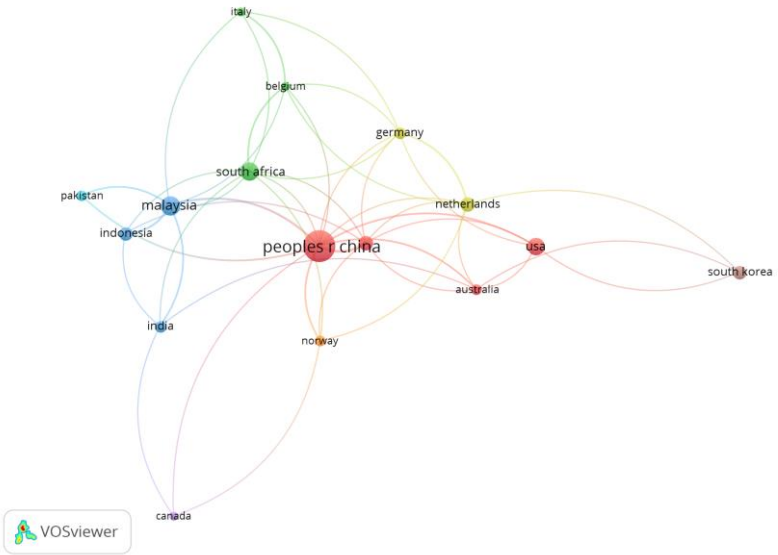


Figure 4. Network Map: Co-authorship – Countries of Authors
Source: Authors

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Figure 4 focuses on the origin of the authors and shows the collaboration between authors from different countries. The largest node represents "China", indicating that authors from this country are the most active in the research and have extensive international collaboration. Other important nodes are the USA, the Netherlands, Germany, South Korea, India and Malaysia. The coloured clusters indicate regional collaboration.

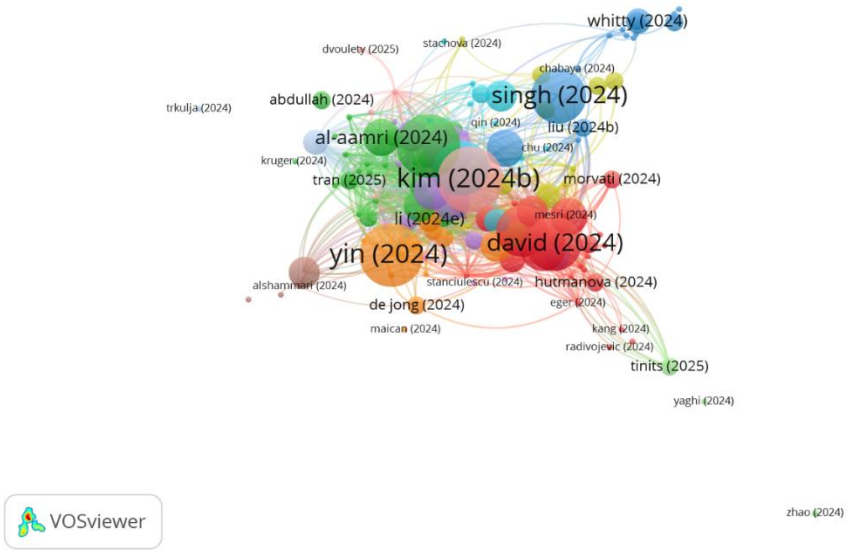


Figure 5. Network Map: Bibliographic Coupling – Documents
Source: Authors

Figure 5 shows how the articles are connected based on the bibliographical coupling. Bibliographic coupling focuses on measuring the relatedness between scientific articles, authors, institutions, or countries based on the number of shared references they cite. The size of the node depends on how important the document is in the network analysed. Large nodes with names such as “David (2024)”, “Yin (2024)” and “Kim (2024)” indicate that these articles are key to the topic of worker motivation and education because they have strong connections to others.

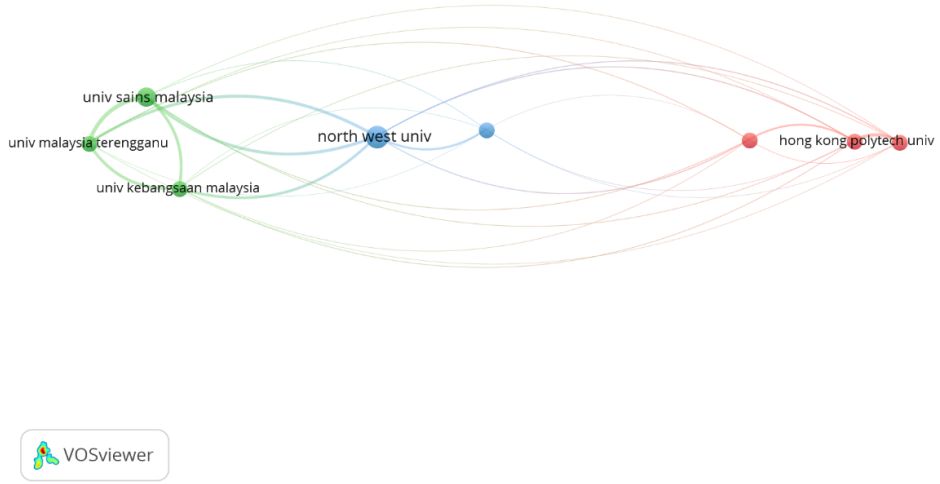


Figure 6. Network Map: Bibliographical Coupling – Organisations
Source: Authors

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Figure 6, on the other hand, illustrates how documents are connected between scientific institutions through bibliographic coupling—institutions are thus linked if their authors cite the same sources. The green node shows universities from Malaysia, while the blue node is linked to other institutions, which may indicate that researchers collaborate with multiple research institutions. The red node represents The Hong Kong Polytechnic University.

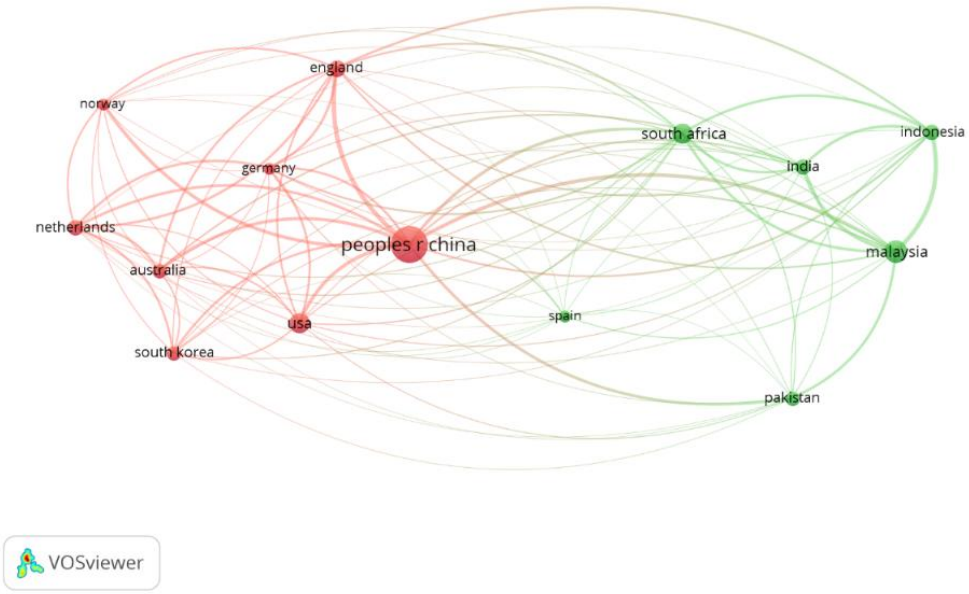


Figure 7. Network Map: Bibliographical Coupling – Countries
Source: Authors

Figure 7 illustrates the relatedness between countries based on the bibliographical coupling. Therefore, in this network map, countries that cite the same scientific papers will be listed. Each node represents one country that contributes to research on motivation and education. The size of a node indicates the importance of that country in the research network, and the lines between nodes indicate the strength of the link between countries. The more cited sources they share, the stronger the line.

The red region (China, Germany, Norway, South Korea) appears to be strongly interconnected through sharing the same citation references. China dominates this area, which indicates that its published research has a significant impact on motivation and education. The green area, on the other hand, shows countries such as South Africa, India, Malaysia, Indonesia.

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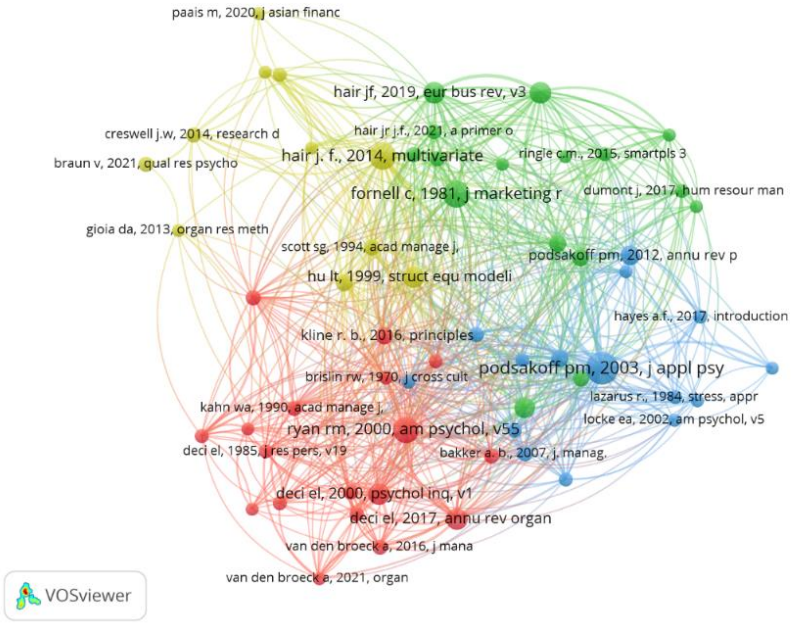


Figure 8. Network Map: Bibliographical Coupling – Cited References
Source: Authors

Figure 8 shows co-citation at the level of cited references, which means that two documents are linked if they were cited together in the same document. Each node represents a specific cited reference, and the size of the node depends on the number of times the reference was cited in the set of documents (in the selected 193 papers). At the same time, the map shows the strength of the connections between references using lines. The more times the references were cited together, the wider the line. The coloured areas then indicate related articles that were frequently cited together.

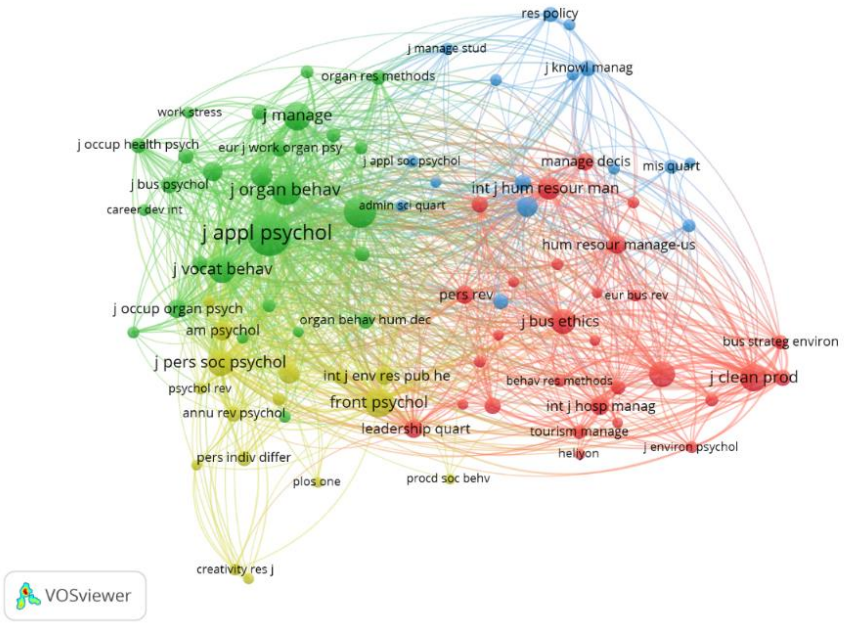


Figure 9. Network Map: Bibliographical Coupling – Cited Sources
Source: Authors

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Figure 9 shows co-citation at the level of cited sources (journals). Each node represents a scientific journal, book or another cited source.

The green area includes journals such as the Journal of Applied Psychology, Journal of Organizational Behaviour, European Journal of Work and Organizational Psychology, and others. The green part of the map is therefore probably focused on work and organizational psychology.

The red area shows the Journal of Cleaner Production, Journal of Business Ethics, Human Resource Management and others. This section is thus related to management, leadership and business ethics.
The yellow section is represented by Journal of Personality and Social Psychology, Frontiers in Psychology, Annual Review of Psychology. The yellow area thus represents articles published by journals that focus on general psychology.

The blue area includes Journal of Management Studies, Journal of Knowledge Management, Research Policy and others.

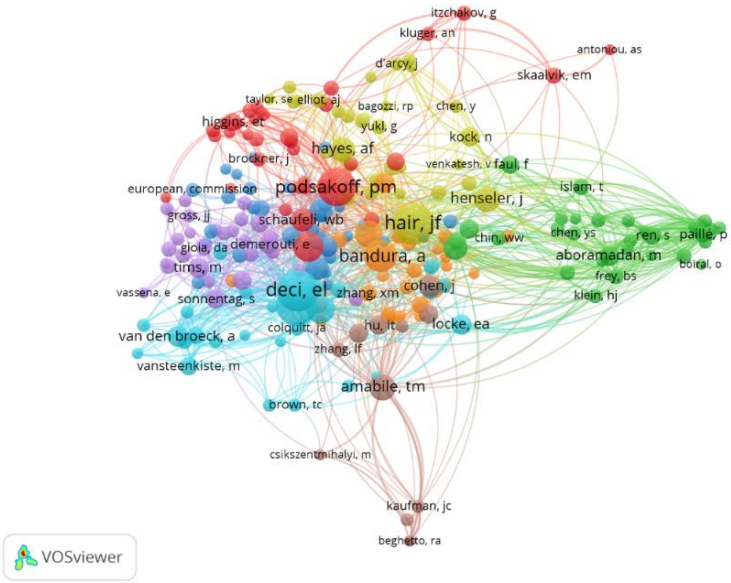


Figure 10. Network Map: Bibliographical Coupling – Cited Authors
Source: Authors

Figure 10 shows co-citation at the level of cited authors. That is, authors are linked if they are cited together in the same paper or document. Each node represents a specific cited author; the size of the node depends on how often the author is cited. The lines again represent the strength of co-citation. The most prominent authors cited are Edward L. Deci, Philip M. Podsakoff, and Joseph F. Hair.

Based on this analysis, an evidence review was conducted using a shortlist of articles carefully selected for their high thematic relevance and their contribution to the research focus.

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Table 2. Evidence reviews in terms of main topics and descriptive results

Main Idea	Used Methods	Authors
Motivation is a very crucial factor for an organization because it also affects the organization´s performance.	Quantitative survey (questionnaire) Analysis of correlations between digital HRM tools and engagement AMO theory (Ability, Motivation, Opportunity)	(Chanda, 2024) (Stachová et al., 2024) (He et al., 2024) (Issaoui et al., 2024) (Benítez-Núñez et al., 2024)
To be motivated, employees must have support from leaders and benefit from on-the-job training.	Cross-sectional design Structural Equation Modeling (SmartPLS) AMO model	(Ismail et al., 2024) (Benítez-Núñez et al., 2024) (Wu et al., 2024) (Qamar et al. 2024).
Autonomy as one of the basic human needs influences intrinsic motivation and drives job satisfaction.	Hierarchical regression analysis SEM Semi-structured interviews	(Zychová et al., 2024) (Y. Liu et al., 2024) (Mesri et al., 2024) (Gagné & Hewett, 2024) (Spieler, 2024)
Ethical leadership positively influences employees' trust in their leaders, loyalty and motivation. This trust, along with work spirit, has a direct impact on proactive employee behaviour, which in turn leads to better work performance. The result of ethical leadership and a positive work environment promotes employee motivation and engagement.	Quantitative survey among 279 employees, SEM-PLS analysis (Structural Equation Modelling – Partial Least Squares) in SmartPLS 4.1.0.0. program Structural Equation Modelling (SEM)	(Abdi & Rahman, 2024) (Gustari & Widodo, 2024) (Jufrizen et al., 2024)
Green HRM positively influences the environmental behaviour of employees (EEB) through motivators. Employee environmental commitment links the relationships between environmental behaviour, green skills and employee performance. Green skills and motivators positively influence performance. That is, when organisations actively promote green initiatives in human resource management, employees are more motivated to engage in green behaviours in the workplace and are more satisfied in the workplace.	Quantitative approach, online questionnaire, data analysis PLS-SEM method, Structured questionnaire, sample of 308 academics from Malaysian universities.	(Alshammari & Asaari, 2024) (Faezah, Yusliza, Ramayah, et al., 2024) (Farooq et al., 2024) (Xing et al., 2024) (Kurowska-Pysz et al., 2024) (Faezah, Yusliza, Chaudhary, et al., 2024)
Digital tools can improve organisational performance and employee engagement. Effective support for digital transformation in companies depends on the skills, motivation and opportunities of employees.	Analysis of correlations between digital HRM tools and employee engagement. AMO Theory (Ability, Motivation, Opportunity) A qualitative case study of Jiangsu Shangshang Cable Group Structured data analysis according to the Gioia model SEM	(Stachová et al., 2024) (Zhen & Ding, 2024) (X. Liu et al., 2024) (Türkes et al., 2024) (Guan et al., 2025) (Yildiz et al., 2024)
Employees are not expressing their full creative potential because they lack the right motivation and organisational support.	Observation Social information processing theory, structural equation modelling and bootstrapping analysis	(Angelova, 2024) (Li et al., 2024) (Zhu et al., 2024)
The main reasons why employees think about changing jobs include unmet expectations, lack of motivation, inadequate professional skills, low pay, limited career development opportunities and lack of recognition.	Analytical, descriptive, quantitative and statistical methods. Quantitative research (n=294), analysis of employee attitudes. Semi-structured interviews	(Samasonok, 2024) (Paresashvili et al., 2024) (Selesho & Matjie, 2024)

Source: Authors

Table 2 shows the main ideas from the selected set of publications. The first column contains the main evidence, i.e., key conclusions and common themes identified in individual studies. The second column focuses on the research methods applied in the studies, and the last column lists the authors of the relevant studies whose research contributed to the identified evidence.

The results from the table 2 are then shown in a mind map for better clarity, see Figure 10.

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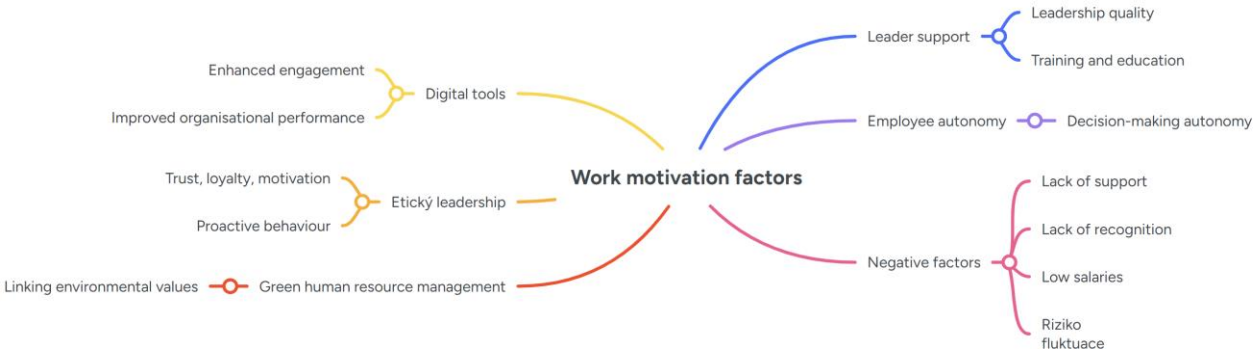


Figure 11. MindMeister mind map of results
Source: Authors using MindMeister

The mind map (Figure 10) shows the main factors that authors of current literature consider to influence work motivation. The main factors include support from managers, employee autonomy, digital tools, ethical leadership, and green human resource management. At the same time, factors that suppress motivation have been identified, including lack of support, lack of recognition, low wages, and the risk of turnover.

5. Discussion

Based on the findings, the research questions can now be answered.

RQ1: What factors are repeatedly proven to be crucial for increasing employee motivation and job satisfaction?

Motivation itself is one of the crucial factors of an organisation, as it affects not only the work commitment or performance of the employee, but also the overall performance of the organisation. (Chanda, 2024; Stachová et al., 2024; He et al., 2024; Issaoui et al., 2024; Benítez-Núñez et al., 2024). Within the analysis, various factors repeatedly appeared in the current publications.

According to Ismail et al. (2024), Benítez-Núñez et al. (2024) and Wu et al. (2024), employee motivation is directly related to quality support from managers (leaders) and professional development opportunities through training.

According to Zychova et al. (2024), Y. Liu et al. (2024), Mesri et al. (2024), Gagné & Hewett (2024) and Spieler (2024), it is necessary to allow employees some autonomy as well, since autonomy is one of the basic human needs that influences intrinsic motivation and controls job satisfaction. Since employees will be given the ability to make decisions about their work, they will also be driven to improve their performance.

Ethical leadership is also one of the factors influencing motivation in the workplace. Leaders who act ethically enhance employee trust and thus strengthen employee loyalty and motivation. This trust, combined with workplace spirit, has a direct impact on proactive behaviour, i.e. acting above and beyond one's normal job duties. Therefore, it appears that ethical leadership and work environment form the basis for employee motivation and commitment (Abdi & Rahman, 2024; Gustari & Widodo, 2024; Jufrizen et al., 2024). In addition to ethical leadership, the concept of green HRM is also gaining importance. This management integrates environmental values into the HR and employee management of companies. Research shows that if a company strives to be green and to lead its employees to do so, employees are more satisfied and thus more motivated to improve performance (Alshammari & Asaari, 2024; Faezah, Yusliza, Ramayah, et al., 2024; Farooq et al., 2024; Xing et al., 2024; Kurowska-Pysz et al., 2024; Faezah, Yusliza, Chaudhary, et al., 2024).

Digital tools represent another factor for higher performance motivation. Such tools can improve the performance of the entire organisation as well as employee engagement. Hence, effective support for digital transformation in companies depends not only on the capabilities, but also on the motivation and opportunities

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of employees (Stachová et al., 2024; Zhen & Ding, 2024; Liu et al., 2024; Türkes et al., 2024; Guan et al., 2025; Yildiz et al., 2024).

Conversely, if employees lack sufficient organisational support and are not motivated, they often do not use their creative potential. Lack of recognition and incentives can lead to passivity and reduced performance (Angelova, 2024; Li et al., 2024; Zhu et al., 2024). At the same time, employees may also think about changing jobs if their expectations are not met, they are not sufficiently motivated, have low wages or limited career development opportunities, or a lack of recognition. These factors reduce long-term job satisfaction and lead to increased turnover in the company (Samasonok, 2024; Paresashvili et al., 2024).

RQ2: What theoretical models (methods) appear in the current literature in relation to employee motivation?

There are various theoretical models in the field of employee motivation that have been proven to work in the research literature. The main models that appear in the literature include the AMO theory and the Structural Equation Modelling (SEM).

The AMO (Ability, Motivation, Opportunity) theory is about the need to develop, motivate and create new opportunities for employees to reach their full potential. This model has been used in studies by authors such as Zhen & Ding (2024), Benítez-Núñez et al. (2024) and Qamar et al. (2024).

The other method used is Structural Equation Modelling (SEM). The SEM method is widely used for the analysis of complex relationships between variables. Through SEM, Faezah, Yusliza, Chaudhary, et al. (2024) found that green HRM influences employee behaviour. Abdi & Rahman (2024), Guan et al. (2025), Yildiz et al. (2024), Xing et al. (2024), Jufrizen et al. (2024) also used this method in their investigations.

Conclusions

The research investigated what motivational factors affect employee performance. Thus, the aim of this paper was to systematise approaches to motivation in the current literature and to identify the main factors that influence motivation. This systematic literature review represented sources published in 2024 on the Web of Science that address how autonomy, leadership support, training, ethical leadership, work environment and digital tools influence work behaviour and employee motivation. The results show that job autonomy, leadership support, green initiative, and the use of digital technology in HR contribute to the development of proactive behaviours, higher satisfaction, and increased overall performance. It can therefore be said that motivation is a complex process that is influenced by several factors, both internal and external.

At the same time, it was found that academic authors in their research on motivation most often use the AMO (Ability, Motivation, Opportunity) theory, which emphasizes supporting employees' abilities, motivating them and providing them with opportunities to use their abilities. Another important method currently used by the authors is Structural Equation Modelling (SEM), which in turn examines the relationship between variables such as green HRM and employee motivation.

The contribution of this paper lies in providing a clear summary of the factors influencing work motivation, as well as outlining theoretical models that can serve as a basis for further research and practical application in human resource management.

A limiting factor of the research was that only literature from 2024 was examined. Another limitation was the choice of keywords, which were only entered into the Web of Science database. The research was also limited by the selection of only one database. Nevertheless, the findings may still prove valuable for companies aiming to adjust their motivational systems within their organisations or serve as a basis for further research.

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GREEN LOGISTICS IN THE WOOD-PROCESSING ENTERPRISES*

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Abstract. Green logistics affects all companies worldwide. Compared to conventional logistics, it has several specificities and differences, especially in relation to the environment. In the context of the wood-processing industry, whose impacts are also reflected in the environment, implementing green logistics in enterprises is more than effective. This study aims to propose measures that could be implemented in wood-processing enterprises and thus increase their sustainability, based on a mapping of the state of green logistics in wood-processing enterprises. The basis of the conducted empirical research is a systematic elaboration of the theoretical foundations of green logistics in the wood-processing industry according to the approaches of domestic and foreign authors. The results of the empirical research in the form of a questionnaire survey, in which 359 wood-processing enterprises participated, revealed the need to pay increased attention to logistics processes in enterprises. In addition to identifying green logistics, the questionnaire survey also focused on identifying potential areas for the future development of wood-processing enterprises. Based on the results and their mathematical-statistical analysis, recommendations within the framework of green logistics in the wood-processing industry were proposed, which have the potential to increase the sustainability of companies in the wood-processing sector. The hypotheses were tested using mathematical-statistical methods. The practical benefits of the study were defined by a detailed treatment of green logistics and proposals for the sustainability of green logistics in the wood-processing industry, which can be systematically followed up in the future.

Keywords: green logistics; wood-processing industry; ecology; sustainability

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JEL Classifications: Q56, Q57, L73, M11

1. Introduction and review of literature

As a separate scientific discipline, logistics has been developing in connection with logistics processes since ancient times (Tang, Liu & Hu, 2020). Even in ancient Egypt, they knew that great works such as the pyramids could only be built under systematic organisation, strategic process management and collective effort. The Byzantine emperor Leontos defined the content of logistics as the movement of people and materials so that the given object is in the required place and at the required time.

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Musolino, Rindone, and Vitetta (2019) defined logistics as going through four basic phases during its history. The first phase was dominated by a distribution model with an emphasis on a commercial approach; the second phase brought an expansion to the area of supply. The creation of interconnected logistics chains within integrated logistics characterised the third phase. In the fourth phase, process deficiencies were eliminated, moving the system towards optimised logistics (Zhang, Li & Peng 2020). After World War II, mathematical methods, linear planning and development plans became the basis of logistics (Kokoab et al., 2019). The logistics and production management method JIT (Just in Time) in the field of information and communication technologies, aims to minimise inventories and deliver material exactly when it is needed, not earlier or later.

Ghomi-Avili et al. (2021) characterise logistics as a scientific discipline whose task is to ensure that the right goods or services are delivered at the right time, to the right place, in the required quality and quantity, to the right customer with optimal costs. Logistics plans, organises, optimises and manages material, information and financial flows, and connects them to the timely fulfilment of all required customer needs using information technologies (Taylor & Van Der Velden, 2019; Song et al., 2020). Logistics manages material, information and financial flows and integrates them to fulfil customer needs quickly (Brecka & Korauš, 2016; Gombár et al. 2022; Dai et al., 2025).

The goal of green-oriented logistics is to integrate environmental aspects into all logistics processes in the company. The key to implementing green logistics is available resources, such as human resources, machinery and equipment or energy, as well as the processes and outputs, including products, services, environmental impact or information. The most significant added value of green logistics for a company is building a positive image and reputation.

Green logistics aims to reduce the environmental impact in accordance with the ISO 14 000 certification. Green logistics is an approach oriented towards reducing the environmental burden caused by the company's logistics activities (Alves, Silva & Rodrigues, 2020). The key green logistics activities are considered to be the optimisation of the transport of goods, the preference of land transport over air transport, the ecological design of products and packaging, the processing of returned products, the recycling of used materials, the reduction of the amount of toxic substances and waste, as well as the use of environmentally friendly materials and many others.

Companies are increasing their productivity by expanding the application of logistics from distribution to production and supply (Fan et al., 2020). Green logistics is still dynamically developing, and no unanimously accepted definition exists (Osintsev & Rakhmangulov, 2025). Chepurna et al. (2025) found 55 distinct available definitions of green logistics in scientific literature published between 2000 and 2023.

The authors Mondal, Giri and Maiti (2020); Mihalčová et al. (2021); Šimberová et al. (2022) describe the logistics chain as a set of organisational units, institutions, or agencies within or around the company that perform functions supporting the marketing of a given product. A logistics chain in which logistics companies, or only forwarders or carriers, participate is called a supply chain. Green procurement logistics, production logistics, distribution logistics and reverse logistics form a comprehensive system of green logistics. Sustainable green logistics aims to focus on the impacts of business activities on the environment, that is, to observe the relationship between individual modes of transport and the level of environmental pollution, or to reduce the energy and material intensity of logistics activities. Sustainable products provide environmental, ethical, social and economic benefits in protecting the health of stakeholders and the environment beyond the limits set by legislation, throughout their entire life cycle (from raw material extraction to disposal) (Tayler & Velden, 2019). Sustainable solutions depict changes in products, systems or services that contribute to reducing negative and increasing positive impacts on sustainable development from an economic, ecological, ethical and social perspective in business (Rajnoha et al., 2016; Kolesnichenko, Sokolinskaya & Popova, 2019; Straková et al., 2021; Berberoglu, Kazancoglu & Sagnak, 2023; Asamoah et al., 2024).

The object of our research is wood-processing enterprises in Slovakia, the wood, furniture and pulp and paper industries and their various legal forms (sole proprietorships, small and medium-sized enterprises, joint-stock companies, etc.). Sedliačiková (2005) points out that one of the main problems of wood-processing enterprises

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in Slovakia is the low level of added value generated by their products. Wood-processing companies form an industry based on the processing of renewable natural raw materials – wood. The European Union is interested in creating healthy economic areas based on renewable raw materials. From this perspective, it is necessary to ensure the availability of the necessary financial resources to purchase safe, environmentally friendly and energy-efficient input materials, new technologies, production equipment and innovations in the wood processing industry. The issue of green logistics in wood processing companies is a highly topical topic, especially in the context of the deepening environmental crisis, characterised by the deterioration of environmental quality, global warming, increased greenhouse gas emissions and the need to promote the principles of sustainable development.

The main goal of the presented study is, based on the identification and evaluation of the current state of green logistics in the wood-processing industry, to formulate measures to strengthen the sustainability of business processes in the wood-processing industry.

2. Methodology and data

To ensure a clear structure and logical continuity, the methodology of the scientific contribution was divided into three phases. The study focuses on the theoretical and practical analysis of the research issue. To achieve the set scientific goal, a detailed analysis of secondary sources related to the issue of sustainable and socially responsible business and activities within sustainable business was carried out in the first phase. The theoretical analysis drew primarily from foreign scientific sources, which were subsequently supplemented by domestic literature. The main focus was on relevant studies published in renowned electronic databases, such as Web of Science (WoS), Science Direct and ProQuest. The methods of analysis, synthesis, induction, deduction, comparison, description and concretisation were used to process the theoretical part of the study.

After analysing the theoretical information, the survey method was used – a questionnaire form of the survey, which appeared to be the most appropriate method of obtaining the necessary data to achieve the main goal of the presented study. The survey method served as the primary source of information for the research part of the work. Based on the obtained theoretical foundations of the given issue, a questionnaire was compiled, which was anonymous, and the target group of the research was business entities in the wood-processing industry operating in the territory of the Slovak Republic. The questionnaire consisted of 26 purposefully formulated questions focused on the characteristics of wood processing companies, the level of implementation of green logistics principles, and the identification of perceived needs, benefits and barriers associated with its application in practice. The questionnaire survey aimed to obtain relevant data for evaluating the current state and formulating proposals to develop environmentally sustainable logistics processes in this sector. The preparation and distribution of the electronic questionnaire were ensured using the free Google Forms platform.

Calculating the minimum size of a research sample involves assessing the sufficient sample size in terms of the requirements and objectives of a given study. The process involves determining the optimal sample size needed to achieve relevant results. A simple calculation is used to determine the sample size:

$$n = \frac{z^2 \times p \times (1-p)}{c^2} \quad (1)$$

Where:
z – value, substituted from statistical tables (confidence level 95 %, z = 1.96),
p – proportion of the sign, with unknown total values p = 0.5,
c – permissible margin of error (value 2-10 %), research sets a value of around 5 %.

After collecting, processing, and analysing the obtained data, the questionnaire survey was evaluated statistically, numerically, and graphically, and the results were presented using a descriptive method. All types of tests were performed, and the obtained data were analysed and processed using the statistical program STATISTICA 12. The STATISTICA 12 program is specialised software for collecting, processing, analysing statistical data, and drawing statistical conclusions.

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In connection with the primary goal of the presented scientific study, the following hypotheses were formulated, which resulted from the current knowledge of the issue being addressed:
H_1: It was assumed that most wood-processing companies in Slovakia perceive the introduction of green logistics in the company as important.

Logistics processes have an impact in various ways on both the environment and the business environment Malá, 2017). Therefore, dealing with procurement, production, distribution and reverse logistics in the enterprise remains essential. Green-oriented logistics makes it possible to differentiate the environmental aspects of all enterprise logistics processes, define mistreatment, and minimise errors in logistics processes.
H_2: It was assumed that most enterprises interviewed applied green production strategies and environmental management.

Material flows and their management are an integral part of the overall concept of production management and the philosophy of production logistics. It is a vital process for the company, even if it does not directly affect the end customers. Unless the enterprise can ensure effective and efficient management of input material flow, the production process cannot produce products at the required price and at the time when these products are required for distribution to customers. Incorporating smart logistics into business practice will require long-term preparation and strategic planning support (Kokab et al., 2019).
H_3: It was assumed that most businesses surveyed did not use alternative fuel vehicles for transport.

Transport is one of the key areas in logistics and contributes significantly to environmental pollution. The most significant negative effect of transport on the environment is the emissions themselves; other equally significant externalities of transport are noise and vibration caused by trucks, planes or trains. This trend is already well established in the innovative world, while in Slovakia, it has been used only to a small extent so far.
H_4: It was assumed that most businesses would show interest in the green logistics model and thus contribute to better sustainability.

To incorporate green logistics into companies, a range of innovative technologies and especially green products are needed (Nicoletti & Appolloni, 2024). Sustainable solutions (Kolesnichenko, Sokolinskaya & Popova, 2019) are product changes or innovations, service changes, or systems changes that reduce negative and increase positive sustainability impacts (economic, environmental, ethical, and social).

The research sample should be representative of the baseline population, so it will be validated using Pearsen's Chi-square test. Pearson's Chi-Square test is one of the most well-known goodness-of-fit tests based on the difference between observed (Xi) and expected (Npi) frequencies. The test characteristic for the Chi-squared test (where k is the number of counts) is:

$$\chi^2 = \sum_{i=1}^{k} \frac{(X_i - Np_i)}{Np_i} \tag{2}$$

Where:
x – Chi-squared test value,
X_i – observed values,
N_{pi} – expected values.

The final part of the study is based on the methods of analogy, synthesis, deduction and summarisation, where the summary of conclusions is subsequently strategically supplemented by the use of a systems approach, which allows for the formulation of the future direction of the presented research.

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3. Results

The calculation of the minimum scope of the research shows that the size of the sample of enterprises in the questionnaire survey, which ensures sufficient representation and statistical significance, is at least 358 enterprises operating in Slovakia in the wood-processing industry. We contacted a total of 2,549 enterprises through direct communication via email. Of the total group of respondents contacted, 359 enterprises completed the questionnaire, representing a relatively low return rate of 14.08%. The statistical level of the minimum scope of the research sample, i.e. 358 responses from the questionnaire survey, was exceeded, since 359 responses were recorded. It follows from the above that the achieved results can be generalised to the entire basic set.

At this point, it is necessary to clarify again the issue of green logistics in Slovakia with regard to the topic of the thesis. The definition of green logistics is absent in the legislative conditions of the Slovak Republic. Since the object of the thesis in a narrower sense is the wood-processing industry in Slovakia, the theoretical background of the thesis shows that we consider the following, briefly summarised definition of green logistics to be the guiding one.

The first question from the questionnaire served as an important element in the survey conducted, as it is generally expected that sustainability is used more in larger companies. The questionnaire survey results showed that medium-sized enterprises were the most represented, accounting for 69.92 % (251 enterprises). This was followed by small enterprises with 25.07 % (90 enterprises) of the total number of enterprises responding, and the smallest representation was from large enterprises with only 5.01 % (18 enterprises) responding. The answers to the question on which market the company prefers to focus on showed that more than half of the companies supply their products to the national market 57.90 %, 26.05 % to the regional market, 9.95 % to the local market and the remaining 6.10 % of the companies also offer their products or services within the EU market. Of the 359 wood-processing enterprises in Slovakia, 69.92 % (250 enterprises) are involved in wood working, 20.06 % (72 enterprises) in furniture production and 1.95 % (7 enterprises) in pulp and paper production. The remaining 8.07 % of enterprises indicated the other option.

Through the first hypothesis, we verified whether a statistically significant majority of wood-processing enterprises in Slovakia perceive the introduction of green logistics in their enterprise as important. Up to 80 % of companies declared a positive attitude towards ecology, 10 % of companies stated that they have no attitude towards ecology, and the remaining 10 % have a neutral attitude towards ecology - they do not care or cannot comment on this issue. The results of the univariate chi-square goodness-of-fit test (at the $\alpha = 0.05$ level) showed that there is a statistically highly significant difference in the number of enterprises that have a positive attitude towards ecology compared to enterprises that have no or a neutral attitude towards ecology. Based on the nature of the data obtained, a Chi-Square test was used to test the hypotheses. The data obtained for the first hypothesis H_1 are presented in Table 1.

Table 1. Relation of the wood-processing enterprise to ecology

	Chi-sqare = 128.76; df = 1; p < 0.0001	
The company's relationship to ecology	Observed frequencies	Expected frequencies
Positive attitude	287	179.5
None, neutral attitude	72	179.5

Source: Own research

When asked in the questionnaire survey whether the enterprise carries out at least some environmental activities, 70 % of enterprises answered positively, while the remaining 30 % of enterprises confirmed that they do not carry out any environmental activities. Based on the chi-square test results, we can further conclude that the number of enterprises that carry out these types of activities is significantly higher than the number of enterprises that are not interested in these types of activities and do not practice them in their enterprises ($x^2 = 56.691$; df = 1; $p < 0.0001$). Based on the results obtained, ***hypothesis H_1 was confirmed.***

To examine the level of environmental responsibility among enterprises, attention was directed to the implementation of green production strategies and environmental management practices. In this context,

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Hypothesis H_2 was formulated with the assumption that the majority of the surveyed enterprises incorporate sustainable approaches into their production processes and actively engage in environmental management. The data shows that up to 80 % of all participating enterprises consider ecology when planning and managing material flows, which represents a significant majority ($x^2 = 128.76$; df = 2; $p < 0.0001$). The second hypothesis was also addressed by a question that addressed whether companies in the wood-processing industry use recyclable and renewable materials in their production (Table 2).

Table 2. Use of recyclable and renewable materials

	Chi-sqare = 211.845; df = 2; p < 0.0001	
Using recyclable and renewable materials	Observed frequencies	Expected frequencies
Yes	251	119.67
No	72	119.67
Partially	36	119.66

Source: Own research

Table 2 shows that 69.92 % of enterprises use recyclable and renewable materials on a regular basis, 10.03 % of enterprises said they use them only sometimes, and the remaining 20.05 % do not use them at all. The test results confirmed the existence of significant differences in the rate of use of these green materials in wood processing enterprises ($x^2 = 211.845$; df = 2; $p < 0.0001$), with a significant majority of enterprises using recyclable and renewable materials.

The research analysed the extent to which companies in the wood processing industry take environmental aspects into account in the production of their products. In particular, it was investigated whether the companies strive to produce environmentally friendly products. The results showed that up to 71 % of enterprises consider the environmental friendliness of their products to be important, while 19 % of enterprises do not attach importance to this aspect, and 10 % of the respondents could not comment on this question. The chi-square test confirmed the existence of statistically significant differences between the different groups of enterprises according to their approach to green production ($\chi^2 = 220.687$; df = 2; $p < 0.0001$). The findings also build on previous test results, indicating businesses' positive attitude towards environmental issues. Here again, the statistical analysis confirmed that a significant majority of wood processing enterprises pay increased attention to the production of environmentally friendly products, which further strengthens and ***confirms the validity of hypothesis H_2***.

Through the third hypothesis H_3 we analysed the distribution process in wood processing enterprises in terms of its impact on the environment – we verified whether a significant majority of wood-processing enterprises use or do not use vehicles powered by alternative fuels for transportation (Table 3).

Table 3. Type of vehicle propulsion in wood-processing enterprises

	Chi-sqare = 229.440; df = 1; p < 0.0001	
Vehicle drive type	Observed frequencies	Expected frequencies
Diesel	323	179.5
Ecological - electric, LPC or CNG	36	179.5

Source: Own research

In terms of type, 89.97 % of wood-processing companies own diesel vehicles in their plants and only 10.03 % own electric, LPG or CNG vehicles. The chi-square test results confirmed that significantly more enterprises still use cars, trucks and all types of diesel vehicles, which are not environmentally friendly as opposed to eco-friendly vehicles. Based on the results from the questionnaire survey, we conclude that ***hypothesis H_3 was confirmed***.

The fourth hypothesis, H4, tested the difference in opinions of wood-processing enterprises on the concept of green logistics. When asked whether the firm planned to implement some part of green logistics in their

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company in the future, 90.25 % (324 enterprises) of the enterprises answered positively, 5.01 % (18 enterprises) of the enterprises could not answer clearly and chose the option "maybe" and about the same number of enterprises (4.74 %) (17 enterprises) answered that they definitely did not. However, we can state with certainty that significantly more enterprises are clearly in favour of introducing green logistics ($x^2 = 516.510$; df = 2; $p < 0.0001$). To test the fourth hypothesis H_4, a question focused on the willingness of companies to invest in the implementation of the green logistics model was also assigned (Table 4). This question was intended to complement the view of the environmental strategies of enterprises in terms of their readiness to allocate funds to environmentally oriented logistics solutions.

Table 3. Type of vehicle propulsion in wood-processing enterprises

	Chi-sqare = 243.682; df = 2; p < 0.0001	
Investing in a green logistics model	Observed frequencies	Expected frequencies
Yes	256	119.67
Depends on the financial requirements	25	119.67
No	78	119.66

Source: Own research

71,31 % (256 enterprises) of enterprises in the wood-processing industry would be willing to invest in a suitable green logistics model, 6,96 % (25 enterprises) of enterprises said that their decision would depend on the financial complexity of this model, and 21,73 % (78 enterprises) of enterprises would not invest in such a model. There are statistically significant differences between the number of enterprises with different attitudes towards investing in a green logistics model suitable for their enterprise, with a significant majority of f enterprises saying they would definitely invest in such a model ($x^2 = 243.682$; df = 2; $p < 0.0001$). Based on the findings, ***hypothesis H_4 was confirmed***.

Based on the processing and analysis of the data obtained, several measures have been proposed, the implementation of which could significantly contribute to increasing sustainability in enterprises operating in the wood-processing industry. These measures are mainly aimed at promoting environmentally oriented logistics processes, more efficient use of resources and strengthening the environmental identity of enterprises. One of the essential steps is to clearly define the current state of green logistics in the Slovak Republic, which is currently absent in legislative terminology and comprehensive strategic frameworks. At the same time, it is necessary to identify the main barriers that prevent a more effective application of the principles of green logistics, especially in terms of economic, technological and knowledge constraints in the sector. At the core of the proposed approach is the concept of green logistics, which includes ecological principles applied across all logistics processes. In procurement, emphasis should be placed on selecting suppliers with environmental certifications and demonstrable sustainable practices. Production should be oriented towards the processing of recyclable and renewable raw materials, while the resulting products should meet environmental standards and be labelled with appropriate eco-certifications. In distribution, the environmental burden needs to be reduced through the use of electric or other environmentally friendly means of transport and handling equipment, the reduction of non-recyclable packaging materials and the implementation of low-energy 'green warehouses'. In the area of recycling and waste management, we recommend introducing a returnable packaging system, monitoring emissions and noise, and actively treating production residues. From the point of view of energy sustainability, investing in renewable energy sources, especially photovoltaic systems, represents an important solution, whose economic payback according to available analyses is up to 7 years. A complementary technology is using virtual batteries to store surplus electricity efficiently. Reverse logistics is also an integral part of the concept, which involves reverse flows of materials and products - for example, the collection and reuse of scraps, sawdust or defective products. These can then be reprocessed or upcycled (e.g., to produce pallets or decorative products), significantly extending the materials' life cycle and reducing waste. Environmental management certification (ISO 14001) is also an important tool to support this approach and should be complemented by the responsible use of resources and the reduction of the ecological footprint. In addition to internal measures, external communication of environmental values through marketing is also recommended, strengthening the company's brand and innovation potential in sustainability.

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In conclusion, the systematic implementation of the above measures can contribute not only to reducing the environmental burden but also to increasing the competitive advantage of wood processing enterprises. At a time of rising energy costs and increasing social pressure for environmental responsibility, these steps appear to be a prerequisite for the long-term sustainability of enterprises in the wood-processing industry.

4. Discussion and conclusions

The questionnaire survey results provide a robust statistical basis for evaluating the current state and attitudes of wood-processing enterprises in Slovakia toward the concept of green logistics and broader environmental responsibility. Despite a relatively low response rate of 14.08 %, the final sample size (n = 359) exceeded the calculated minimum threshold (n = 358), ensuring the representativeness and generalizability of the findings across the entire population of enterprises in the Slovak wood-processing industry. The confirmed first hypothesis (H_1) reflects the prevailing positive orientation of wood processing enterprises towards environmental values, with up to 80 % of respondents declaring an active or supportive attitude towards ecology. The high statistical significance of the results ($\chi^2 = 128.76$; $p < 0.0001$) confirms that environmental issues are no longer perceived as a peripheral topic but represent an integral part of strategic decision-making. Similarly, 70 % of the companies carry out at least some environmental activities, indicating a growing awareness of sustainability across the sector. These results correspond with research by Asamoah et al. (2024) who likewise highlight the growing environmental orientation of businesses as part of their identity and competitive advantage. Our research findings are also consistent with international studies. Starostka-Patyk et al. (2024) found in their research in Poland that more than 75 % of manufacturing companies already integrate environmental elements into internal processes and also plan to extend green strategies to logistics. Rahman and Hossain (2025), in their study of small and medium-sized enterprises, highlighted the importance of a positive environmental attitude as a starting point for implementing green logistics, which is consistent with our findings that environmental awareness is relatively high in the Slovak wood-processing industry. The second hypothesis (H_2), concerning applying green production strategies and environmental management, was empirically supported. A significant majority of companies (80 %) reported that they take environmental aspects into account in their planning and management of material flows, which is in line with Mondal, Giri and Maiti (2020) assertion that environmental elements are increasingly being incorporated into strategic processes, even in industries based on primary raw materials. Moreover, 69.92 % of the respondents reported the regular use of recyclable and renewable materials, confirming that environmental measures are not isolated initiatives but are becoming a standard part of production systems. These findings are consistent with a study by Fatorachian and Kazemi (2025), who find that firms with developed environmental management are more likely to use renewable raw materials, reducing their overall carbon footprint. Similarly, Roy and Mohanty (2024) showed that in wood and furniture companies in India, environmental certification and the use of green materials have a direct positive impact on the long-term efficiency of the companies. However, in the case of the third hypothesis (H_3), the results point to a weaker degree of greening, especially in the area of transport logistics. Up to 89.97 % of enterprises use diesel vehicles, while eco-friendly alternatives (electric, LPG or CNG) represent only 10.03 %. This situation may be due to several factors, including high upfront investment in green vehicles, limited infrastructure and the absence of effective financial incentives, as also reported by Mihalčová et al. (2021). Although the manufacturing sector has made progress, distribution processes are still lagging, posing a challenge for future improvements in corporate environmental performance. A more positive picture was provided by the fourth hypothesis (H_4), which focused on companies' future intentions and willingness to invest in green logistics. As many as 90.25 % of the enterprises declared their interest in implementing elements of green logistics, and 71.31 % of the respondents stated that they would be willing to make a real investment in this model. Although a smaller proportion of businesses weigh in mainly due to the expected financial costs, the statistically significant differences ($\chi^2 = 243.682$; $p < 0.0001$) suggest that the potential for developing green logistics in the sector is considerable. This positive trend is in line with the research of Rahman and Hossain (2025), who report that investment appetite is one of the main indicators of future readiness to implement sustainable measures. It also significantly reflects confidence in the long-term returns to eco-innovation and its reputational benefits. This trend is also supported by the study of Šimberová et al. (2022), according to which enterprises perceive green innovations as an investment in long-term competitiveness. The findings confirm that green strategies are becoming increasingly established in the wood-processing industry, with the main motivator being not only regulation but also self-initiative and business responsibility. However, the challenge

remains to reduce the ecological footprint in transport, waste management, and reverse logistics areas. At the same time, there is a need for a more favourable legislative framework and financial mechanisms to facilitate the wider application of green technologies and logistics solutions.

The implemented research also has some limitations, which are mainly the accuracy of the obtained data and information, sampling error (few actively involved respondents in the questionnaire survey, insufficient representation of enterprises despite meeting the minimum size of the research sample), or the structure and wording of the questions in the questionnaire itself, which despite the efforts to be unambiguous may have been misinterpreted by some respondents. This is particularly the case for complex terms such as 'green logistics', which are not uniformly defined by legislation or practice and may have affected some responses' quality. Another potential risk is the subjectivity of the answers, as the research works with stated attitudes rather than objectively measured data. Despite these limitations, the findings contribute to the debate on sustainable entrepreneurship in the wood processing sector. The results provide a starting framework for future research that could focus on a deeper analysis of specific environmental measures and their economic efficiency and deepen knowledge in implementing environmental innovations in logistics processes. At the same time, it would be useful to follow up with qualitative research (through interviews or case studies) that would provide a deeper insight into the motivations and barriers of enterprises in putting green logistics principles into practice.

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CUSTOMER SEGMENTATION AND PERCEPTION OF SERVICE QUALITY IN DIGITAL TOURISM*

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Abstract. Digital communication plays an essential role in shaping customer experience and satisfaction in tourism. This paper focuses on the perception of communication effectiveness and service quality in the context of digital tourism. The main objective is to analyse how selected forms of digital communication and service delivery affect customer perception and whether differences arise between customer segments based on digital literacy and gender. The research was conducted using a questionnaire survey among a sample of 437 respondents from the Slovak Republic. The collected data were statistically processed using the Mann-Whitney U test to verify the hypotheses regarding customer segmentation. The results confirmed that digital literacy significantly influences the perception of communication quality—digitally proficient customers perceive service communication more positively. In contrast, no statistically significant gender differences were found in service satisfaction, neither in product offerings nor in service processes. The findings highlight the importance of tailored digital communication strategies and the potential of more interactive and participative approaches in enhancing customer experience in digital tourism. From the point of view of exploratory behaviour, the exploratory information-seeking dimension turned out to be insignificant. However, the research showed that webroomers prefer exploratory acquisition. The differences between the purchasing channels in terms of other analysed factors also proved to be significant. In all cases, higher tendencies were identified for webrooming. The paper upholds the idea of integrating purchase channels and highlights the need to track the purchase journey of customers who interact with businesses through many different channels and touchpoints, both online and offline. The paper will serve marketers, as a better understanding of customers' purchasing behaviour will help businesses set up more relevant marketing and business strategies, thus improving their market position. Towards the end, the paper presents business recommendations and suggests possibilities for further research.

Keywords: digital communication; digital tourism; service quality; customer segmentation; digital literacy

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1. Introduction

In recent years, the digital transformation of society has profoundly influenced both the structure and delivery of tourism services. The growing accessibility of digital technologies has reshaped how travellers search for information, plan trips, and interact with service providers. As a result, digital communication is no longer a supplementary tool but a core element in managing customer relationships, building trust, and enhancing user experience. At the same time, the concept of service quality remains central to customer satisfaction and loyalty in tourism, yet its perception may vary across user groups with different levels of digital literacy or demographic characteristics. In this context, understanding how various customer segments perceive digital communication and service quality is becoming increasingly relevant for service providers seeking to adapt to diverse user expectations in the digital tourism landscape.

To better understand these dynamics, it is essential to anchor the analysis in relevant theoretical frameworks. The following section provides an overview of key concepts related to digital communication in tourism, perceived service quality, and customer segmentation, which together form the foundation for the empirical part of this study. These frameworks help clarify the interplay between technology adoption and user behaviour in digital environments. By integrating perspectives from communication theory, service management, and consumer psychology, a more holistic view of customer experience in tourism can be achieved. Such a multidisciplinary approach ensures that the study captures both the technological and human dimensions of service delivery.

2. Literature Review

The digitalisation of tourism has introduced complex challenges and opportunities that fundamentally transform how tourism services are delivered, perceived, and consumed. As digital platforms increasingly mediate the interaction between service providers and consumers, traditional paradigms of communication and quality assessment are rendered insufficient. Consequently, there is a growing imperative to reconceptualise these constructs in light of rapidly evolving user behaviours and expectations in virtual environments.

Addressing these dynamics necessitates a multidisciplinary analytical framework, drawing from marketing communication theory, service quality models, and insights from digital consumer behaviour. The tourism sector, shaped by the accelerated adoption of digital technologies, exemplifies the broader societal shift toward platform-mediated experiences, wherein customer perceptions are formed through a complex interplay of online touchpoints, user-generated content, and algorithmically curated interactions. In such a context, service evaluation no longer relies solely on tangible encounters but is increasingly influenced by digital signals, interface design, and information transparency.

This section provides a conceptual overview of three interrelated domains essential for understanding these developments: digital communication in tourism, perceived service quality, and customer segmentation. These theoretical lenses offer a robust foundation for examining the mechanisms through which consumers engage with digital tourism services and for identifying how these interactions vary according to users' digital literacy, expectations, and socio-demographic profiles.

2. Digital Communication in Tourism

Digital technologies have fundamentally changed the way tourism services are presented, perceived, and consumed. Communication between service providers and customers now takes place primarily through online channels such as websites, social media, and mobile applications. As a result, digital communication has gained strategic importance—not only as an informational tool, but also as a means of building trust, transparency, and a positive customer experience (Gretzel et al., 2006; Buhalis & Law, 2008; Aliffianto & Andrianto, 2022; Borrego-Baslalobre el al., 2025).

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However, communication effectiveness is not universal—different customer segments may interpret the same message differently. One of the key factors here is digital literacy, which influences how users search for, process, and act on information (Krajčík et al., 2023). Customers with a higher level of digital competence are typically more responsive to online content, navigate service offerings more easily, and engage more with interactive or visual formats (Tiago et al., 2020; UNWTO, 2022; Li et al., 2021). On the other hand, less digitally skilled users may be more passive, which can lead to lower trust or satisfaction with services.

The digital transformation of society has significantly reshaped the tourism industry, influencing both operational processes and customer expectations. As noted by Stryzhak (2022), the digital economy affects all sectors, with tourism being one of the most impacted. Online platforms such as booking and itinerary services, digital payments, and review systems are now indispensable components of travel-related decision-making. The widespread use of these tools demonstrates not only technological advancement but also a fundamental shift in consumer behaviour (Xiang et al., 2015).

Digital communication, in this context, serves a dual function: it facilitates service delivery and plays a central role in shaping perceptions of quality, brand reliability, and user satisfaction (Gretzel et al., 2006; UNWTO, 2022). According to Hojeghan and Esfangareh (2011), digital infrastructure and communication technologies have evolved from simple marketing tools into drivers of value creation in tourism. This means businesses must design their digital strategies with awareness of how various customer segments—distinguished by age, gender, or digital literacy—interpret and respond to information (Xiang et al., 2015).

Importantly, the level of digital integration is uneven across regions and user groups. As highlighted by Alamoudi et al. (2025), countries with lower economic growth often leverage digitalisation to boost tourism, but access and skills remain key limiting factors (Buhalis & Law, 2008; UNWTO, 2022). Therefore, segmenting users based on digital competencies is essential for personalised and effective communication, as also suggested by Stankov and Gretzel (2020), who emphasise the emerging role of digital well-being as a core component of modern travel experience design.

In summary, digital maturity—both on the side of service providers and their customers—has become a key determinant of satisfaction, perceived value, and loyalty in digital tourism. For providers, this underscores the importance of adaptive strategies that combine technological innovation with accessible, targeted communication to meet the evolving expectations of digitally diverse customer bases (Gretzel et al., 2006; Gretzel, 2022).

3. Perceived Service Quality

In the context of digital tourism, customer segmentation has become an increasingly strategic practice as service providers strive to personalise user experiences across digital platforms. Traditional segmentation models based on basic demographics (e.g., age, gender, income) are no longer adequate to capture the complexity of modern traveller behaviour. The growing integration of digital technologies enables more dynamic segmentation approaches that leverage behavioural, psychographic, and technographic data (Mariani et al., 2018; Dolnicar, 2020; Ben Said et al., 2024; Xu et al., 2024).

Digital environments now generate vast volumes of user-generated content—such as reviews, comments, and ratings—representing a valuable data source for understanding customer preferences. Jardim and Mora (2021) propose a novel sentiment-based segmentation method that clusters digital tourism users based on the polarity of sentiments expressed in their online reviews. This approach, grounded in lexicon-based sentiment analysis and clustering algorithms such as K-Means, enables tourism businesses to identify customer groups with similar emotional responses and tailor services accordingly. For instance, the study by Jardim and Mora demonstrates how tourists' sentiment-based clusters can reveal generational differences in perception. Users aged 18–34 often expressed more positive sentiments toward tourism services, while older segments (e.g., 60–80 years) showed more neutral or negative reactions. This insight allows businesses to adjust their digital strategies and service offerings to engage underrepresented or less satisfied user groups better.

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Advanced segmentation methods also account for varying degrees of digital literacy and technological readiness. As noted by Buhalis & Sinarta (2022) and Wang et al. (2024) digital natives tend to prioritise speed, mobile compatibility, and automation, while older or less tech-savvy users prefer simplicity and human support. Recognising these preferences is crucial for crafting inclusive digital touchpoints and communication styles. Moreover, with the emergence of AI and machine learning technologies, micro-segmentation is becoming a practical reality. These systems dynamically adjust service recommendations, marketing messages, or even interface layouts in real-time based on individual user behaviour (Tussyadiah, 2020; Ghesh et al., 2024). Such adaptive systems reflect a shift from static segmentation to responsive digital ecosystems in tourism.

Sentiment analysis and automated clustering enhance personalisation and improve strategic planning and service design. By capturing the emotional drivers behind user behaviour, tourism providers can proactively redesign underperforming offerings, refine marketing content, and strengthen customer satisfaction and loyalty (Reisenwitz & Fowler, 2019; Jardim & Mora, 2021; Adeniran et al., 2023).

In summary, effective customer segmentation in digital tourism now depends on leveraging real-time user data, advanced clustering techniques, and sentiment-based insights. These tools enable providers to better understand diverse user expectations, customise service delivery, and foster more meaningful engagement throughout the customer journey.

Recent studies have increasingly utilised fuzzy set theory and expert models to address decision-making challenges in tourism and related sectors. For example, Gavurova et al. (2023) proposed a fuzzy decision support model for evaluating healthcare projects, demonstrating fuzzy logic's flexibility in complex prioritisation scenarios. Similarly, Gavurova and Polishchuk (2025a) developed a decision-making support system for travel planning tailored to individuals with disabilities, emphasising inclusivity in tourism services through fuzzy-based personalisation. Their subsequent work (Gavurova & Polishchuk, 2025b) introduced an integrated expert model for assessing tourist safety risks, combining economic and technological criteria to enhance trip security. Other research (Skare et al., 2023a; 2023b; 2023c) has explored fuzzy multicriteria frameworks for evaluating tourism sustainability, infrastructure investments, and tourist satisfaction stratified by social class (Skare et al., 2024). These contributions collectively underscore the growing relevance of hybrid decision-support methodologies – including fuzzy models and AI-driven clustering – in refining tourism analytics and digital service design.

4. Customer Segmentation in Digital Tourism

In the context of digital tourism, customer segmentation has become an increasingly strategic practice as service providers strive to personalise user experiences across digital platforms. Traditional segmentation models based on basic demographics (e.g., age, gender, income) are no longer adequate to capture the complexity of modern traveller behaviour. The growing integration of digital technologies enables more dynamic segmentation approaches that leverage behavioural, psychographic, and technographic data (Mariani et al., 2018; Dolnicar, 2020; Xu et al., 2024).

Digital environments now generate vast volumes of user-generated content—such as reviews, comments, and ratings—representing a valuable data source for understanding customer preferences. Jardim and Mora (2021) propose a novel sentiment-based segmentation method that clusters digital tourism users based on the polarity of sentiments expressed in their online reviews. This approach, grounded in lexicon-based sentiment analysis and clustering algorithms such as K-Means, enables tourism businesses to identify customer groups with similar emotional responses and tailor services accordingly.

For instance, the study by Jardim and Mora demonstrates how tourists' sentiment-based clusters can reveal generational differences in perception. Users aged 18–34 often expressed more positive sentiments toward tourism services, while older segments (e.g., 60–80 years) showed more neutral or negative reactions. This insight allows businesses to adjust their digital strategies and service offerings to engage underrepresented or less satisfied user groups better. Advanced segmentation methods also account for varying digital literacy and technological readiness degrees. As noted by Buhalis & Sinarta (2022) and Wang et al. (2024), digital natives

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Moreover, micro-segmentation is becoming a practical reality with the emergence of AI and machine learning technologies. These systems dynamically adjust service recommendations, marketing messages, or even interface layouts in real-time based on individual user behaviour (Tussyadiah, 2020; Ghesh et al., 2024).

Such adaptive systems reflect a shift from static segmentation to responsive digital ecosystems in tourism. Sentiment analysis and automated clustering enhance personalisation and improve strategic planning and service design. By capturing the emotional drivers behind user behaviour, tourism providers can proactively redesign underperforming offerings, refine marketing content, and strengthen customer satisfaction and loyalty (Reisenwitz & Fowler, 2019; Jardim & Mora, 2021).

In summary, effective customer segmentation in digital tourism now depends on leveraging real-time user data, advanced clustering techniques, and sentiment-based insights. These tools enable providers to better understand diverse user expectations, customise service delivery, and foster more meaningful engagement throughout the customer journey.

5. Methods and Methodology

The aim of the research was to analyse the impact of selected forms of digital communication and service quality on customer perceptions in the context of digital tourism, while also examining whether different customer segments (based on digital literacy and gender) exhibit variations in these perceptions.

The research focused on customers using digital tourism services, with the research sample selected through random sampling. Data collection was conducted via an online questionnaire distributed among respondents within the territory of the Slovak Republic. The collected data were processed using the statistical software Statistica, and the Mann–Whitney U test was employed to test the individual research hypotheses, given the ordinal nature of the variables and the assumed non-parametric distribution of the data. To address the research objective, the following hypotheses were formulated:

H_1: We hypothesise that there are statistically significant differences in the perception of the communication and promotional strategies of digital tourism services based on the level of customers' digital literacy.
H_{2a}: We hypothesise that there are statistically significant differences in customer satisfaction with the product offerings of digital tourism services based on gender.
H_{2b}: We hypothesise that there are statistically significant differences in customer satisfaction with the process-related aspects of service delivery in digital tourism based on gender.

6. Survey Results

The research sample consisted of 437 respondents. The sample size was determined based on a combination of statistical calculations and practical considerations. Considering the total population of Slovakia, approximately 5.4 million inhabitants, the sample size was designed with regard to the desired confidence level and acceptable margin of error. Due to resource constraints and practical challenges associated with data collection, particularly through online surveys, the final number of respondents was set at 437. In constructing the sample, emphasis was placed on ensuring representativeness with respect to key demographic characteristics, such as age, gender, and geographic distribution. A larger proportion of the sample was composed of women, accounting for 313 respondents (71.6%), while men represented a smaller share with 124 respondents (28.4%).

The collected data provide a relevant basis for subsequent analysis in the field of customer segmentation and perception of service quality in digital tourism.

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Effective communication represents a key conduit of information and a critical component of the digital environment. Within the context of this research—focused on the influence of digital communication on customer perceptions in the realm of digital tourism—one of the examined dimensions was the communication strategy. The specific aim of this research question was to determine whether customers perceive information regarding current developments (e.g., offers, services, or changes) as being communicated regularly and reliably.

Table 1. Perception of the Regularity of Information Disclosure

	Frequency	Cumulative Frequency	Relative Frequency (%)	Cumulative Relative Frequency (%)
Definitely yes	112	112	25.51	25.51
Rather yes	213	325	48.52	74.03
I don't know	53	378	12.07	86.10
Rather no	50	428	11.39	97.49
Definitely no	11	439	2.51	100
Total	439	439	100	100

Source: Own processing

The rapid development of digital tourism requires flexible and transparent communication with customers. The results presented in Table 1 indicate that the majority of respondents perceive communication from digital tourism service providers as reliable and consistent, with nearly three-quarters (74.03%) responding positively (somewhat agree or strongly agree). This suggests that the core informational communication practices—such as publishing offers, updates, or service changes—are functioning well and are perceived as effective and transparent. However, the neutral stance of 12.07% of respondents and the negative assessment by 13.9% highlight that not all customers have the same experience regarding information accessibility. This group may include customers with lower levels of digital literacy, who navigate digital environments with less confidence, or those whose specific needs are not addressed by standard communication practices.

Overall, the results indicate a strong foundation in digital communication, but also reveal gaps in the visibility or accessibility of information for certain customer segments. This highlights the need for improvements in the form, frequency, and personalisation of published information, particularly for customers with varying levels of digital literacy.

Effective digital communication, however, cannot be viewed solely through the lens of formally published information. Social media platforms have become a crucial tool in contemporary digital tourism practices, enabling not only rapid content dissemination but also relationship-building with customers through interaction and feedback. In digital tourism, social media plays a key role in reaching and informing customers, as well as shaping their overall perception of the brand and the quality of services provided. At the same time, these platforms serve as spaces for feedback and the sharing of customer experiences. As part of this research, we analysed how customers evaluate the visibility and quality of digital tourism service presentation on social media (see Table 2).

Table 2. Perception of Service Presentation on Social Media

	Frequency	Cumulative Frequency	Relative Frequency (%)	Cumulative Relative Frequency (%)
Definitely yes	78	78	17.77	17.77
Rather yes	185	263	42.14	59.91
I don't know	94	357	21.41	81.32
Rather no	67	424	15.26	96.58
Definitely no	15	439	3.42	100
Total	439	439	100	100

Source: Own processing

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As the data shows, the majority of respondents perceive the presentation of digital tourism services on social media positively – the combination of responses "definitely yes" (17.77%) and "rather yes" (42.14%) accounts for more than 59% of all respondents. A neutral stance of "I don't know" was taken by 21.41% of respondents, which may indicate limited awareness or a more passive approach to following online content. On the opposite end, 15.26% of respondents answered "rather no," and 3.42% expressed a clearly negative view ("definitely no"). Although these figures represent a minority, they highlight the importance of strengthening digital identity and adopting more targeted communication on social media.

In connection with hypothesis H1, we assume that the perception of the quality and frequency of online presentation may differ depending on the level of customers' digital literacy. For this reason, these responses will be analysed using the Mann-Whitney U test to verify the statistical significance of differences between individual segments. At the same time, the results will also be compared by gender, in accordance with hypotheses H2a and H2b, which focus on gender differences in the perception of the product and process aspects of services.

In the service environment, the quality of the final experience is often directly dependent on the quality of the people providing the service. This is especially true in the field of digital tourism, where the customer is frequently in contact with digital representatives of the brand, whether it be customer support, consultants, guides, or other professionals who represent the service provider in the online space. Therefore, our research focused on how customers perceive the involvement of these individuals in their personal development—that is, whether they feel that their digital interaction with the service brings added value also in terms of personal growth (e.g., gaining knowledge, support in decision-making, inspiration), see Table 3 below.

Table 3. Perception of Providers' Influence on Customers' Personal Development

	Frequency	**Cumulative Frequency**	**Relative Frequency (%)**	**Cumulative Relative Frequency (%)**
Definitely yes	44	44	10.02	10.02
Rather yes	150	194	34.17	44.19
I don't know	87	281	19.82	64.01
Rather no	132	413	30.07	94.08
Definitely no	26	439	5.92	100
Total	439	439	100	100

Source: Own processing

The results indicate that only a smaller portion of respondents clearly perceive digital tourism service providers as contributing to their personal development—10.02% responded "strongly agree" and 34.17% "somewhat agree." In contrast, a significant portion of customers expressed uncertainty ("not sure" – 19.82%) or a rather negative perception ("somewhat disagree" – 30.07%, "strongly disagree" – 5.92%). These findings suggest that digital interactions with services are still perceived mainly in functional and informational terms, rather than as developmental or personally inspiring experiences.

In the following analysis, we will examine whether the perceived personal benefit of services is related to the level of customers' digital literacy, as proposed in Hypothesis H1. We will also investigate whether there are differences in evaluations between men and women, which will be analysed under Hypotheses H2a and H2b, focusing on gender differences in the perception of product and process quality in the field of digital tourism.
In addition to examining perceptions of communication and the quality of information provided, our research also focused on the level of customer engagement. User involvement in service activities represents a key element of the modern approach to building relationships between customers and brands. Actively involving customers in the creation or delivery of services can significantly enhance their satisfaction and loyalty. In the context of digital tourism, this may include opportunities to contribute to content creation, recommend products, participate in digital campaigns, or engage in community-driven activities. This part of the research aimed to

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determine the extent to which customers feel that service providers encourage them to take part in such active participation (see Table 4).

Table 4. Perception of Support for Active Participation by Service Providers

	Frequency	Cumulative Frequency	Relative Frequency (%)	Cumulative Relative Frequency (%)
Definitely yes	21	21	4.78	4.78
Rather yes	80	101	18.22	23.00
I don't know	100	201	22.78	45.78
Rather no	161	362	36.67	82.45
Definitely no	77	439	17.55	100
Total	439	439	100	100

Source: Own processing

The results show that customers generally do not feel sufficiently supported to participate actively in digital tourism projects. As many as 36.67% of respondents selected "rather no" and another 17.55% chose "definitely no," which together represent more than half (54.22%) of all responses. Only 18.22% of respondents selected "rather yes," and just *4.78% expressed a clearly positive view ("definitely yes"). The proportion of "I don't know" responses (22.78%) indicates uncertainty or a lack of information provided by the service providers. These findings suggest that digital tourism services could improve their communication and participatory strategies by more actively involving customers in content creation and co-decision-making.

Based on the findings from the descriptive part of the research, we proceeded to test the predefined research hypotheses. The aim was to examine whether certain customer characteristics, such as the level of digital literacy or gender, influence how they perceive the quality of communication and the provision of digital tourism services. In the following section, we present the results of testing hypotheses H1, H2a, and H2b.

The aim of the research hypothesis H1 was to determine whether there are statistically significant differences in the perception of the communication and promotional strategies of digital tourism services based on the level of customers' digital literacy. In the context of digital tourism, digital literacy represents a key factor influencing how customers interact with content, make decisions based on marketing communication, and use digital tools when planning their trips.

The hypothesis was tested based on two questionnaire items. The first focused on whether respondents take into account the form of promotion when choosing a company operating in the tourism sector. The second asked whether respondents would welcome new forms of marketing communication from these companies. Digital literacy was assessed through a self-evaluation item in which respondents rated their ability to use digital tools for planning and booking travel services (see Table 5).

Table 5. Differences in Perception Based on Digital Literacy

Digital Literacy	Description						
	N	AM	Mdn	SD	U	Z	p
Lower level	272	2.80	2.75	.746	11589.0	-8.522	<.001
Higher level	165	3.45	3.50	.748			

Source: own processing

To verify the differences between groups of respondents with lower and higher digital literacy, we used the Mann-Whitney U test, as the analysed variables were ordinal in nature and a normal distribution could not be assumed. The results displayed in Contingency Table 1 confirmed the stated research hypothesis – H1 is

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accepted. It was found that there is a statistically significant difference in the perception of marketing communication between customers with lower and higher levels of digital literacy, $U = 10{,}400.0$, $p < 0.001$. Specifically, we found that customers with a higher level of digital literacy perceive the communication and promotional strategies of digital tourism services significantly more positively (Mdn = 3.50) than respondents with lower digital literacy (Mdn = 2.70).

The aim of research hypothesis H2 was to determine whether there are statistically significant differences in satisfaction with digital tourism services based on the gender of customers. Within this hypothesis, two sub-alternative hypotheses were defined:
H2a: We assume that there are statistically significant differences in customer satisfaction with the product offerings of digital tourism services based on gender.
H2b: We assume that there are statistically significant differences in customer satisfaction with the process-related aspects of service delivery based on gender.

To test the stated hypotheses, we used the Mann-Whitney U test, which was appropriate given the ordinal nature of the data and the assumption of non-normal distribution. Customer satisfaction was assessed in two dimensions: product-related and process-related, with responses from men and women being compared (Table 6).

Table 6. Differences in Satisfaction Based on Customer Gender

Satisfaction Area	Description							
	Gender	**N**	**AM**	**Mdn**	**SD**	**U**	**Z**	**p**
Product Offering	Men	124	2.60	2.40	0.729	17,739.5	-1.408	0.159
	Women	313	2.70	2.60	0.766			
Process Aspects	Men	124	2.64	2.40	0.668	18,230.0	-0.993	0.321
	Women	313	2.72	2.60	0.767			

Source: own processing

Based on the results presented in Table 6, we reject hypothesis H2, as the tests did not show statistically significant differences between men and women. It was found that there is no significant difference in the level of satisfaction between customers of different genders, neither in relation to the product offering ($U = 17{,}739.5$, $p = 0.159$), nor in the process-related aspects of service delivery ($U = 18{,}230.0$, $p = 0.321$). This suggests that both men and women perceive the quality of digital tourism services similarly, with the median level of satisfaction ranging from *Mdn* = 2.40 to 2.60.

7. Discussion

The research results highlight several important findings that reflect the current state of digital tourism services from the customers' perspective. Most respondents perceive providers' communication activities positively, especially regarding information sharing and social media presentation. This trend can be interpreted as evidence that basic informational communication is well-managed and fulfils its role within marketing and service support.

On the other hand, findings related to personal development and customer participation reveal significant gaps. More than half of the respondents stated that they do not feel actively involved in the provider's activities and do not perceive developmental benefits from the services. These results align with broader trends emphasising the need to transform customers from passive recipients into active co-creators of the experience.

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Another significant finding was the confirmation of research hypothesis H1—it was shown that customers' digital literacy has a statistically significant impact on the perception of communication and marketing activities. Digitally proficient respondents evaluated the services more positively, highlighting the need for a differentiated approach in digital communication, including educational and supportive elements for less experienced users.

In contrast, hypothesis H2, which assumed gender-based differences, was not confirmed. This can be interpreted as a positive finding—digital tourism services are perceived consistently regardless of gender differences, which enhances their universality and inclusiveness.

Based on the research results, we recommend that providers of digital tourism services focus on several key areas. First and foremost, it is important to increase customer interactivity and participation—for example, by involving them in content creation, competitions, feedback collection, or community activities. Strengthening participation can also contribute to a greater sense of engagement and brand loyalty. We further recommend placing greater emphasis on the developmental aspect of services, particularly through educational content, personalised recommendations, and decision-making support, all of which can enhance the overall customer experience.

Communication should also be tailored to the digital literacy level of customers. For less proficient users, it is advisable to create simple and intuitive interfaces, tutorials, or chatbots, while more tech-savvy users may benefit from advanced digital solutions such as self-service portals (Duran et al., 2024), gamification, or augmented reality (Song et al., 2024). The results also showed that services are perceived relatively equally regardless of gender, and thus, we recommend maintaining a gender-neutral approach and avoiding stereotypical portrayals in marketing campaigns. Finally, providers should place greater emphasis on regularly collecting feedback and engaging in active two-way communication with customers—through satisfaction surveys or user reviews—which can serve as a valuable tool for continuous service quality improvement.

The research demonstrated that digital communication in the tourism sector has a strong impact on customer satisfaction and engagement, particularly in the context of their digital skills. The findings suggest that the future success of tourism services lies in the combination of high-quality digital infrastructure, targeted content, and active relationship-building with customers. For the future, it is recommended to expand the research by incorporating qualitative methods or applying it in an international context to enable comparisons of digital consumer behaviour across cultures.

Conclusion

The conducted research has provided valuable insights into how customers perceive selected aspects of digital communication and service quality in the context of digital tourism. By analysing both descriptive and inferential data, the study confirmed that effective and consistent communication plays a key role in building customer trust and satisfaction. A majority of respondents positively evaluated the regularity of information dissemination and the visibility of tourism services on social media platforms, which suggests that foundational communication strategies are functioning well.

However, the study also revealed several areas with potential for improvement. Specifically, aspects related to personal development and active customer participation in service-related activities were rated less positively. These findings highlight a gap between basic service delivery and the broader expectations of digitally active users who increasingly seek personalised experiences and opportunities to engage with service providers beyond the transactional level.

A major contribution of this research lies in confirming that the level of digital literacy significantly influences customers' perceptions of communication quality. Respondents with higher digital competence perceived marketing efforts and information strategies more positively than those with lower skills. This supports the need for segmented communication approaches that cater to different levels of digital maturity. On the other hand, the hypothesis regarding gender-based differences (H2) was not supported, indicating that men and women

perceive digital tourism services in a relatively similar way in terms of both product offering and service delivery.

In summary, the research underlines the importance of not only maintaining a solid digital communication presence but also developing strategies that promote co-creation, support personal engagement, and adapt to varying levels of digital skills. The findings may serve as a foundation for future development of inclusive, customer-oriented digital tourism services. Further research could explore qualitative dimensions of user experience or expand into international comparisons to better understand cross-cultural differences in digital tourism consumption.

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