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Environmental sustainability practices and ROA: A configurational analysis of IBEX 35 firms in Energy and Industry & Construction

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Abstract

Background: The transition from voluntary sustainability narratives to more standardised and auditable disclosure requirements in Europe (CSRD/ESRS) has intensified the need for evidence on how observable environmental practices relate to financial outcomes. Persistent disagreement among commercial sustainability ratings, especially on environmental components, reinforces the case for using auditable indicators in sustainability-performance research.

Purpose: This study identifies which configurations of environmental sustainability practices are associated with high financial performance in Spanish IBEX-listed firms, and whether those pathways differ across Energy and Industry & Construction.

Study design: Using hand-collected data from 2023 corporate reports for 15 IBEX-listed firms, we calibrate three environmental conditions, renewable energy share, waste recovery, and EMAS maturity, and apply fuzzy-set Qualitative Comparative Analysis (fsQCA) to examine pathways to high return on assets (ROA).

Findings: No single environmental practice emerges as necessary for high ROA. Sufficiency differs by sector: in Energy, no stable sufficient configuration is retained under the adopted consistency threshold, suggesting ROA is shaped by additional drivers beyond this parsimonious set. In Industry & Construction, two sufficient pathways highlight equifinality: one combines high waste recovery with EMAS maturity despite low renewable share, while the alternative one links high renewable share to high ROA in the absence of both waste recovery and EMAS maturity. These results support a non-additive view within the environmental pillar; social and governance dimensions are outside the scope of the present design.

Limitations/implications: The study is scoped to the environmental pillar and a single fiscal year; future research should extend the design to multi-year panels, incorporate assurance/verification quality, and test broader ESG dimensions as European reporting standards evolve.

Keywords

Environmental sustainability, environmental practices, fsQCA, IBEX 35, ROA, CSRD/ESRS, EU Taxonomy

Introduction

Environmental sustainability has become a strategic cornerstone for companies. This study examines how configurations of environmental practices are associated with financial performance

among Spanish IBEX 35 firms, using fuzzy-set Qualitative Comparative Analysis (fsQCA) to identify sector-specific combinations linked to HIGH ROA (high return on assets). Sustainability responds to regulatory and societal pressures and can also be a source of competitive advantage (Li,

2025), while growing climate concerns have spurred the use of environmental sustainability criteria in reporting and investment frameworks (Hales, 2021). In this study, we focus on the environmental pillar and treat “ESG” as an umbrella term referring to the broader reporting and capital-market context.

The Sustainable Development Goals (SDGs) (ONU, 2015), the Paris Agreement (UNFCCC, 2015) and the European Green Deal (European Commission, 2019) offer a common framework in Europe. IBEX 35 companies report under the Non-Financial Reporting Directive (NFRD) (Parlamento Europeo y Consejo de la Unión Europea, 2014) and, increasingly, the Corporate Sustainability Reporting Directive (CSRD) (Parlamento Europeo y Consejo de la Unión Europea, 2022), which introduces European Sustainability Reporting Standards (ESRS) as mandatory reporting standards. Evidence on whether environmental management improves financial performance is mixed (Orellana et al., 2025). Some practices yield benefits and customer loyalty (Whelan et al., 2021), but implementation can entail short-term costs. Differences by industry, regulation, policy maturity, and stakeholder perceptions help explain this lack of consensus (Roffé & Ignacio González, 2024). In this paper, “financial performance” is operationalized as ROA, a relative indicator that supports cross-firm comparability by relating earnings to the asset base employed.

A key reason for the lack of consensus in the sustainability-performance literature is that environmental outcomes and economic outcomes are often not shaped by single practices in isolation. Firms typically deploy interdependent initiatives (e.g., operational circularity, renewable sourcing, and verified environmental management systems) whose effects may be complementary, contingent, and non-linear. In such settings, additive approaches that estimate independent “net effects” of single indicators can miss conjunctural dynamics, where a practice is only performance-relevant when combined with other practices. This motivates a configurational approach that is able to represent equifinality (more than one configuration may align with the same outcome) and causal asymmetry (the configurations associated with high performance may differ from those associated with low performance).

Commercial environmental ratings (e.g., Bloomberg, Refinitiv) face methodological discrepancies and rely on heterogeneous, self-

reported data, increasing greenwashing risk (Marquis et al., 2016; Berg et al., 2022). Recent evidence shows that disagreement across ESG/environmental rating providers is economically meaningful (valuation/returns effects) and can blur greenwashing signals, reinforcing the case for transparent, directly observable indicators (Hu et al., 2023; Kim & Koo, 2023; Sun et al., 2024; Anselmi & Petrella, 2025). Against this backdrop, this study relies on transparent, report-based indicators that are available for listed firms under the European reporting regime, and it evaluates how their configurations relate to financial performance within sector-specific contexts.

Despite abundant sustainability-performance and ESG-performance research, few studies examine how small sets of core environmental practices combine (rather than add up) to align with stronger financial performance in comparable listed-firm samples. This is the research problem addressed here: whether, within a harmonized European disclosure environment and within environmentally material sectors, distinct combinations of environmental practices are systematically associated with higher ROA, and whether such combinations differ between Energy and Industry & Construction. Our sample covers energy and industrial IBEX 35 firms, high-impact sectors in the low-carbon transition facing strong regulatory and societal scrutiny. We apply fsQCA (Ragin, 2009) to the 2023 disclosures and audited accounts of 15 firms, conducting sector-specific analyses to preserve comparability within each sector.

The article combines a theoretical and sectoral lens drawing on the resource-based view and institutional/stakeholder perspectives to explain why observable environmental practices may (or may not) translate into financial performance under the European disclosure regime (Barney, 1991; Hart, 1995; Susen & Etter, 2024). Organizational change, potentially involving culture, leadership, and stakeholder engagement, is used as an interpretive lens in the Discussion, while the empirical model relies on auditable environmental practice indicators. In this framing, organizational culture is treated as an enabling condition: a sustainability-oriented culture can support the implementation consistency, internal coordination, and credibility of environmental initiatives, which may in turn shape their association with financial performance. Accordingly, culture is discussed as a contextual driver that can help explain why

comparable environmental practices may not translate into comparable outcomes across firms. Importantly, we do not model organizational culture as a separate fsQCA condition in this study. Given the small-N configurational design and the goal of relying on auditable, comparable indicators, culture is treated as an interpretive mechanism. We partially capture the institutionalization of environmental routines through EMAS_MAT (environmental management and verification maturity), and we use the culture lens in the Discussion to interpret heterogeneity in the observed practice–performance associations.

The paper is structured as follows: Section 1 reviews the literature and research questions; Section 2 outlines the regulatory context; Section 3 details data, QCA rationale, and calibration; Section 4 presents results; Section 5 discusses the findings; Section 6 concludes; and Section 7 outlines limitations and future research.

1. Theoretical framework

1.1. Environmental sustainability

Environmental sustainability has become a core pillar of corporate strategy, especially in resource-intensive sectors such as energy and industry (Ji et al., 2019). It entails the efficient use of natural resources to minimize ecological impact, commonly tracked through indicators of CO₂ emissions, energy and water consumption, waste generation, and the use of sustainable raw materials. Adoption and monitoring of these indicators are guided by widely recognized frameworks, including the United Nations Global Compact, ISO 14001 environmental management systems (ISO, 2015; Zubeltzu-Jaka et al., 2024; Valero-Gil et al., 2024; Benzidia et al., 2025), the Carbon Disclosure Project (CDP) recommendations, and the SDGs, which increasingly shape corporate objectives and reporting practices. In Europe, environmental performance is disclosed through sustainability reports and NFIS mandated by the NFRD and reinforced by the CSRD (Leal Filho et al., 2025). These directives, applicable to listed companies such as those in the IBEX 35, require transparency and alignment with internationally recognized standards, while the requirements for independent external assurance were more heterogeneous under the NFRD, depending on member-state transposition and national implementation (Kotsantonis et al., 2016; Parlamento Europeo y

Consejo de la Unión Europea, 2022, 2014). The CSRD strengthens this framework and progressively makes assurance more systematic and mandatory across the EU (Parlamento Europeo y Consejo de la Unión Europea, 2022). Together, these elements embed environmental sustainability into corporate governance and strategy, turning it from an isolated set of practices into a systematized management approach. Within the EU sustainable finance package, the EU Taxonomy has also shaped how firms classify and communicate environmentally sustainable activities (Tonnarello et al., 2025; Brabec & Macháč, 2025).

1.2. Relationship between environmental sustainability and financial performance

The link between environmental sustainability and corporate financial performance has been debated for decades. Early views framed environmental initiatives primarily as a cost imposed by regulatory pressure and stakeholder demands, with a presumed negative impact on margins. Subsequent evidence paints a more complex picture, and one that can be favourable, suggesting that environmental initiatives may support risk management, process efficiency, reputational capital, and market differentiation (Orlitzky et al., 2003; Wu, 2023). Yet the empirical record remains mixed (Corrales-Cano & Gómez-Zapata, 2023). Some studies show that firms with greater potential for improvement capture outsized gains from adopting sustainable practices (Chaihuaque, 2021), while others find no direct effect of Corporate Social Responsibility (CSR) on financial outcomes unless mediated by factors such as explicit environmental strategies, eco-innovation, or operational capabilities (Surroca et al., 2010). These discrepancies point to strong contextual contingencies: sector dynamics, regulatory regime, company size, and competitive intensity all shape whether and how sustainability investments pay off.

Overall, a proactive and strategically integrated approach appears more likely to yield financial benefits, especially when environmental objectives are embedded in core processes rather than treated as peripheral compliance tasks. At the same time, an institutional and critical lens cautions that some commitments may be largely symbolic responses to external expectations, disconnected from substantive operational change. Distinguishing genuine transformation from superficial adaptation is therefore essential, both analytically and in practice, to understand when environmental

initiatives translate into superior financial performance and when they primarily serve legitimacy.

1.3. Sustainable organizational culture: strategic conversation

Organizational culture is central to translating environmental ambition into performance. In Denison's model, culture comprises shared practices, beliefs, and values that shape organizational effectiveness (Denison, 1990). A sustainability-oriented culture engages employees in environmental goals, aligns systems and incentives with ecological performance, anticipates regulatory shifts, and embeds environmental protection into the organization's mission. Rather than a stand-alone program, sustainability becomes a cross-cutting strategic conversation that reaches all levels and functions (Hart, 1995). Senior leadership plays a catalytic role: articulating a coherent vision that links financial and environmental objectives, allocating resources, ensuring regulatory compliance, and stewarding corporate reputation, thereby creating opportunities for long-term competitive advantage (Rojo-Suárez et al., 2024).

However, culture is difficult to observe directly with consistent, auditable indicators across firms, and small-N configurational designs require parsimony. Therefore, we do not operationalize culture as a standalone condition in the fsQCA model. Instead, we treat sustainability-oriented culture as an enabling mechanism that supports the routinization, coordination, and credibility of environmental initiatives (Hu et al., 2023; Sneideriene & Legenzova, 2025). In empirical terms, we focus on observable manifestations of such institutionalization: renewable energy deployment (REN_SHARE), operational circularity outcomes (WASTE_REC), and the maturity of formal environmental management and verification systems (EMAS_MAT), which captures the degree to which environmental practices are embedded in management routines and externally validated.

1.4. From the Triple Bottom Line (TBL) to institutional theory

Multiple theoretical perspectives inform the sustainability–performance nexus. TBL framework (Elkington, 1997) broadens corporate success metrics to include environmental and social dimensions, encouraging firms to evaluate outcomes beyond traditional financial indicators

(García-Sánchez et al., 2020; Orlitzky et al., 2003). Recent scholarship emphasizes the strategic integration of the SDGs and the institutionalization of non-financial reporting as levers to embed sustainability into decision making (Adams, 2017; Leal Filho et al., 2025).

From the resource-based view (RBV), environmental capabilities, such as pollution prevention routines, clean-tech know-how, and stakeholder engagement processes, can be valuable, rare, and hard to imitate, thereby supporting sustained competitive advantage (Hart, 1995). Complementing this, Stakeholder Theory highlights that proactively addressing stakeholder expectations may reduce conflict, secure critical resources, and enhance financial outcomes (Donaldson & Preston, 1995; Freeman, 2010). Institutional Theory explains why firms converge on sustainability practices: coercive, normative, and mimetic pressures encourage adoption to gain legitimacy and meet evolving regulatory and societal norms (DiMaggio & Powell, 1983; Meyer & Rowan, 1977). In practice, these perspectives are not mutually exclusive; they illuminate how sustainability can be simultaneously a source of innovation and efficiency (RBV), a response to stakeholder claims, and a reflection of institutionalized expectations.

Building on these literatures, we adopt a configurational approach that recognizes complexity, equifinality (multiple paths to similar outcomes), and conjunctural causation (outcomes emerging from combinations of conditions rather than single factors). QCA is well suited to uncover such patterns, allowing us to examine how specific bundles of environmental practices align with high financial performance (ROA) across different contexts.

Building on the above literature, we address the gap in understanding how configurations of environmental practices relate to financial success. The following research questions (RQ) are formulated to guide the analysis:

- RQ1: Are there differences in the combinations of environmental practices associated with high ROA between the energy and industrial industries?
- RQ2: Which environmental conditions appear most frequently in the sufficient configurations retained under the adopted consistency criterion (if any are retained) in each sector?
- RQ3: What sufficient configurations (if any) of environmental practices are

associated with high ROA in IBEX 35 companies in the Energy and Industry & Construction sectors under the adopted calibration and consistency criteria?

2. Regulatory framework

Environmental reporting by large European companies is shaped by an evolving regime that seeks greater transparency and comparability. For the period relevant to this study (reporting year 2023), Spanish listed firms fell under the NFRD (Parlamento Europeo y Consejo de la Unión Europea, 2014). In Spain, Law 11/2018 (Gobierno de España, 2018) implemented the NFRD by requiring public-interest entities, such as IBEX 35 companies, to publish annual NFIS covering environmental, social, and governance topics. The NFRD permitted use of internationally accepted standards, notably the Global Reporting Initiative (GRI), which many IBEX 35 firms have historically adopted to structure sustainability disclosures and key environmental indicators.

Looking ahead, the CSRD substantially expands the scope and depth of sustainability reporting and strengthens requirements related to standardisation and assurance. The European Sustainability Reporting Standards are set out in the Commission Delegated Regulation (EU) 2023/2772 (European Commission, 2023), which specifies detailed disclosure requirements intended to enhance consistency, materiality assessment, and auditability. Although these standards were adopted in 2023, their application is phased in across reporting cycles starting with financial years after 2023 for the first wave of in-scope undertakings.

This regulatory evolution is complemented by the European Green Deal (European Commission, 2019), which anchors the EU’s climate-neutrality ambition and drives related measures in sustainable finance and industrial policy. Among these, the EU Taxonomy Regulation (Regulation (EU) 2020/852) (European Parliament and Council of the European Union, 2020) defines criteria for environmentally sustainable economic activities, shaping corporate strategy and investor expectations and reinforcing demand for robust, decision-useful sustainability information.

Against this backdrop, our study employs indicators and criteria largely consistent with GRI and other established frameworks for two pragmatic reasons. First, the 2023 data analysed were prepared under the NFRD regime, frequently using GRI Standards, enabling comparability

across IBEX 35 firms. Second, while ESRS promises greater standardization, it was not yet in force for the period studied. Using GRI-aligned metrics therefore grounds our analysis in actually disclosed information while remaining coherent with the NFIS content required by NFRD/CSRD. We acknowledge that ESRS will likely supersede GRI in the European context; future research should incorporate ESRS-based datasets as they become available, but for this study the chosen approach best reflects the regulatory and reporting realities of 2023.

3. Methodology

This study uses a configurational approach to examine how bundles of environmental practices relate to financial performance among IBEX 35 firms. The underlying idea is that environmental practices are often implemented as complementary packages, which makes fuzzy-set Qualitative Comparative Analysis (fsQCA) suitable. fsQCA models graded set-memberships and allows the exploration of alternative configurations linked to the same outcome (equifinality), while also accommodating potential differences between the drivers of high and low performance (causal asymmetry).

The unit of analysis is the firm. The sample includes 15 IBEX 35 firms split into two sectors: Energy (N=9) and Industry & Construction (N=6). To facilitate traceability, cases are referenced using anonymized codes (EN1–EN9 and IND1–IND6). Table 1 shows the sample structure and the case-coding scheme.

Table 1 Sample and case coding (N=15)

Sector	Code	Cases
Energy (N=9)	EN	EN1–EN9
Industry & Construction (N=6)	IND	IND1–IND6

Source: the authors

These sectors were selected to ensure within-sector comparability and environmental materiality. Both sectors are closely related to key sustainability dimensions (energy transition, circularity, and management/verification systems), which provides meaningful variation in environmental practices within each sector. Analyses are conducted by sector to limit structural heterogeneity associated with business models and asset structures, and to keep comparisons coherent.

The analysis focuses on fiscal year 2023, ensuring temporal alignment between the environmental practices reported and the financial performance measured, and avoiding cross-year mixes where reporting and verification criteria may vary. The study relies on audited consolidated financial statements and corporate disclosures published for the same year.

Financial performance is operationalized through ROA (Return on Assets). ROA is appropriate for cross-firm comparisons because it relates earnings to the asset base employed. The outcome is HIGH_ROA, defined as graded membership in the set of firms with “high ROA”, rather than a binary classification.

$$ROA = \frac{Net\ income}{Total\ assets} \times 100$$

Condition selection balances substantive relevance, comparability, and empirical feasibility in a configurational design. Priority is given to proportional indicators (less dominated by firm scale), complemented by an ordinal indicator capturing environmental verification/management maturity. The final specification uses three conditions per sector, which supports interpretability and limits the proliferation of uninformative combinations. Organizational culture is conceptualized as a latent enabling context rather than a measured condition in this design. EMAS_MAT is included as an observable indicator of management-system institutionalization and verification maturity, which is closely related to the embedding of environmental routines within the organization. Table 2 summarizes the operationalization of the outcome and conditions.

Table 2 Model variables and operationalization

Type	Variable	Definition / raw measure	Data type
Outcome	HIGH_ROA	ROA 2023 (%) → fuzzy membership	Continuous
Condition	REN_SHARE	% renewable energy	Continuous (%)
Condition	WASTE_REC	% waste recovered	Continuous (%)
Condition	EMAS_MAT	EMAS status: no / partial / yes	Ordinal

Source: the authors

Calibration transforms raw measures into fuzzy memberships (0–1) using the direct method with

three anchors: full non-membership (0.05), crossover (0.50), and full membership (0.95). For sector coherence, anchors for continuous variables are set using the sector-specific empirical distribution for 2023 (P25, median, P75). The ordinal condition EMAS_MAT is calibrated directly (0 = no EMAS; 0.67 = partial/limited EMAS; 1 = full EMAS). Table 3 reports the anchors used.

Table 3 Calibration anchors (P25 / median / P75) by sector (2023)

Sector	Variable	Full-out (0.05)	Crossover (0.50)	Full-in (0.95)
Energy (N=9)	REN_SHARE (%)	42.0	71.00	96.6
	WASTE_REC (%)	75.0	92.50	95.8
	HIGH_ROA (%)	3.20	4.03	5.14
Industry & Construction (N=6)	REN_SHARE (%)	22.9	32.00	47.5
	WASTE_REC (%)	69.6	79.88	86.0
	HIGH_ROA (%)	3.98	4.97	5.87
		Low	Medium	High
Both (assigned membership scores)	EMAS_MAT	0	0.67	1

Source: the authors
EMAS_MAT is an ordinal indicator calibrated by direct assignment (0, 0.67, 1), not by percentile-based anchors

If a value is not available for a given condition in a specific case, its membership score is treated as missing only in the analyses that include that condition. Raw values are reported in Appendix 1, and calibrated membership scores in Appendix 2.

For instance, WASTE_REC is missing for EN8 (Energy), so Energy analyses involving WASTE_REC use an effective N=8 for that condition.

Based on calibrated memberships, sector-specific truth tables are constructed to identify configurations sufficient for HIGH_ROA. A minimum frequency of 1 per configuration is applied, with a consistency threshold in the 0.80-0.85 range. Consistency and coverage (raw and unique) are reported. Solutions are obtained using Quine–McCluskey minimization in fsQCA 3.1, reporting intermediate and parsimonious solutions.

Necessity analysis was conducted prior to sufficiency assessment by sector, reporting necessity consistency and coverage for each condition (REN_SHARE, WASTE_REC, EMAS_MAT). Following common practice, conditions were considered potentially necessary only if necessity consistency approached high levels (≈ 0.90). As reported in Appendix 3, none of the single conditions reaches this benchmark; therefore, we do not identify any necessary environmental practice for HIGH_ROA under the current specification.

To illustrate causal asymmetry, we also conducted a mirror sufficiency assessment using the negated outcome ($\sim$ HIGH_ROA; i.e., $LOW_ROA = 1 - m(HIGH_ROA)$) with the same condition set, calibration, and consistency criteria. The observed configurations and their metrics for LOW_ROA are reported in Appendix 4.

4. Results

This section reports, for each sector, the environmental configurations associated with HIGH_ROA (high return on assets, expressed as fuzzy scores between 0 and 1). Using the calibrated scores (Appendix 2), a sector-specific truth table was constructed. For each row (configuration), we report sufficiency consistency (the extent to which the configuration behaves as a subset of HIGH_ROA) and coverage (the share of HIGH_ROA explained by the configuration). For readability, configurations are displayed in Boolean form (presence/absence) using an operational 0.5 threshold.

The Table 4 presents the observed configurations in each sector and their main metrics (frequency, consistency, and coverage), together with an indicator of whether they meet the adopted selection criterion (consistency ≥ 0.80).

Table 4 Observed configurations and sufficiency metrics (fsQCA, by sector)

Sector	Configuration	Frequency (X>0.5)	Consistency	Coverage (raw)	Selected (≥ 0.80)
Energy	$\sim$ REN_SHARE * WASTE_REC * $\sim$ EMAS_MAT	3	0.73	0.49	No
Energy	REN_SHARE * $\sim$ WASTE_REC * EMAS_MAT	1	0.57	0.19	No
Energy	$\sim$ REN_SHARE * $\sim$ WASTE_REC * EMAS_MAT	1	0.53	0.16	No
Energy	REN_SHARE * WASTE_REC * $\sim$ EMAS_MAT	1	0.36	0.13	No

Energy	REN_SHARE * $\sim$ WASTE_REC * $\sim$ EMAS_MAT	1	0.31	0.12	No
Industry & Construction	$\sim$ REN_SHARE * WASTE_REC * EMAS_MAT	1	1.00	0.17	Yes
Industry & Construction	REN_SHARE * $\sim$ WASTE_REC * $\sim$ EMAS_MAT	3	0.80	0.65	Yes
Industry & Construction	$\sim$ REN_SHARE * WASTE_REC * $\sim$ EMAS_MAT	2	0.15	0.11	No

In fsQCA, 0.5 represents the crossover point (maximum ambiguity), indicating neither membership nor non-membership in a set. Therefore, when reporting truth-table frequencies and case membership in configurations, we follow standard practice and count/list only cases with configuration membership **greater than 0.5**. Cases scoring exactly **0.5** are treated as crossover and are not considered as supporting either the presence or the negation of a condition in the case listings.

Source: the authors

Because traceability matters in small-N designs, the Table 5 lists the case codes supporting each configuration and provides additional diagnostic indicators (PRI and ΣX) that complement the main table. We use sufficiency consistency (≥ 0.80) as the primary inclusion criterion for selecting configurations. PRI is reported as a diagnostic of whether a configuration is more consistent with HIGH_ROA than with its negation; given the small-N setting and the aim of transparency, we do not impose a hard PRI cutoff, but interpret configurations with modest PRI more cautiously.

Table 5 Case traceability and additional diagnostics by configuration (PRI and ΣX)

Sector	Configuration	Cases (codes)	PRI	ΣX (empirical relevance)
Energy	$\sim$ REN_SHARE * WASTE_REC * $\sim$ EMAS_MAT	EN3, EN6, EN9	0.51	2.33
Energy	REN_SHARE * $\sim$ WASTE_REC * EMAS_MAT	EN7	0.17	1.17
Energy	$\sim$ REN_SHARE * $\sim$ WASTE_REC * EMAS_MAT	EN4	-0.77	1.11
Energy	REN_SHARE * WASTE_REC * $\sim$ EMAS_MAT	EN2	-1.20	1.32
Energy	REN_SHARE * $\sim$ WASTE_REC * $\sim$ EMAS_MAT	EN5	-1.54	1.38
Industry & Construction	$\sim$ REN_SHARE * WASTE_REC * EMAS_MAT	IND3	0.40	0.51
Industry & Construction	REN_SHARE * $\sim$ WASTE_REC * $\sim$ EMAS_MAT	IND1, IND4, IND5	0.72	2.46
Industry & Construction	$\sim$ REN_SHARE * WASTE_REC * $\sim$ EMAS_MAT	IND2, IND6	-4.68	2.22

Source: the authors

In Energy (N=9), none of the observed configurations reaches the sufficiency threshold

(consistency ≥ 0.80). The best-fitting row is $\sim\text{REN_SHARE} * \text{WASTE_REC} * \sim\text{EMAS_MAT}$ (consistency=0.73; coverage=0.49), but it remains below the selected criterion. Accordingly, for this sector the results do not allow the identification of “sufficient recipes” under a strict consistency standard using these three conditions. This constitutes an informative null result for the Energy sector under the current specification. Because no configurations are retained as sufficient (consistency ≥ 0.80), RQ2 cannot be assessed for Energy in terms of “frequently appearing conditions” within sufficient recipes, and RQ3 yields no stable sufficient configuration under the current condition set. The best-fitting row ($\sim\text{REN_SHARE} * \text{WASTE_REC} * \sim\text{EMAS_MAT}$; consistency=0.73; coverage=0.49) is reported descriptively as the closest empirical pattern, but it remains below the adopted sufficiency threshold.

In Industry & Construction (N=6), two configurations meet the sufficiency criterion for HIGH_ROA (consistency ≥ 0.80). Based on these rows, minimization does not further reduce terms (with three conditions, the pattern is already compact), so the intermediate solution coincides with the two selected configurations. In the Table 6, we report these configurations along with their fit metrics and the supporting cases.

Table 6 Sufficient configurations for HIGH_ROA in Industry & Construction (intermediate solution)

Configuration (intermediate solution)	Frequency (X>0.5)	Cases	Consistency	PRI	Coverage (raw)
$\sim\text{REN_SHARE} * \text{WASTE_REC} * \text{EMAS_MAT}$	1	IND3	1.00	0.40	0.17
$\text{REN_SHARE} * \sim\text{WASTE_REC} * \sim\text{EMAS_MAT}$	3	IND1, IND4, IND5	0.80	0.72	0.65

Source: the authors

At the solution level (the fuzzy union of the terms), the Industry & Construction solution reaches consistency=0.836 and coverage=0.827. Descriptively, the first configuration combines a low renewable share with high waste recovery and higher EMAS maturity, whereas the second combines a high renewable share with low waste recovery and lower EMAS maturity. In this section we report these patterns as configurational results; their substantive interpretation is developed in the Discussion.

4.1 Sensitivity analysis (robustness)

Robustness was assessed through reasonable variations in two elements of the procedure: the

calibration anchors (alternative percentiles) and the consistency threshold used to retain sufficient rows. Accordingly, three sensitivity scenarios were considered. The baseline specification uses sector-specific anchors (P25/Median/P75) and a consistency cutoff of 0.80. Scenario S1 keeps the same cutoff (0.80) but applies alternative sector-specific anchors (P20/Median/P80). Scenario S2 retains the baseline anchors (P25/Median/P75) and increases the consistency cutoff to 0.85.

In the Table 7, we report, by sector, whether the retained configurations change across scenarios and how the main fit indicators (consistency and coverage) are affected.

Table 7 Sensitivity analysis summary (robustness diagnostics)

Scenario	Energy: effect on solutions	Industry & Construction: effect on solutions
Base	No sufficient configurations retained (best row: $\sim\text{REN_SHARE} * \text{WASTE_REC} * \sim\text{EMAS_MAT}$; consistency = 0.739; coverage = 0.494)	Two sufficient configurations retained: $\sim\text{REN_SHARE} * \text{WASTE_REC} * \text{EMAS_MAT}$ and $\text{REN_SHARE} * \sim\text{WASTE_REC} * \sim\text{EMAS_MAT}$ (solution consistency = 0.836; coverage = 0.827; no change in terms)
S1	No sufficient configurations retained (best row: $\sim\text{REN_SHARE} * \text{WASTE_REC} * \sim\text{EMAS_MAT}$; consistency = 0.745)	Same two configurations retained; fit changes slightly (solution consistency = 0.844; coverage = 0.817; no change in terms)
S2	No sufficient configurations retained (best row remains below cutoff: consistency = 0.739)	Only $\sim\text{REN_SHARE} * \text{WASTE_REC} * \text{EMAS_MAT}$ retained; the second term is dropped (solution consistency = 1.000; coverage = 0.171)

Source: the authors

Overall, the sensitivity analysis suggests that, for Industry & Construction, the structure of the solution is stable under moderate changes in calibration anchors (Base vs. S1), with only small shifts in fit. When a more stringent consistency cutoff is applied (S2), the solution becomes more restrictive: only the perfectly consistent term is retained, and coverage decreases accordingly. For Energy, no sufficient configurations are retained under the baseline or alternative-anchor specifications, and the best-performing row remains below the sufficiency threshold, indicating weaker configurational evidence for HIGH_ROA within the current condition set.

5. Discussion

This study adopts a configurational perspective to examine how bundles of environmental practices are associated with higher financial performance (HIGH_ROA). This approach is particularly suitable in corporate sustainability research

because environmental practices rarely operate in isolation. Firms typically implement interdependent initiatives that can reinforce each other or, in some cases, act as substitutes. A configurational lens therefore helps describe how different combinations align with performance within a given sectoral and institutional setting.

The results differ by sector. In Energy, none of the observed configurations reaches the sufficiency threshold under the selected condition set. This absence of retained sufficient configurations is substantively meaningful: it suggests that, under the current condition set and strict consistency criterion, high ROA in Energy is not consistently aligned with any stable environmental “recipe,” making the identification of recurrent conditions within sufficient configurations (RQ2) not applicable for this sector. This does not imply that environmental practices are unrelated to financial outcomes. Rather, it indicates that, in this subsample and year, HIGH_ROA is not consistently aligned with a stable bundle defined by renewable energy share, waste recovery, and EMAS maturity. A plausible interpretation is that the Energy sector combines heterogeneous operating profiles and additional performance drivers that are not captured by the parsimonious model, which may limit the emergence of sufficiently consistent “recipes” for HIGH_ROA.

In Industry & Construction, two sufficient configurations are identified. Their coexistence illustrates equifinality: different environmental bundles can be compatible with higher ROA within the same sectoral setting. Interpreting this equifinality through the culture lens, the pathway combining high waste recovery with EMAS maturity (despite low renewable share) is consistent with a more institutionalized, routinized approach to environmental management, i.e., practices embedded in systems, audits, and operational discipline. By contrast, the alternative pathway in which high renewable share aligns with high ROA in the absence of both waste recovery and EMAS maturity suggests a more “structural” route, potentially driven by energy sourcing choices or asset mix rather than deep internalization. This interpretation is consistent with our conceptualization of culture as an enabling mechanism rather than a modelled condition. This contrast reinforces our argument that environmental outcomes can be achieved through different logics, and that the role of internal embedding (culture/routines) may vary across pathways.

One configuration emphasizes operational circularity and verified environmental management, while the other canters on renewable energy share with weaker alignment on the other two dimensions. The key implication is not that one bundle is “better,” but that high-performing cases may align with different combinations depending on materiality, governance choices, and implementation sequencing.

The mirror analysis for LOW_ROA (Appendix 4) yields different sufficient patterns than those associated with HIGH_ROA, supporting the causal asymmetry logic motivating the configurational approach.

The sensitivity checks support a cautious reading. In Industry & Construction, the solution structure remains stable under moderate shifts in calibration anchors, with only small changes in fit. When the consistency cutoff is raised, the solution becomes more restrictive and coverage decreases as expected. In Energy, the absence of sufficient configurations persists across tested specifications, indicating weaker configurational evidence for HIGH_ROA within the current condition set.

From a managerial standpoint, the findings support a bundle-based view of environmental strategy. Rather than relying on isolated “best practices,” firms may align environmental actions with operational realities and governance arrangements. At the same time, the absence of stable configurations in Energy suggests that sector-specific diagnostics are needed before drawing prescriptive conclusions.

Conclusions

This study contributes to the sustainability–financial performance literature by applying fsQCA to assess how combinations of environmental practices are associated with higher ROA in a comparable set of IBEX 35 firms. The findings are sector-specific. In Energy, no sufficient configuration emerges under the selected condition set, indicating limited configurational regularities within this model. In Industry & Construction, two sufficient configurations are identified, highlighting equifinality and the relevance of bundle-based interpretations. Overall, the results suggest that environmental strategy is better approached as a set of interdependent practices whose alignment with financial performance depends on sector context, governance arrangements, and implementation choices.

Limitations and future research

This study has several limitations. First, it focuses on a single year (2023), which limits the ability to capture dynamics, lagged effects, and temporal shifts in reporting practices. Second, the case base is small ($N=15$) and split by sector, so the results should be interpreted as configurational evidence within the sample rather than as generalizable sector-wide claims. Third, the model is intentionally parsimonious (three conditions) to preserve interpretability and avoid overfitting, but this may omit relevant environmental dimensions, particularly for Energy. Fourth, environmental indicators may differ across firms in measurement boundaries, assurance levels, and disclosure choices, which can introduce noise even among highly visible listed companies. Fifth, we do not directly measure sustainability-oriented culture or leadership processes; future research could incorporate explicit culture proxies (e.g., validated textual measures or mixed-method case evidence) and examine how cultural embedding moderates the practice-performance relationship.

Future research can extend this design in several ways. A natural step is to increase the number of cases by adding years and/or comparable firms, which would support more stable truth tables and stronger cross-case patterns. Researchers may also test alternative financial outcomes (e.g., ROS or ROE) and incorporate intensity-based environmental indicators where feasible. Finally, mixed-method follow-ups (e.g., focused case comparisons or expert-informed validation of specific bundles) could help explain why different configurations emerge within the same sector.

Declarations

Availability of data and materials

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Appendices

Appendix 1. Raw values by case (2023)

Case	ROA (%)	REN_SHARE (%)	WASTE_REC (%)	EMAS status
EN1	1.71	71.00	77.00	yes
EN2	3.57	97.00	97.00	no
EN3	1.80	42.00	93.00	no
EN4	4.03	13.46	92.00	yes
EN5	3.20	96.60	69.00	no
EN6	5.24	37.00	95.40	no
EN7	5.14	91.00	40.00	partial
EN8	6.52	100.00		no
EN9	4.76	61.10	98.40	no
IND1	3.74	37.00	79.76	no
IND2	2.14	3.14	88.00	no
IND3	5.22	27.00	80.00	yes
IND4	6.08	68.53	66.30	no
IND5	12.92	51.00	47.50	no
IND6	4.71	21.55	97.00	no

Appendix 2. Calibrated set-membership scores by case (2023)

Case	m(HIGH_ROA)	m(REN_SHARE)	m(WASTE_REC)	m(EMAS_MAT)	HIGH_ROA (>0.5)	REN_SHARE (>0.5)	WASTE_REC (>0.5)	EMAS_MAT (>0.5)
EN1	0.000	0.500	0.069	1.000	0	C	0	1
EN2	0.164	0.952	0.982	0.000	0	1	1	0
EN3	0.000	0.050	0.610	0.000	0	0	1	0
EN4	0.500	0.003	0.479	1.000	C	0	0	1
EN5	0.050	0.950	0.019	0.000	0	1	0	0
EN6	0.961	0.031	0.930	0.000	1	0	1	0
EN7	0.950	0.909	0.000	0.670	1	1	0	1
EN8	0.999	0.966		0.000	1	1		0
EN9	0.874	0.268	0.995	0.000	1	0	1	0
IND1	0.025	0.721	0.491	0.000	0	1	0	0
IND2	0.000	0.000	0.980	0.000	0	0	1	0
IND3	0.694	0.165	0.514	1.000	1	0	1	1
IND4	0.974	0.999	0.020	0.000	1	1	0	0
IND5	1.000	0.974	0.000	0.000	1	1	0	0
IND6	0.316	0.033	1.000	0.000	0	0	1	0

“C” denotes the **crossover point** in fsQCA ($m = 0.500$), i.e., maximum ambiguity: the case is classified as neither a member nor a non-member of the set. In the coded columns, we assign **1** when $m > 0.5$, **0** when $m < 0.5$, and **C** when $m = 0.5$. Blank cells indicate **missing data** (not available values).

Appendix 3. Necessary condition analysis for HIGH_ROA (by sector)

Sector	Condition	N	Necessity consistency	Necessity coverage
Energy	REN_SHARE	9	0.532	0.517
Energy	WASTE_REC	8	0.705	0.604
Energy	EMAS_MAT	9	0.260	0.438
Industry & Construction	REN_SHARE	6	0.722	0.751
Industry & Construction	WASTE_REC	6	0.291	0.291
Industry & Construction	EMAS_MAT	6	0.231	0.694

Necessity consistency values are well below commonly used “necessity” benchmarks (≈ 0.90), indicating that no single condition is necessary for HIGH_ROA in either sector

Appendix 4. Mirror sufficiency analysis for ~HIGH_ROA (LOW_ROA), by sector

Sector	Configuration	Frequency (X>0.5)	Consistency	Coverage (raw)	Selected (≥0.80)
Energy	~REN_SHARE * ~WASTE_REC * EMAS_MAT	1	0.944	0.233	Yes
Energy	REN_SHARE * WASTE_REC * ~EMAS_MAT	1	0.805	0.236	Yes
Energy	REN_SHARE * ~WASTE_REC * ~EMAS_MAT	1	0.798	0.245	No
Energy	REN_SHARE * ~WASTE_REC * EMAS_MAT	1	0.471	0.123	No
Energy	~REN_SHARE * WASTE_REC * ~EMAS_MAT	3	0.360	0.187	No
Industry & Construction	~REN_SHARE * WASTE_REC * ~EMAS_MAT	2	0.873	0.650	Yes
Industry & Construction	~REN_SHARE * WASTE_REC * EMAS_MAT	1	0.595	0.102	No
Industry & Construction	REN_SHARE * ~WASTE_REC * ~EMAS_MAT	3	0.217	0.179	No

Students' perception of the importance of soft skills in the business context of Hungary and Serbia

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Abstract

Background: Soft skills have a considerable influence on the personal and professional development of future employees, affecting employment opportunities and work success.

Purpose: The aim of the empirical analysis described in this paper is to define the groups of key soft skills in the business context of Hungary and Serbia. The obtained results aid the creation of a unique methodology in soft skills teaching and assessment at the universities of these neighbouring countries with a high potential for mutual transfer of students and workforce.

Study design/methodology/approach: Authors performed factor analysis and Spearman's correlation on a sample of 906 students during 2023 from the Budapest Business University, Hungary and from the University of Novi Sad, Serbia.

Findings/conclusions: Based on the obtained results, it was determined that there are three groups of skills most crucial for the employer. The group of business agility skills includes leadership, entrepreneurial, team and time management skills. People skills are: IT skills, language skills, empathy, appearance, ethical and moral skills, presentation skills. The group of innovative thinking skills includes: strategic thinking, creativity and problem-solving skills. Spearman's correlation indicated that there was a statistically significant positive correlation between students' perception on the possibility that they can learn all the mentioned soft skills groups during higher education, as well as a statistically significant negative correlation with the willingness to pay for extra courses in the field of the mentioned soft skills groups.

Limitations/future research: The first limitation is geographical focus of our sample and the second limitation of the study is that we examined the importance of soft skills solely from the students' perspective. In the future, such research should be obtained in all neighbouring countries, as well as through employee survey.

Keywords

Soft skills, Factor analysis, Innovative thinking soft skills, Business agile soft skills, Spearman correlation, Serbia, Hungary

Introduction

Changes in the business environment due to constant innovation as well as increasing internationalization ought to trigger novel educational trends. Besides, Jarjabka et al., stated that “the COVID-19 pandemic has had an unpredictable effect on the actors of society and the economy worldwide” (2024, p. 2). The development of soft skills has become a central focus in training new employees due to the rise of remote work (Ferreira et al., 2023). Furthermore, the changing psychological profiles of new student generations advocating different social values also have a significant impact on the creation of new curricula, including a wide range of now required competencies and personal skills. To be competitive, the new workforce must expand its hard academic skills with a spectrum of soft skills (Wats & Wats, 2009). They pointed out: “Hard skills contribute to only 15% of one's success while the remaining 85% is soft skills” (Wats & Wats, 2009, p. 1). Authors Fletcher and Thornton (2023) stated that soft skills are increasingly prioritized over hard skills in the hiring process (p. 411). Therefore, soft skills are “must-have” skills in today's fiercely competitive international business landscape, preparing students to operate in the knowledge-driven economy (Nusrat & Sultana, 2019; Strampe & Rambe, 2024; Villazon Montalvan et al., 2024). As stated by Balcar (2016) and Krawczyk-Sokolowska et al., (2021), the importance of soft skills exceeds the individual interest of students or employees because seen from the company's point of view, soft skills are as productive as hard skills, yet often the productivity of hard skills themselves depends on their combination with soft skills. The mutual interest of universities and businesses to develop a set of adequate soft skills calls for continuous cooperation between academic institutions and businesses, which is, however, currently still at minimal level in most countries (Sujova et al., 2021). Given the previously stated research gap, the aim of this research is to define the groups of key soft skills in the business context of Hungary and Serbia, and accordingly provide the guidelines on how to create adequate curricula in the future.

Thus, students need to develop and refine their soft skills while pursuing their undergraduate degrees (Villazon Montalvan et al., 2024). It becomes clear that universities should focus on developing an adequate set of soft skills for future

employees. In order to facilitate this, especially under today's influence of globalization, there is a great interest in trying to identify common soft skills set across different cultural contexts (Kechagias, 2011). However, to date there has not been one definitive list of generic soft skills. Given that these skills are culturally determined, it is necessary to analyse the neighbouring countries sharing a border and determine whether there is a possibility to create soft skills clusters for easier comparison and thereby smooth student and workforce transfer. In different European countries, there are different classifications of soft skills and their clustering (Cinque, 2016), which makes further comparison difficult. Therefore, this study examines the importance of soft skills among business students from Hungary and Serbia.

Hungary's business environment was selected due to the fact that, ever since the political changes of 1990 (Gubik & Karajz, 2014), there has been a process of internationalization as part of the European Union and beyond, where the workforce acquires a set of vital competencies, relevant both within the state borders and beyond. Such intentions also appeared in the business environment in the Republic of Serbia, but considerably later than in Hungary, which means, Hungary can offer valuable guidelines in this regard. Hence, this study addresses specific research questions: What are the most important groups of soft skills in the business context of Hungary and Serbia? Based on the results of this empirical research on a sample of 906 students from both Hungary and Serbia, the authors identified key areas for soft skills development at university level in these border countries. The conclusions of this empirical research are significant in ensuring that the new generation workforce becomes internationally competent and can reach its full cross-border cooperation potential. The paper also makes recommendations for enabling students to become fully equipped with soft skills in business, ready for the Hungarian and Serbian labour market.

The paper is structured as follows: section two offers a theoretical framework so as to better understand the concept of “soft skills” for education as well as different approaches to soft skills classifications. Section three focuses on the methodology, while section four presents the quantitative analysis results by highlighting the groups of key soft skills for the Hungarian and

Serbian labour market. The paper closes with concluding remarks.

1. Theoretical background: Soft skills in education

Many authors stated as well as Sipos et al., (2023) that: "There are many significant changes in higher education systems; the tertiary education environment is highly dynamic, competitive and uncertain, the global expansion of higher education has created an increasing demand for the comparison of universities" (p. 178). Therefore the modernisation of curricula and introduction of teaching soft skills into hard skills courses (Schulz, 2008) is indispensable. Besides the rising emphasis on integrating soft skills into teaching methods across various courses, the number of subjects focusing specifically on soft skills is limited.

Soft skills can also be called employability skills, as is the case of Australia (Wats & Wats, 2009). This was supported by the findings that soft skills were crucial for young graduates' employability (Abdullah et al., 2019). Furthermore, Jarjabka et al., (2024) think that: "the development of teachers' digital teaching competence is crucial for effectively infusing technology into teaching in the post COVID era" (p. 8). The comparison of employment rates in Hungary and Serbia revealed that there was an increase in Hungary in the first quarter of 2023, while in Serbia youth unemployment was remarkably high. To raise young people's employment rates, it is necessary to educate them in the field of soft skills in both of these countries. The author Csapo (2007) highlighted that educational institutions showed willingness to intensify training in the field of soft skills, but it was still in the planning stage, not yet implemented. The best period for acquiring employability skills is college education (Nathan, & Rajamanoharane, 2016). Furthermore, the authors Caggiano et al., (2020) believed that graduates should present a list of learned soft skills in their CV, as this indicates their ability to adapt to different business environments. They not only emphasized the superiority of soft skills against hard skills, but argued that the two were mutually complementary, together creating a highly capable future employee.

Soft skills can be defined as intra- and inter-personal skills that are of immense importance for personal and professional development (Abdullah-Al-Mamun, 2012; Cambronero-Alonso, 2021; Kechagias, 2011). The significance of soft skills is

not limited to individual interest, but also extends to organizational interest, given that employees with an adequate soft skills set contribute to organizational development and effectiveness (Krawczyk-Sokolowska et al., 2021). Employees apply these skills unconsciously in the course of their work. Some soft skills which are increasingly important in today's knowledge-driven economy according to authors Wats and Wats (2009) are: "complex problem solving, innovation and creativity, visualization of new markets, understanding social and global implications, working in new environments and with people of different cultures and countries, developing new products and services etc." (p. 1). In addition to the previously mentioned, there is an extensive list of different soft skills such as: "clear communication, meaningful feedback, conflict resolution, understanding of human behaviour in a group setting, etc." (Parente et al., 2012). Based on the World Economic Forum Report (2016), the top ten soft skills in 2020 were problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgment, and decision making, service orientation, negotiation, and cognitive flexibility. Given that there is no single list of the necessary set of soft skills based on the workplace (Schleutker, 2022), and that there are many different classifications for numerous soft skills (Malykhin et al., 2021), universities are faced with the dilemma of which specific soft skills to incorporate into their official curricula. Therefore, the crucial soft skills should be grouped into clusters of importance for all activities.

So far there are different lists of soft skills depending on the contextual elements. However, as the author Gibb (2014) stated: "Different clusters of soft skills may be seen in different contexts, although they all share a common purpose" (p. 456). Thus, the most common groups of soft skills are Skills related to the business world, People skills and Innovative thinking skills. Another author, Cinque (2016) highlighted common soft skills such as: Basic/fundamental skills, Skills related to the business world, People-related skills, Personal skills and attributes, Conceptual/thinking skills and Skills related to the community.

1.1 Business agile skills

Seven years ago, the need for additional knowledge in business and project management was highly ranked as missing soft skills for newly employed, as stated by Schulz (2008). Today, the situation is

no better, so educators must be exhorted to take special responsibility in integrating this type of soft skills within their regular curricula. As author Maulana (2023) noted there is the necessity for business school to enhance the development of soft skills for its bachelor students. Various authors grouped different skills into a business skill set. For example, according to Kechagias (2011) and Cinque (2016) such a skills group would include innovation skills and enterprise skills. Conversely, Sousa and Rocha (2017) stated that the key soft skills for the successful business operation were leadership, team and time management skills. In his doctoral dissertation Schleutker (2022) grouped the following soft skills: leadership, negotiation, commitment to organization, as well as empathy, people management and strategic orientation. It must be mentioned that in this research, business and people skills were mixed. Not only do the skills included within business skills vary, but so are the names used to denote those skills groups. For instance, Poblete Ruiz (2015) defined them as Systemic competencies, which contained organizational, entrepreneurial and leadership skills, whereas Kaushik and Bansal (2015) denoted them as influencing skills & leadership. Among the vital soft skills within this group, the authors named: leadership, entrepreneurial, team and time management skills.

Leadership skills as business soft skills have the strongest influence on employment opportunities of young graduates (Abdullah et al., 2019). However, the results of a study on a sample from Finland, the Netherlands, Portugal, and Spain were devastating, indicating that leadership is among the less rated soft skills by employees (Schleutker, 2022, p. 105). Leadership skills include the ability to lead, communicate (Choudary & Ponnuru, 2015), influence, support and motivate employees. The final effects of leadership on employees depend on the quality of communication in the leader-employee relationship, so it should enable clear and comprehensive information conveyance (Schleutker, 2022). Entrepreneurship skills rely partly on leadership skills (Cimatti, 2016) and include readiness for entrepreneurial business and risk taking. As authors Strampe and Rambe (2024) stated, acquiring these skills will improve entrepreneurial readiness behaviour of the students namely being prone to venture creation, finding innovative financing schemes and possibilities for venture growth. Furthermore, Team Work and Cooperation, which represent Team management skills, are characterized as highly potential for

learning new generations (Schleutker, 2022, p. 107). Today, when everything is fast paced, it is essential to mention Time management skills that enable employees to multitask in an adequate time frame in order to achieve a good balance of business and private obligations, reduce stress and burnout, as well as the intention to leave work.

1.2 People skills

People skills are crucial since employees spend a considerable time at work interacting with various people. Some authors name this group of skills as social competencies that allow individuals to effectively manage interpersonal interactions, develop and sustain relationships, and collaborate successfully with others (Lamri & Lubart, 2023). Other authors named it as interpersonal skills focusing on communication between departments and beyond the organization, skills for efficient meetings and presentation (Ferreira et al., 2023). Consequently, it comes as a surprise to find that both business representatives and higher education teachers claim that a large number of students lack skills such as online as well as face-to-face communication, speaking, listening, writing and empathy (Cinque, 2016, p. 176). The skills within this group should help establish adequate inter-employee relationships. These skills are of particular importance in the day and age of multinational and global teams requiring different people to establish close, effective, and long-lasting relationships with other team members. It must be emphasized that the development of this particular group of soft skills is indispensable for the Millennials, Generation Y, and Generation Z, particularly since they grew up using technology as the main source of communication (Dean, 2017), with reduced empathy and often lacking ethics and morality.

ISFOL (1994, 1998), i.e. the Istituto per lo Sviluppo della Formazione Professionale dei Lavoratori, defined people-related skills as a set comprising interpersonal or social skills, emotional skills, cognitive skills, and communication skills. They added the following skills as well: IT skills, language skills, empathy, appearance, ethical and moral skills, presentation skills.

Language skills and specifically language proficiency are vital in the globalization and digitalization era where many new companies operate through teams made up of employees from multilingual societies. Hence, communication in both native language and foreign languages are

considered key competencies for lifelong learning (European Union, 2006).

Empathy, as one of today's crucial soft skills that develops through emotional intelligence, is rated with low learning potential. Analysed graduates with a minimum of three years of work experience have a low level of empathy (Schleutker, 2022, p. 106). This result is rather concerning given that empathy has a positive effect on employee satisfaction and productivity (Reynolds & Scott, 1999). In addition, empathy has a domino effect on other soft skills within this group such as ethical and moral skills that enable decision-making by taking into account responsibility towards society (Shakir, 2009). Empathy together with ethical and moral skills influence the formation of an individual's personality (Ngang & Chan, 2015). The more students and future employees possess the mentioned skills, the more likely they are to apply high moral standards in their professional practice, the more likely they are to establish a relationship of trust with colleagues.

Appearance as one of the selected soft skills from this group is significant due to body-language, as well as the ability of people to express and present themselves in the best way, indirectly affecting presentation skills, which are also within this group of soft skills. Today, employees who are extroverted and good at socializing are rated better than their superiors.

1.3 Innovative thinking skills

To address the challenges of this era, innovative thinking skills are crucial, like creativity and critical thinking (Poláková et al., 2023). In the business context of the USA a framework of necessary skills has been defined underlining a special group of thinking skills, which include: Creative Thinking, Decision Making, Problem Solving, Seeing Things in the Mind's Eye, Knowing How to Learn and Reasoning (The Secretary's Commission on Achieving Necessary Skills, 1991). According to Cinque (2016), the Conceptual/thinking skills group includes collecting and organizing information, problem-solving, planning and organizing, learning-to-learn skills, thinking innovatively and creatively, systems thinking (p. 170). It should be noted that certain skills from this soft skills group, most prominently critical and structured thinking, as well as problem solving abilities are absent in higher education (Schulz, 2008). Today in the age of digitization, these skills are gaining more and

more ground as information becomes widely accessible, thereby requiring filtration. Also, in the days of increasing uncertainty, quick decisions are expected to be made to solve emerging problems. Soft skills such as strategic thinking is crucial in the process of effective strategy determination for a successful flexible business in an uncertain future as well as ensuring a competitive advantage (Al-Qatamin & Esam, 2018).

Creativity as one of these skills is indispensable in order to attain different perspectives and enable new employees to think outside the box. For example, a research results from Finland, the Netherlands, Portugal and Spain show that among analysed 21 soft skills, the importance of creativity was ranked as seventh. On the one hand, it has a low learning potential, but on the other, graduates with at least three years of working experience have a high level of creativity (Schleutker, 2022, p. 105).

According to many authors, critical thinking and problem solving go hand in hand, and are based on the employee's ability to explain a problem by utilizing previous experience and analogous situations, as well as to build an adequate solution and implement it (Tang, 2020).

All the mentioned skills in combination lead to a revolutionary novel view that may bring about the emergence of innovations of various kinds and increasingly better business results of the company.

2. Methodology

The field study was conducted in Hungary and Serbia in 2023. A questionnaire-based survey consisted of 19 questions about the demographic characteristics of the respondents, the degree of their 22 soft skills development and its importance for the employability in labour market. Cluster sampling was used as the primary sampling method. Cluster sampling was considered suitable for the study where universities are in focus because fields of study and academic levels were organized into clusters from which students could be selected (Strampe & Rambe, 2024).

Thus, the research was conducted based on a total sample of 906 students of all levels (Bachelor, Master and PhD students), more precisely 661 students from the Budapest Business University in Hungary and 245 students from the University of Novi Sad, Faculty of Economics Subotica in Serbia. The first six questions were on the respondent's general information, such as country, gender, age, level of education and work

experiences. Next, there were nine questions with the aim to analyse the development of soft skills from the individual and university level, as well as four questions regarding the importance of soft skills regarding the employee and labour market. For example: "In your opinion, which soft skills do employers today expect from young people?; After completing secondary education, what skills should a young person have?; Upon completing higher education, what skills should a young person have?; Considering the skills listed, how well do you think you meet employers' expectations?; Soft skills can be learned at school; Education prepares students/learners for the challenges of the labour market; Would you spend money on training to improve your soft skills?"; etc. (Juhász et al., 2025, pp. 16-21).

For the purpose of this study the authors analysed 22 soft skills, like "Language skills, IT skills, Appearance, Good communication skills, Critical thinking, Leadership skills, Entrepreneurial skills, Ability to work in a team, Ethical and moral skills, Strategic thinking, Time management skills, Planning and organisational skills, Communication skills, Presentation skills, Self-awareness, Problem solving skills, Empathy, Creativity, Flexibility, Ability to manage stress and conflict and Emotional intelligence" (Juhász et al., 2025, p. 17). These skills were deemed as most vital and the authors analysed how those can be grouped into key areas to integrate those skills into education at university level. Survey reliability was analysed using the Cronbach alpha coefficient, whose value for the questionnaire was 0.937, i.e. a good reliability of the scale and good internal consensus of the statements in the questionnaire. Nunnally (1978) recommended a minimum of 0.7 for Cronbach's alpha coefficient.

The respondents' gender distribution indicated that the majority (61.5%) was female, with 38.5% male. Regarding the age of the respondents, 53% of students were under the age of 20, 45.9% were between 21 and 30, while only 1% are between 31 and 40, with 0.1% over the age of 41. Students' age distribution differed by country, since in Serbia almost all students were in the 21-30 age range, while in Hungary most students were under 20. This difference stemmed from the different dynamics of starting elementary school in Serbia and Hungary. Regarding work experience, there was also a difference between countries, as most students from Hungary already had some kind of work experience, unlike students from Serbia. Overall, 15.6% of students had no work

experience, 33.9% of students worked less than 6 months, 19.1% worked up to 12 months, while 31.4% had work experience of more than 12 months. In terms of the workplace where they gained their work experience, the majority of 73.4% worked as employees, while 5.5% held managerial positions, and a mere 1.2% were owners, whereas the rest did not hold any of the positions offered.

To analyse key groups of soft skills, Exploratory factor analysis was applied and the following hypothesis was developed:

H1: Among the 22 soft skills, more than two underlying latent factors can be identified.

Furthermore, the following hypotheses were analysed using Spearman's correlation:

H2: There is a statistically significant relationship between importance of possessing particular soft skills and students' perception that they can learn those soft skills during their studies.

H3: There is a statistically significant correlation between importance of possessing particular soft skills and students' willingness to pay extra for improving their soft skills.

3. Empirical results

To analyse the 22 different soft skills, the authors used exploratory factor analysis to see if these soft skills will group themselves and single out the key factors as the most important soft skills cluster which should be developed in universities in Hungary and Serbia. Cattell (1973) stated that in EFA each factor created a distinct cluster making interpretation easier. Before performing EFA, the authors analysed the correlation matrix. It showed a number of relations with the coefficient of correlations higher than 0.3, therefore factor analysis could be performed. Furthermore, EFA was deemed suitable for this sample as it exceeded 300 participants. As Yong and Pearce (2013) stated: "If we have a larger sample size it will diminish the error in data" (p. 80).

Maximal similarity analysis and Varimax rotation method were implemented as the data extraction method, along with Bartlett's sphericity test and the Kaiser-Meyer-Olkin (KMO) test and the Goodness of Fit Test.

The KMO value of the variables was 0.835. It was suitable since it should have been at least 0.6 (Kaiser, 1974). Moreover, the value obtained by Bartlett's sphericity test for χ^2 (78) was 2997.747, which was highly significant at $p < 0.000$ level. If it is significant, it shows that there are patterned

relationships amongst the variables (Yong & Pearce, 2013).

The factor analysis eliminated some soft skills whose factor loadings were less than 0.50 and reduced the original list of 22 soft skills to 13 key soft skills which can be grouped. Those 13 soft skills were clustered into three groups: Skills related to the business world, People skills and Innovative thinking skills. These three underlying soft skills groups accounted for 55.801% of total variance, leaving 44.199% of the total variance unexplained. The minimum threshold factor loading in social sciences is 0.30 when deciding whether to accept an item or variable as belonging to a factor or component (Peterson, 2000, p.264).

Table 1 Soft skills groups as a key area for education in Hungary and Serbia

Description	Eigenvalue	% of variance	Cumulative % of variance
Business agility skills	4,385	33,728	33,728
People skills	1,530	11,771	45,499
Innovative thinking skills	1,339	10,302	55,801

Source: the authors

The next table shows the rotated factors, where the soft skills with factor loadings below 0.50 have been removed.

Table 2 Soft skills groups

Soft skills	Business agility skills	People skills	Innovative thinking skills
Team management	,821		
Entrepreneurs hip	,818		
Leadership	,630		
Time management	,617		
IT skills		,749	
Language skills		,657	
Empathy		,588	
Appearance		,585	
Ethic		,559	
Presentation skills		,520	
Strategic thinking			,811
Creativity			,804
Problem solving			,656

Source: the authors

The first group or factor includes four soft skills such as Team management, Entrepreneurship,

Leadership and Time management, forming a cluster called Business agility skills. The second group or factor includes IT skills, Language skills, Empathy, Appearance, Ethnic and Presentation skills, forming a cluster called People skills. The third group or factor includes three soft skills such as Strategic thinking, Creativity and Problem solving, forming a cluster called Innovative thinking skills.

In order to analyse the proposed hypotheses H2 and H3, the authors performed Spearman's correlation in SPSS software.

Table 3 Spearman's correlation

Soft skills		BAS	PS	ITS	SPL	WP
Busi. agility Skills-BAS	r Sig.	1				
People Skills-PS	r Sig.	,557** ,000	1			
Innov. thinking skills-ITS	r Sig.	,636** ,000	,626** ,000	1		
Stud. percep.ab out learning-SPL	r Sig.	,065* ,049	,155** ,000	,086* ,000	1	
Willi. to pay-WP	r Sig.	-,069* ,038	-,012 ,710	-,008 ,801	,042 ,211	1

Source: the authors

The table above presents the results of Spearman's correlation, which indicated that there was a statistically significant relationship of low strength between all groups of soft skills, such as Business agility skills ($r = .065$, $p = .049$), People skills ($r = .155$, $p = .000$) and Innovative thinking skills ($r = .086$, $p = .000$) with students' perception that they can learn soft skills during their studies. This confirmed Hypothesis H2. Hypothesis H3 was not confirmed because a negative statistically significant relationship of small strength was detected, and only between Business agility skills and the students' readiness to spend money on the improvement of this skill ($r = -.069$, $p = .038$). With other groups of soft skills, this relationship was not statistically significant.

4. Discussion

Based on the surveyed students and their perception of the importance of soft skills, it can be stated that in Hungary and Serbia employees face higher expectations concerning soft skills than technical or hard skills. The same statement was derived from the research on Hungarian students

from 2021 that soft skills are being more valued than hard skills by employers, specifically soft skills as leadership functioning skills, communication support skills and organisational knowledge support skills (Horváth-Csikós & Juhász, 2022). Furthermore, Hungarian students emphasize the importance of individualistic soft skills to enhance their competitiveness (Laurisz et al., 2024). More precisely, in our empirical research, we derived three crucial soft skills groups as Business agility skills, People oriented skills and Innovative thinking skills. Although there is no unified classification of the most important soft skills (Malykhin et al., 2021), many authors indicated that the previously mentioned soft skills were common soft skills crucial for the labour market (Cinque, 2016; Kumar et al., 2022; Majid et al., 2019; Velásquez et al., 2024). On the other hand, there were also studies in which soft skills were grouped differently, but also included the previously mentioned important soft skills. For instance, Klaus et al. (2007) defined four soft skills categories like employees' personal, social, communication and self-management skills, as opposed to Schulz (2008) who distinguished three groups of soft skills such as personal, interpersonal and additional skills; and in line with Schulz (2008), Shakir (2009) also gave his classification that includes personal, interpersonal, problem solving and decision making skills, unlike Khanna (2015) who singled out professional excellence and self-management skills. For effective organizational performances, employees must have all three groups of skills, Business, People and Innovative skills, because the most essential are communication, teamwork and problem solving skills (Emanuel et al., 2021).

From the perspective of Hungarian employers analysed in 2021, Critical thinking, Problem-solving, Adaptability, Resilience, and Creativity (Obermayer et al., 2023) can form the group Innovative thinking skills that is derived in our empirical research. Another group of authors found five most important skills for the sampled engineering students as Problem solving, Reliability, Resilience, Communication and Independent work (Holik et al., 2023) which can form the group People and Innovative thinking skills, identified in our empirical research. Aside from the mentioned two groups of skills, our research showed that Hungarian students should possess one more crucial group of skills, which is Business Agile Skills. This gives the additional value to our paper. From the perspective of Serbian

engineering students, the five most important soft skills are: Communication, Team management, Leadership, Flexibility and Problem solving (Milić et al., 2023), which can group all three groups of soft skills identified in our research. Therefore, it is necessary to ensure that students can make a successful transition from university education to the labour market, which requires students to be taught the crucial soft skills. Given that a statistically significant connection between Business agility soft skills and students' willingness to pay for additional development of the same skills was identified, it is necessary to make courses free and available within the study programs. In order to include soft skills in university curricula, a constant connection between educators and employees is necessary (Cimatti, 2016). Cinque (2016) cautioned that universities and businesses should not be in "parallel universes" (p. 391) but rather in the same one.

Conclusion

Through our empirical analyses, we tried to minimize the research gap associated with the fact that there are no definitive lists of future soft skills, and that there are a lot different lists of important soft skills, yet they correspond with some specific groups of soft skills (Juhász et al., 2023). Furthermore, as authors Papp et al., (2023) noted, in Hungary, students' curricula are less likely to include soft skills, which made this research more challenging. In addition, based on the authors' expertise and knowledge, the same situation exists in Serbian education. Consequently, the results of our research focus on three groups of soft skills such as Business agility skills, People skills and Innovative thinking skills, which must be incorporated in the future students curriculum.

Students could learn the necessary soft skills as part of traditional courses implementing game-based, project-based and competition-based learning, as well as management simulations (Malykhin et al., 2021). Soft skills could be successfully communicated through workplace simulation practices (Kechagias, 2011) or in the form of dual education through internship workplace. However, in countries with a lengthy university curriculum accreditation process, as is the case in Serbia, it is necessary to create short-cycle studies to master the missing soft skills in a relatively short time. These programs do not need to be accredited and should be designed together with the needs of employers in terms of required competencies of new employees. In fact, given that

soft skills are also termed as 'life skills' by some authors (Cinque, 2016), they ought to be included in lifelong learning programs that should be available at all universities with the acquisition of a Soft Skills Certificate. In this process, the university would take on the considerable obligation to create an awareness of the importance of soft skills among the students and motivate them to enrol in additional courses or programs. Another recommendation is to create practical-oriented research, as in Belgium at the University of Ghent, or to establish a Career Centre, as in France (Cinque, 2016). Universities could thus mediate between students and the labour market by identifying which soft skills a student lacks in order to be employed in a newly opened workplace.

While the intention to create an integrated common European university program for developing soft skills has already existed, the authors of this paper believe that this is not possible due to cultural differences and different conditions on the labour market. Therefore, unification should be limited to neighbouring countries and countries with similar cultural, traditional, political, and economic conditions. Likewise, for bordering countries at a lower level of economic development, it would be beneficial to create a unique program with another bordering country that is at a higher level of development, so as to help with future better development and becoming a more competitive country on the global market.

Important theoretical implications can arise from this paper and we performed challenging task of assessing most important groups of soft skills as must-have for new generation employees in the Hungarian and Serbian business context.

Practical implications bring the findings about guidelines for creating national educational policy on incorporating soft skills, as well as significant insights for universities and educational stakeholders in the process of updating, rethinking and implementing new curricula criteria based on developing soft skills in higher education students, particularly in the Hungarian and Serbian context.

A major limitation of our study is the geographical focus of our sample, which was restricted to two neighbouring countries, namely Serbia and Hungary, where contrast country-level skill gaps is possible. In the future research, we should analyse the country-level skill gaps between these two countries, and generalise our findings by including other neighbouring countries in the research context. The second limitation of the study is that we examined the importance of soft

skills solely from the students' perspective. Future research could benefit from comparing these findings with the employer's perspective.

Declarations

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Adoption of Cloud Computing Technologies in Hospitality Enterprises and Their Impact on Business Performance: The Case of Türkiye

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Abstract

Background: Cloud computing (CC) has emerged as a transformative technology that offers flexibility, scalability, and cost efficiency to enterprises across various sectors, including tourism and hospitality. Despite its potential, the level and determinants of cloud computing adoption (CCA) in the hospitality industry, particularly in developing countries, remain insufficiently explored.

Purpose: This study aims to identify the key factors that facilitate or hinder the adoption process of cloud computing in accommodation businesses operating in Türkiye and to analyse the impact of this technology on business performance.

Study design/methodology/approach: A theoretical model was developed by integrating the Diffusion of Innovation (DOI) theory and the Technology-Organization-Environment (TOE) framework. Within this model, 11 constructs were formulated, their reliability and validity were tested and regression analyses were conducted to examine the relationships between CCA determinants and business performance outcomes.

Findings/conclusions: The results show that compatibility has a strong positive effect on the adoption of CC in hospitality enterprises, while complexity and security and privacy concerns negatively affect adoption. External support and technological readiness were also found to be significant positive predictors. Conversely, relative advantage, top management support, organizational resources and competitive pressure did not have significant effects. Importantly, the study reveals a positive and significant relationship between CCA and business performance, highlighting the strategic potential of this technology for hospitality enterprises.

Limitations/future research: The study is limited to hospitality enterprises in Türkiye and future research could extend the analysis to other countries or service sectors. Further studies employing longitudinal or mixed-method approaches may also deepen understanding of the long-term effects of CCA.

Keywords

Cloud Computing, Hospitality Enterprises, Diffusion of Innovation (DOI) Theory, Technology-Organization-Environment (TOE) Framework, Business Performance

Introduction

The incorporation of Industry 4.0 technological frameworks into tourism operations is fundamentally reshaping the sector through the concept of "smart hospitality." While tourism as a whole typically demonstrates slower uptake of

technological innovations (Gomes et al., 2024), the accommodation sector has historically distinguished itself through early technology adoption (Zeqiri & Youssef, 2020; Buhalis & Law, 2008).

Cloud infrastructure, recognized as a contemporary application delivery mechanism in

global service markets (Danylenko et al., 2019), presents substantial prospects to the accommodation industry as an innovative and decentralized framework facilitated by contemporary Industry 4.0 instruments (Taqi et al., 2025). Evidence suggests that cloud infrastructure exercises perhaps the most profound influence within the hospitality domain, and as primary information systems transition to cloud environments, it functions as an enabler for additional cloud-dependent digital solutions (Wynn & Jones, 2022). This prominence stems from the fact that computational and operational dimensions of digital, smart, and intelligent technologies predominantly depend upon cloud infrastructure (Hsu, 2024).

Cloud infrastructure holds strategic value in the hospitality sector due to its capacity to respond quickly to changing guest expectations and facilitate revenue-enhancing strategies (Mansour et al., 2020). Cloud-based applications enhance operational performance by strengthening communication between leadership and staff and make processes more efficient by establishing instant connections between digital and physical systems (Sujood et al., 2023). These solutions, which digitise reservations, guest transactions, inventory management, and financial processes (Anwar et al., 2024; Wynn & Jones, 2022), accelerate the digital transformation of businesses by increasing customer satisfaction and competitiveness (Buhalis & Leung, 2018; Çankaya Kurnaz & Kurnaz, 2022). Cloud infrastructure, integrated with 5G, the Internet of Things (IoT) and smart city technologies (Tabrizchi & Kuchaki Rafsanjani, 2020), plays a critical role in data processing and storage, becoming a fundamental technology in the hospitality sector in terms of operational efficiency, customer experience and competitive advantage.

Despite the cloud infrastructure's capacity to provide economically and temporally efficient services, it is noteworthy that a significant proportion of organizations in both developing countries (Khayer et al., 2020) and across the European Union have yet to adopt this technology (Bania & Geradin, 2024). The main reasons for this include the complexity of transferring data from legacy systems to cloud-based platforms, uncertainties regarding the commercial benefits and organizational outcomes of the technology, the absence of industry-specific standards, low levels of technological readiness, concerns about service

reliability, and discrepancies between expected and actual performance (Khayer et al., 2020).

Comparable obstacles appear to have manifested within the Turkish tourism industry, as evidenced by the Twelfth Development Plan (2024-2028), which has highlighted the necessity for the tourism sector to embrace digital transformation to develop a competitive framework responsive to rapidly evolving demand patterns. The plan articulates an objective to implement a "seamless end-to-end travel" model throughout the sector by digitally connecting all participants across the tourism value chain. Within this framework, the plan emphasizes that assistance will be extended toward strengthening the technological capabilities of particularly small-scale tourism operations and cultivating digital competencies among their workforce (T.C. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2024). Nevertheless, available scholarship indicates that research examining factors affecting CCA within hospitality organizations remains considerably limited. This scarcity hampers thorough comprehension of challenges associated with CC implementation in hospitality contexts. Accordingly, these circumstances have established the rationale for the present investigation. Aligned with this overarching objective, the study pursues responses to the following inquiries:

1. What are the fundamental factors influencing the adoption of CC by hospitality enterprises and how are these factors shaped within the context of the Turkish hospitality sector?
2. Is there a significant relationship between the adoption of CC and the performance of hospitality enterprises?

1. Background

1.1. DOI

DOI Theory, developed by Rogers (1962) and used for over sixty years, is a powerful theoretical framework for understanding how new ideas and technologies spread (Valente, 2003; Wamba & Queiroz, 2022). According to Rogers (2003), diffusion is 'the process by which an innovation is communicated over time through specific channels among members of a social system.' Unlike other change theories, DOI does not focus on changing individuals; instead, it focuses on the process of reshaping products and applications to fit the needs of individuals and groups (Robinson, 2009). Rogers (1995) emphasised that the rate of adoption depends on the perceived characteristics of

innovations and defined five key characteristics in this context: relative advantage, compatibility, complexity, trialability and observability. DOI is widely used as an important model in information systems research that links technology characteristics with user perceptions (Oliveira et al., 2014).

1.2. TOE Framework

In response to criticism that previous organisational adoption frameworks inadequately incorporated environmental factors, TOE Framework developed by Tornatzky and Fleischer (1990) is one of the earliest examples of comprehensive models aiming to explain the likelihood of innovation adoption (Awa & Ojiabo, 2016). TOE defines three fundamental contexts that shape an organisation's process of adopting technological innovations: technological, organisational and environmental.

1.3. CCA Related Studies

CCA decisions have been analysed through empirical studies based on various theoretical approaches. For example, in user-centred studies, factors such as Perceived Usefulness and Personal Innovativeness (Ahmed et al., 2020), User-Friendly Interface, Security, Flexibility and Reliability (Tella et al., 2020) have been found to influence adoption intentions. In the context of organisational and environmental factors, Server Location in Bangladesh (Khayer et al., 2020), Top Management Support and Government Policy in Ghana (Entsie et al., 2025; Atuah et al., 2023), Competitive Pressure and External Expertise in the Indian education system (Singh & Mansotra, 2019) and Corporate Competencies in Australia (Senarathna et al., 2018) have been decisive. Relative Advantage and Compatibility have commonly shown positive effects (Athambawa et al., 2023; Atuah et al., 2023), while the effect of Complexity has been found to be insignificant in some studies (Entsie et al., 2025). The perception of Regulatory Support as a barrier among SMEs in South Africa (Sithole & Ruhode, 2021) and the identification of economic barriers, brain drain, and infrastructure deficiencies as significant issues in Lebanon, where adoption is strongly associated only with technological factors (Baalbaki et al., 2025), demonstrate that the impact of factors varies by geography and sector. Furthermore, it has been shown that Information and service quality improves business operations.

A review of the literature reveals that some studies on the adoption of CC have been conducted using secondary data (Entsie et al., 2026; Holler & Westner, 2025) and that the majority of research has focused on SMEs (Amini & Bakri, 2015; Nosheen et al., 2025; Suttidee & Savithi, 2025), libraries (Tella et al., 2020; Ibrahim et al., 2025), the oil and gas sector (Oduoza & Lawan, 2026), and the public sector (Entsie et al., 2025). However, studies conducted specifically on accommodation businesses are limited in number and have small sample sizes (Ayoobkhan & Kaldeen, 2020), focusing solely on the level of adoption (Godolja et al., 2025), or examining the relationship between adoption and business performance without comprehensively addressing the adoption factors explaining this relationship (Hui & Mohammadi, 2024). The fundamental difference of this study is that it is an empirical research conducted with a large sample size, comprehensively examining the factors affecting the adoption of CC and the effects of this adoption on business performance within the same model, and testing these relationships in the context of Türkiye, an emerging economy, thereby filling existing gaps in the literature while offering contextual and comparative original contributions.

1.4. Combining DOI and TOE

DOI Theory faces criticism for its inadequacy in explaining collective adoption behaviours, particularly those involving elements such as network externalities, while also failing to accelerate decision-making processes and ensure sustainability (Rogers, 2003; Haider & Kreps, 2004; García-Avilés, 2020). On the other hand, TOE framework has been criticised for the lack of clarity in contextual variables and shortcomings in explaining adoption mechanisms (Wang et al., 2010). These limitations have led to the widespread integration of more robust frameworks such as DOI and TOE to increase explanatory power and include the environmental dimension, rather than relying on a single model in the academic field (Oliveira & Martins, 2011; Gangwar & Date, 2016). In this study, an integrated use was deemed appropriate because TOE explains adoption at the organisational level by addressing technological, organisational, and environmental aspects simultaneously, while DOI emphasises individual elements (Khayer et al., 2020; Oliveira et al., 2014). Research examining the organisational adoption of information technologies has supported both theories with strong empirical

evidence (Ahmed & Saidu, 2022), and current literature indicates that they retain their strategic importance (Holler & Westner, 2025). The integration of these two theoretical approaches provides a more robust and comprehensive framework for analysing adoption processes by addressing the diffusion of technological innovations and organisational adaptation from a multidimensional perspective (Oliveira et al., 2014; Sahin, 2006).

2. Research Hypotheses and Model

Key independent variables within the model, under the DOI framework, comprise relative advantage, compatibility and complexity. Additional independent variables within the model, under the TOE framework, include technological readiness, security and privacy concerns, cost savings, competitive pressure, top management support, and organizational resources. Dependent variables in this investigation are CCA and business performance.

2.1. Research Hypotheses

2.1.1. Relative Advantage

Relative Advantage, derived from Rogers' DOI theory, expresses how much better an innovation is perceived to be than the idea it replaces (Rogers, 2003) and, in CC, expresses the perception of reducing operational costs and increasing commercial benefits (Lian et al., 2014). Numerous studies on CCA (Sithole & Ruhode, 2021; Al Hadwer et al., 2021; Athambawa et al., 2023; Atuah et al., 2023) have confirmed that relative advantage has a positive effect on adoption. Therefore, the following hypothesis is proposed:

H1. Relative advantage will positively affect the CCA.

2.1.2. Compatibility

The compatibility dimension stems from Rogers' DOI theory and refers to 'the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters' (Rogers, 2003). The scientific literature emphasises that compatibility with existing business models, corporate strategies and customer expectations is among the priority issues for organisations adopting CC (Priyadarshinee et al., 2017; Alkhater et al., 2018). Numerous studies (Athambawa et al., 2023; KardanMoghaddam et al., 2022; Lawan et al., 2021; Atuah et al., 2023) show that this factor is an important determinant.

Therefore,

H2. Compatibility will positively affect the CCA.

2.1.3. Complexity

Complexity is defined in Rogers' DOI theory as 'the degree to which an innovation is perceived as relatively difficult to understand and use' (Rogers, 2003). Academic discussions emphasise that complexity delays the adoption process by making technologies difficult to learn and complicating workforce adaptation (Stieninger et al., 2014; Priyadarshinee et al., 2017). Numerous studies (Al Hadwer et al., 2021; AlBar & Hoque, 2019; Lawan et al., 2021; Athambawa et al., 2023) confirm that complexity negatively affects CCA. Hence,

H3. Complexity will negatively affect the CCA.

2.1.4. Security and Privacy Concerns

Security and privacy concerns are the main reasons why many organisations hesitate to adopt cloud services. In particular storing data with external providers leads to a loss of control and increased vulnerability to potential privacy breaches (Lian et al., 2014; Alkhater et al., 2018). Alkhater et al. (2018) found in their research that security and privacy concerns continue to hinder the adoption of cloud services. Similarly, other studies (Stieninger et al., 2018; Priyadarshinee et al., 2017; AlBar & Hoque, 2019) highlight the impact of security and privacy concerns on CCA. Therefore,

H4. Security and privacy concerns will negatively affect the CCA.

2.1.5. Cost Savings

CC enables organisations to focus on core business processes and innovation rather than technological operations by reducing the burden of system maintenance and routine updates. This technology allows companies to achieve strategic cost savings by minimising infrastructure investments, energy consumption and maintenance costs (Oliveira et al., 2014; Guo et al., 2025). Among the most significant advantages presented by CC is cost reduction, a point consistently highlighted within scholarly literature (Lin & Chen, 2012; Khayer et al., 2020; Chen et al., 2022). Investigations (Amini & Bakri, 2015; Ming et al., 2018) have established the influence of cost savings on CCA. Therefore,

H5. Cost savings will positively affect the CCA.

2.1.6. Top Management Support

Top management support also increases the rate of innovation adoption by helping businesses overcome technological challenges (Yadegaridehkordi et al., 2020). Therefore, top management support is seen as an indispensable element for effective CC implementation (Ramdani & Kawalek, 2009; Alkhater et al., 2018). Numerous studies confirm the importance of this support (AlBar & Hoque, 2019; Lawan et al., 2021; Gui et al., 2021; Atuah et al., 2023). Hence,

H6. Top management support will positively affect the CCA.

2.1.7. Organizational Resources

Organizational resource designates a firm's capacity to facilitate new technology adoption regarding technology, finance, human capital and workforce (Powell & Dent-Micallef, 1997). CCA is frequently regarded as an expensive, intricate and extensive endeavour and the existence of organizational resources including adequate budget, skilled human capital, time and executive-level backing proves substantially important for successful process execution (Lian et al., 2014). Thus,

H7. Organizational Resources will positively affect the CCA.

2.1.8. Competitive Pressure

Competitive pressure refers to the level of pressure organisations perceive from their competitors (Alkhater et al., 2015) and has historically been recognised as a significant factor in technology adoption. For companies seeking to gain a competitive advantage in the market CCA has become a strategic imperative; early adopters gain advantages such as operational efficiency, market differentiation and real-time data access (Gamage, 2019; Amini & Bakri, 2015). Most research indicates that this relationship is robust and positive (Singh & Mansotra, 2019; AlBar & Hoque, 2019; Lawan et al., 2021). Therefore,

H8. Competitive pressure will positively affect the CCA.

2.1.9. External Support

Government agencies, society and suppliers play a critical role in identifying new technology requirements and providing the necessary resources for implementation (Albugmi et al., 2016). Service providers, in particular, facilitate the adoption process by guaranteeing uninterrupted data access (Gamage, 2019). External support such

as government policies and regulatory frameworks are key factors determining the CCA; organisations actively leverage environmental factors such as government incentives to strategically justify their cloud investments (Yadegaridehkordi et al., 2020; Nosheen et al., 2025; Ali et al., 2026). Most studies have demonstrated the effectiveness of this factor (Gamage, 2019; Karim & Rampersad, 2017; Pathan et al., 2017). Hence,

H9. External support will positively affect the CCA computing.

2.1.10. Technological Readiness

Technological readiness refers to an organisation's existing technical infrastructure, such as hardware, software and networks, as well as the willingness and capacity of its human resources to effectively adopt and integrate new technologies (Alkhater et al., 2015; Nosheen et al., 2025). Most studies (Lawan et al., 2021; KardanMoghaddam et al., 2022; AlBar & Hoque, 2019) clearly demonstrate the positive effect of technological readiness on adoption. Hence,

H10. Technological readiness will positively affect the CCA.

2.1.11. Business Performance

CC plays a critical role in providing competitive advantage and superior performance by facilitating access to strategic resources (Chen et al., 2022). It also positively impacts financial indicators such as return on investment, profit margin, and market share (Rawashdeh and Rawashdeh, 2023), while increasing operational flexibility and innovation capacity (Chen et al., 2022). Therefore, the strategic and effective CCA creates a direct and positive impact on business performance by providing businesses with cost reduction, revenue growth, and competitive advantage (Chen et al., 2022; Khayer et al., 2020; Garrison et al., 2015; Rawashdeh & Rawashdeh, 2023; Hui & Mohammadi, 2024). Accordingly, the following hypothesis is proposed:

H11. The CCA will positively affect business performance.

2.2. Research Model

A theoretical model based on the integration of the DOI and the TOE frameworks has been developed to identify the key factors influencing CCA and its impact on business performance. The integrated research model is shown in Figure 1.

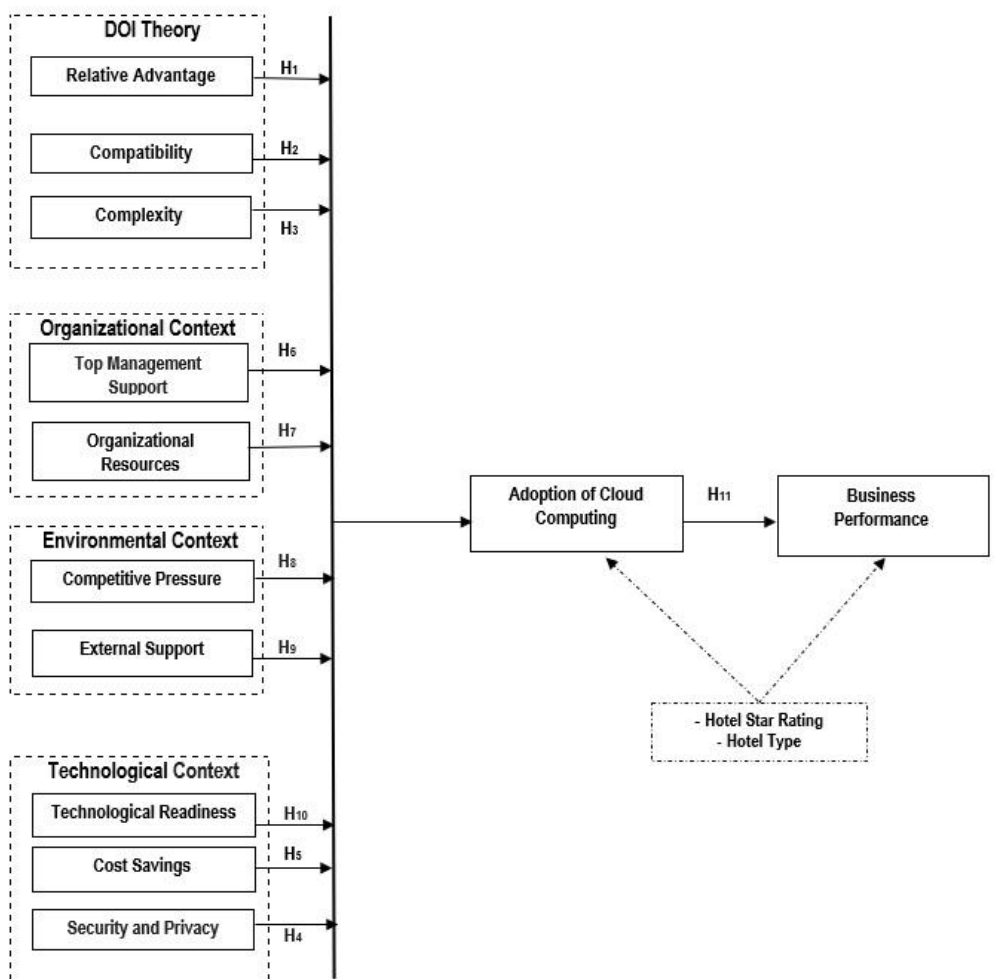


Figure 1 Research Model
Source: the authors

In this study, two control variables, the star rating of the establishment and the corporate structure of the enterprise, were included to reduce the variance in CCA and business performance that could potentially be influenced by these factors. Large hospitality enterprises are more likely to possess greater financial and human resources, which can lead to variances in both the CCA (Oliveira et al., 2014) and business performance (Khayer et al., 2020). Similarly, to address potential variances in adoption and performance arising from operational characteristics related to the corporate structure of the enterprise, the corporate structure was included in the model as another control variable.

3. Research Methodology

The questionnaire used in this study to collect data from senior managers and/or owners of businesses consists of two sections. The first section of the

questionnaire covers socio-demographic variables relating to the businesses and participants. The second section consists of statements relating to the external and internal latent variables included in the research model. Within the scope of the research, items related to complexity, compatibility, relative advantage, cost savings, management support, organisational resources, competitive pressure, external support, security and privacy concerns, business performance and technological readiness were evaluated using a five-point Likert scale and participants were asked to express their opinions on a scale ranging from ‘strongly disagree (1)’ to ‘strongly agree (5)’. The scale items used in the study were developed by drawing on previous studies in the relevant literature, and this 42-item scale is presented in detail in Appendix 1.

In quantitative research, the representativeness of the sample is critical to achieving valid and

reliable results (Neuman, 2014). Accordingly, data were collected using purposive random sampling from different accommodation establishments operating in Türkiye's seven geographical regions. This method allows for the selection of the subgroup that will contribute most to the research objective from within the randomly determined sample group, enabling the collection of more in-depth and rich data compared to standard random sampling (Baltacı, 2018). In particular, the inclusion of senior and middle managers directly responsible for information technology investments and operational decision-making processes in the research increased the suitability of the data obtained and the credibility of the research. The data collection process was conducted on a voluntary basis via email and corporate communication channels, with strict adherence to confidentiality and ethical principles. The 646 responses obtained from a total of 920 businesses (70% response rate) were reduced to a final sample of 609 valid surveys after excluding incomplete and invalid questionnaires. This sample size exceeds the limits considered sufficient in the literature for PLS-SEM modelling and allows for reliable analysis (Hair et al., 2021).

3.1. Data Analysis

The data obtained within the scope of the research were analysed using SPSS 25.0 and SmartPLS 4 software. Descriptive statistics such as frequency, percentage, mean, and standard deviation were used to reveal general trends regarding the participant profile and variables. The PLS-SEM approach was adopted to test the research model and hypotheses. The choice of this method was influenced by its ability to simultaneously assess the psychometric properties of measurement items, flexibly analyse complex models involving multiple latent variables and structural relationships, and not require strict normality assumptions (Urbach & Ahlemann, 2010; Sarstedt et al., 2022). Due to its estimation-focused structure and capacity to produce robust results, PLS-SEM is widely used in tourism and marketing literature (Hair et al., 2021; Yadegaridehkordi et al., 2020). It provides a suitable and reliable analytical framework for examining the determinants of CCA and its effects on business performance, particularly in models that integrate different theoretical frameworks, such as DOI and TOE, as in this study.

4. Findings and Interpretations

This section presents the findings obtained from the research and interprets them in light of the relevant literature.

4.1. Demographic Characteristics of Participants and Information on Hospitality Enterprises

An examination of the demographic profiles in Table 1 reveals that the majority of participants are in the middle-aged group (76.7%, aged 31-60). The gender distribution is relatively balanced. In terms of educational level, university graduates are in the majority (68.1%) and most participants hold critical positions in technology management and decision-making processes. Consequently, the participants' experience and educational level enhance the reliability of the findings obtained within the scope of the research and the representativeness of the assessments regarding technological innovations.

From the perspective of hospitality enterprises, the sample primarily consists of mid- and upper-segment hotels (59.6%) and encompasses establishments located in Türkiye's major tourist destinations and large cities (Istanbul, İzmir, Bursa, Muğla, Mersin, Antalya). The geographical distribution of the participants is diversified to include enterprises of various scales from different regions of Türkiye. This diversity enhances the generalizability of the obtained data across the country. In terms of operational tenure, the majority of the enterprises have been in business for many years (68.3%, 6 years and over), indicating their experience and maturity within the sector. Regarding corporate structure, independently owned enterprises predominate (75.2%) and their primary scope of operation is mostly at the local level (61.4%). These structural characteristics increase the sample's representativeness concerning the propensity for technology investment and innovation adoption, thereby strengthening the overall validity of the collected data. In conclusion, both the participant profile and the enterprise characteristics provide a solid foundation that supports the research's inferences regarding technology use and digital transformation processes.

Table 1 Numerical and Percentage Distributions of Information on Hospitality Enterprises and Demographic Variable

Individual Characteristics	Number (n)	%	Enterprise Characteristics	Number (n)	%		Number (n)	%
			Enterprise Rating			Enterprise Service Years		
Age			Star					
18-30	107	17.6	1 Star	28	4.6	1-5 year	109	17.9
31-45	236	38.8	2 Star	66	10.8	6-9 year	198	32.5
46-60	231	37.9	3 Star	123	20.2	10-15 year	218	35.8
61 and over	35	5.7	4 Star	134	22.0	15 and over	84	13.8
Gender			5 Star	106	17.4	Province of Enterprise		
Male	328	53.9				Istanbul	107	17.6
Female	281	46.1	Boutique Hotel	91	14.9	Izmir	91	14.9
Education						Bursa	67	11.0
Middle School	27	4.4	Holiday Village	61	10.0	Muğla	53	8.7
High School	94	15.4	Corporate Structure			Mersin	42	6.9
Associate Degree	140	23.0	Chain Enterprise	151	24.8	Antalya	35	5.7
Bachelor's Degree	273	44.8	Independent Enterprise	458	75.2	Gaziantep	30	4.9
Postgraduate Degree	75	12.3	Operation Type			Adana	24	3.9
Position						Trabzon	21	3.4
General Manager	92	15.1	National	123	20.2	Kayseri	17	2.8
Department Manager	116	19.0	International	112	18.4	Balıkesir	18	3.0
IT Manager	190	31.2	Local	374	61.4	Ankara	16	2.6
Business Owner	177	29.1	Total	609	100.0	Samsun	13	2.1
Other	34	5.6				Rize	11	1.8
Total	609	100.0				Nevşehir	10	1.6
						Diğer	54	8.9
						Total	609	100.

Source: the authors

4.2. Analysis Results for the Research Scale

The reliability, convergent validity, and multicollinearity assessments of the measurement model are presented in Table 2. Internal consistency reliability was first evaluated using Cronbach’s alpha and Composite Reliability (CR) values. For all constructs, Cronbach’s alpha coefficients exceeded the recommended threshold of 0.70, indicating a high level of internal consistency (Nunnally, 1978; Hair et al., 2021). Similarly, CR values for all constructs were 0.90 or higher, further confirming the robustness of the measurement model in terms of internal reliability (Jöreskog, 1971; Gefen et al., 2000; Hair et al., 2021). Convergent validity was assessed through Average Variance Extracted (AVE) values, all of which exceeded the recommended minimum value of 0.50, indicating that each construct sufficiently explains the variance of its associated indicators (Hair et al., 2019). In addition, all standardized outer loadings were above 0.70, confirming strong relationships between the observed indicators and their respective latent constructs (Chin, 1998; Hair et al., 2021). Furthermore, skewness and kurtosis values fell within the acceptable range of ± 2 , indicating no severe deviations from normality (George & Mallery, 2010). To assess potential

multicollinearity issues, Variance Inflation Factor (VIF) values were examined and found to range between 1.889 and 4.157, remaining below the critical thresholds and indicating no multicollinearity concerns within the model (O’Brien, 2007; Kline, 2011; Hair et al., 2019). Overall, these results demonstrate that the measurement model meets the recommended criteria for reliability and validity and is suitable for subsequent structural model analysis.

Table 2 Reliability, Validity, Factor Loadings, and Statistical Analysis Findings for the Research Variables

Variables	O	Std. Dev.	Skewness	Kurtosis	VIF	Factor Loadings	Cronbach's alpha	CR	AVE
Relative Advantage	3.33	0.96	-0.674	-0.557			0.967	0.967	0.936
Item1					2.287	0.853			
Item2					2.076	0.801			
Item3					2.367	0.831			
Item4					2.378	0.833			
Item5					2.245	0.843			
Compatibility	3.24	0.99	-0.648	-0.701			0.886	0.921	0.745
Item1					2.382	0.881			
Item2					2.104	0.837			
Item3					2.454	0.863			
Item4					2.455	0.871			
Complexity	2.99	1.12	-0.241	-1.305			0.911	0.925	0.757
Item1					2.602	0.774			
Item2					2.663	0.858			
Item3					3.032	0.890			
Item4					3.006	0.949			
External Support	3.19	0.94	-0.601	-0.673			0.889	0.923	0.750
Item1					2.372	0.876			
Item2					1.975	0.823			
Item3					2.753	0.885			
Item4					2.648	0.879			
Organizational Resources	3.31	0.95	-0.702	-0.455			0.885	0.921	0.743
Item1					2.345	0.866			
Item2					2.059	0.832			
Item3					2.432	0.872			
Item4					2.579	0.879			
Competitive Pressure	3.23	0.96	-0.561	-0.537			0.862	0.915	0.783
Item1					2.150	0.896			
Item2					2.091	0.854			
Item3					2.457	0.903			
Top Management Support	3.27	0.97	-0.577	-0.602			0.854	0.910	0.772
Item1					2.004	0.890			
Item2					2.162	0.863			
Item3					2.178	0.882			
Technological Readiness	3.26	0.92	-0.663	-0.383			0.852	0.910	0.771
Item1					2.055	0.875			
Item2					1.957	0.859			
Item3					2.448	0.899			
Security and Privacy	2.97	1.15	-0.126	-1.291			0.890	0.929	0.814
Item1					2.364	0.843			
Item2					2.692	0.924			
Item3					2.919	0.936			
Cost Savings	3.23	1.01	-0.506	-0.862			0.852	0.910	0.772
Item1					1.907	0.865			
Item2					2.197	0.877			
Item3					2.278	0.893			
CCA	4.30	1.57	-0.933	-0.574			0.931	0.967	0.936
Item1					4.157	0.965			
Item2					4.157	0.970			
Business Performance	3.29	0.91	-0.653	-0.227			0.873	0.913	0.725
Item1					1.986	0.827			
Item2					1.889	0.813			
Item3					2.629	0.884			
Item4					2.537	0.880			

Mean (M) | Standard Deviation (SD) | Variance Inflation Factor (VIF) | Composite Reliability (CR) | Average Variance Extracted (AVE)

Source: the authors

According to the Fornell & Larcker (1981) criterion used in assessing discriminant validity, the square root of a construct's Averaged Variance Explained (AVE) value should be greater than that construct's correlation coefficients with other constructs; this indicates that the construct shares more variance with its own indicators and possesses sufficient discriminant validity (Fornell

& Larcker, 1981; Hair et al., 2019). Upon examining the correlation matrix in Table 3, it is observed that the square root of AVE values written in bold on the diagonal are greater than the inter-construct correlation coefficients, thus satisfying the Fornell-Larcker criterion. This finding indicates that the measurement model is satisfactory in terms of discriminant validity.

Table 3 Fornell-Larcker Criterion Values

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1-CCA	0.967											
2-External Support	0.487	0.866										
3- Relative Advantage	0.529	0.608	0.832									
4-Security and Privacy Concerns	-0.078	0.217	0.067	0.902								
5-Complexity	-0.086	0.231	0.045	0.639	0.870							
6-Organizational Resources	0.507	0.745	0.673	0.182	0.169	0.862						
7-Cost Savings	0.480	0.609	0.663	0.162	0.144	0.707	0.879					
8-Competitive Pressure	0.340	0.664	0.503	0.309	0.264	0.611	0.496	0.885				
9-Technological Readiness	0.491	0.701	0.613	0.177	0.181	0.714	0.636	0.642	0.878			
10-Compatibility	0.585	0.650	0.831	0.071	0.065	0.717	0.673	0.536	0.681	0.863		
11-Top Management Support	0.457	0.660	0.608	0.167	0.189	0.712	0.640	0.570	0.658	0.661	0.879	
12-Business Performance	0.588	0.692	0.717	0.153	0.125	0.723	0.673	0.597	0.725	0.728	0.653	0.852

Source: the authors

In the study, the Heterotrait-Monotrait (HTMT) ratio analysis was applied to ensure discriminant validity; HTMT is more sensitive in detecting lack of discriminant validity compared to the traditional Fornell-Larcker criterion (Henseler et al., 2015). The generally recommended upper limit for HTMT in the literature is 0.90 and ratios below this value indicate insufficient discrimination between

variables (Hair et al., 2019). When examining Table 4, ratios remain below 0.90. These findings indicate that the latent structures in the model are conceptually distinguishable from one another, that the measurement model preserves the conceptual integrity of each variable and that discriminant validity is therefore ensured.

Table 4 HTMT for Research Variables

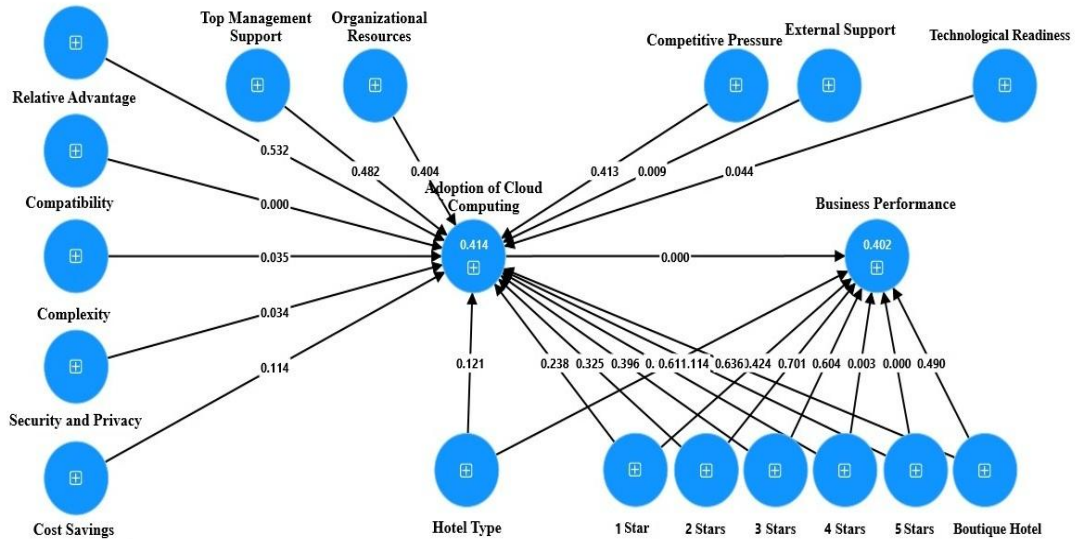
Variables	1	2	3	4	5	6	7	8	9	10	11	12
1- CCA												
2- External Support	0.533											
3- Relative Advantage	0.577	0.685										
4- Security and Privacy Concerns	0.080	0.247	0.093									
5- Complexity	0.065	0.275	0.090	0.718								
6- Organizational Resources	0.557	0.841	0.758	0.212	0.215							
7- Cost Savings	0.537	0.700	0.761	0.196	0.187	0.813						
8- Competitive Pressure	0.375	0.754	0.573	0.358	0.317	0.694	0.576					
9- Technological Readiness	0.550	0.805	0.705	0.210	0.224	0.823	0.747	0.744				
10- Compatibility	0.639	0.734	0.838	0.090	0.108	0.811	0.774	0.611	0.785			
11- Top Management Support	0.504	0.755	0.695	0.197	0.238	0.814	0.745	0.663	0.770	0.756		
12- Business Performance	0.651	0.786	0.813	0.182	0.167	0.823	0.780	0.686	0.841	0.827	0.755	

Source: the authors

4.4. Evaluation of the Research Model and Hypothesis Results

In this section of the research, the hypotheses of the developed research model are addressed in detail, and the findings obtained from the research conducted regarding these hypotheses are

presented. First, Figure 2 shows the structural model obtained as a result of the SmartPLS analysis.



*The figure presents p-values and R²

Figure 2 Results of the Structural Model

Source: the authors

Table 5 Q² and R² Coefficients for the Research Model

Variables	Q ²	R ²	Adjusted R ²
CCA	0.320	0.414	0.397
Business Performance	0.442	0.402	0.393

Source: the authors

Upon examining Table 5, the R² values for the variables of CCA business performance in the model were found to be 0.414 and 0.402, respectively; this indicates that the model explains

approximately 40% of the variance in these constructs. These ratios indicate a moderate level of explanatory power in the context of social sciences (Hair et al., 2017). On the other hand, the Q² values being greater than zero for both variables (0.320 and 0.442) demonstrates that the model possesses predictive relevance. This situation reveals that the model not only explains the available data but is also successful in out-of-sample predictions.

Table 6 Path Coefficients for the Control Variables of the Research

Path	Original Sample (O)	Sample Mean (M)	S.t.d.	t Statistics	p Values
1 Star → CCA	-0.243	-0.254	0.205	1.181	0.238
1 Star → Business Performance	-0.137	-0.142	0.171	0.799	0.424
2 Stars → CCA	-0.150	-0.155	0.153	0.985	0.325
2 Stars → Business Performance	-0.058	-0.059	0.150	0.384	0.701
3 Stars → CCA	-0.108	-0.109	0.127	0.849	0.396
3 Stars → Business Performance	0.064	0.061	0.124	0.519	0.604
4 Stars → CCA	-0.167	-0.170	0.127	1.324	0.186
4 Stars → Business Performance	0.391	0.391	0.131	2.971	0.003*
5 Stars → CCA	-0.213	-0.214	0.135	1.581	0.114
5 Stars → Business Performance	0.563	0.562	0.139	4.051	0.000*
Boutique Hotel → CCA	-0.063	-0.065	0.133	0.473	0.636
Business Type → Business Performance	-0.051	-0.052	0.101	0.508	0.611
Business Type → CCA	-0.130	-0.129	0.083	1.552	0.121
Boutique Hotel → Business Performance	0.086	0.085	0.125	0.691	0.490

*p<0.05, s.t.d.: standard deviation

Source: the authors

Within the scope of the structural model, categorical control variables were converted into dummy variables to enable analytical processing

(Gujarati & Porter, 2009). In this process, one category of the categorical variable was designated as the reference category and was not directly

included in the model; other categories were included in the model comparatively relative to this reference category (Hair et al., 2021). In the research, the corporate structure of the enterprise and the enterprise class were added to the model as control variables; Holiday Village was designated as the reference category for enterprise class and Chain Enterprise was designated as the reference category for corporate structure. In this context, all other enterprise classes and independent enterprises were evaluated relative to their respective reference categories.

According to the structural model analysis presented in table 6, most control variables did not have a significant effect on the CCA and business performance ($p > 0.05$), indicating that lower-star hotels do not play a distinct role in technological

adaptation and performance outcomes. However, the effect of "4-star" hotels on business performance was statistically significant ($\beta = 0.391$, $p = 0.003$) and the effect of "5-star" hotels was highly significant ($\beta = 0.563$, $p < 0.001$).

In the research model, the factors influencing the CCA and the effect of this adoption on business performance were analysed through path coefficients in the structural model. In this context, the obtained findings are presented in Table 7 and the evaluation was conducted by considering the magnitude of the relevant path coefficients, their levels of statistical significance and the direction of their effects. The findings derived from the Partial Least Squares Structural Equation Modelling (PLS-SEM) analysis confirmed that 6 among the 11 hypotheses received support.

Table 7 Path Coefficients for the Research Variables

Path	Original Sample (O)	Sample Mean (M)	Standard Deviation	t Statistics	p Values	Hypothesis
External Support → CCA	0.146	0.146	0.056	2.623	0.009*	H9: Accepted
Relative Advantage → CCA	0.041	0.044	0.066	0.625	0.532	H1: Rejected
Security and Privacy Concerns → CCA	-0.088	-0.093	0.041	2.116	0.034*	H4: Accepted
Complexity → CCA	-0.111	-0.106	0.053	2.104	0.035*	H3: Accepted
Organizational Resources → CCA	0.054	0.053	0.064	0.835	0.404	H7: Rejected
Cost Savings → CCA	0.074	0.074	0.047	1.581	0.114	H5: Rejected
Competitive Pressure → CCA	-0.039	-0.038	0.048	0.819	0.413	H8: Rejected
Technological Readiness → CCA	0.114	0.113	0.057	2.013	0.044*	H10: Accepted
Compatibility → CCA	0.289	0.287	0.067	4.305	0.000*	H2: Accepted
Top Management Support → CCA	0.036	0.034	0.051	0.703	0.482	H6: Rejected
CCA → Business Performance	0.525	0.525	0.033	16.032	0.000*	H11: Accepted

* $p < 0.05$

Source: the authors

4.5. Discussion of Findings

A theoretical framework integrating DOI and TOE perspectives was constructed to identify principal factors shaping CCA within hospitality organizations and its influence on business performance, yielding 11 hypotheses. The findings derived from the Partial Least Squares Structural Equation Modelling (PLS-SEM) analysis confirmed that 6 among the 11 hypotheses received support. Additionally, R^2 values for CCA and business performance variables within the framework were established as 0.414 and 0.401, respectively; this demonstrates that the framework accounts for approximately 40% of variance within these constructs.

According to the research findings, the compatibility variable has a strong, positive and statistically significant effect on the CCA (H2). This indicates that the extent to which CC are

compatible with the existing business processes, infrastructure, and organisational structure of accommodation businesses plays a critical role in adoption decisions. In particular, the ability of systems such as reservation, customer management, payment, and reporting to work in an integrated manner with cloud-based solutions facilitates the adoption of this technology. This finding is supported by numerous previous studies (Athambawa et al., 2023; Phu et al., 2025; KardanMoghaddam et al., 2022; Al-Shura et al., 2018; Lawan et al., 2021; Atuah et al., 2023).

Conversely, the complexity variable negatively and significantly affects the CCA (H3). This result is also consistent with studies in the literature (Stieninger et al., 2018; Al Hadwer et al., 2021; AlBar & Hoque, 2019; Lawan et al., 2021; Sayginer & Ercan, 2020; Athambawa et al., 2023). Therefore, making their systems simpler, more user-friendly and easier to implement, along with

providing effective training and technical support to accommodation businesses, will be an important strategy for increasing adoption rates.

Correspondingly, security and privacy apprehensions similarly exert negative and statistically significant influence on CCA (*H4*). This outcome reveals that hospitality organizations demonstrate hesitant posture toward CC, contemplating customer data security alongside proprietary business information security, user privacy and information leakage vulnerabilities. Alternative investigations within scholarly literature (Phu et al., 2025; Stieninger et al., 2018; Priyadarshinee et al., 2017; AlBar & Hoque, 2019) similarly validate this adverse influence of security and privacy apprehensions on CCA. Within this framework, cloud service providers treating security and privacy apprehensions of hospitality organizations seriously, presenting reliable solutions will fulfil critical functions in elevating adoption rates.

The influence of the external support variable on CCA was established as positive and statistically significant (*H9*). This discovery demonstrates parallels with alternative investigations (Nosheen et al., 2025; Karim & Rampersad, 2017; Ali et al., 2026; Yadegaridehkordi et al., 2020). The CCA by accommodation businesses is facilitated by support from the external ecosystem, such as suppliers and regulatory bodies. This situation demonstrates that corporate ecosystem actors, such as government agencies and suppliers, serve as critical catalysts in technological adaptation. In summary, external environmental support plays an important role in enabling organisations to adopt innovative technologies more quickly.

Correspondingly, technological readiness level similarly exerts positive and significant influence on CCA (*H10*). This discovery proposes that the more advanced the prevailing technological infrastructure of hospitality organizations, the more straightforward their trajectory of adopting such innovative technologies can become. Numerous investigations within scholarly literature (Lawan et al., 2021; KardanMoghaddam et al., 2022; AlBar & Hoque, 2019; Al-Shura et al., 2018; Ayoobkhan & Kaldeen's 2020; Nosheen et al., 2025) validate this research discovery, unambiguously demonstrating that technological readiness fulfils critical functions in CCA.

Contrary to the prevailing view in the literature, this study found no statistically significant effect of relative advantage on CCA (*H1*). This finding

differs from numerous studies suggesting that factors such as cost advantage, flexibility, and operational efficiency positively influence technology adoption (Al Hadwer et al., 2021; Atuah et al., 2023; Athambawa et al., 2023). This situation can be explained by the fact that decision-makers in Turkish hospitality enterprises do not yet perceive the benefits offered by CC as concrete and short-term gains. Particularly in the highly competitive Turkish tourism sector, operational priorities such as customer satisfaction, price competition, and occupancy rates may have taken precedence over technology investments, thereby weakening the perception of relative advantage. Furthermore, factors such as system adaptation requirements, hidden costs, and concerns about loss of control may overshadow the advantages offered by this technology (Oliveira et al., 2014). In this respect, the findings are consistent with the limited number of studies that reveal that relative advantage may not be a fundamental determinant in every context (Gutierrez et al., 2015; Ming et al., 2018).

This study diverges from a broad literature that treats cost savings as a fundamental determinant (Khayer et al., 2020; Ayoobkhan & Kaldeen, 2020; Chen et al., 2022; Ming et al., 2018). This unique finding in the Turkish context can be explained by macroeconomic factors such as exchange rate fluctuations and uncertain demand patterns overshadowing long-term savings expectations, and by decision-makers perceiving hidden costs associated with CC investments such as licensing, system adaptation, and integration as significant risk factors. This finding demonstrates that cost advantage is not an element that automatically triggers technology adoption in every sectoral and national context; rather, local economic dynamics and operational priorities significantly shape this perception.

Contrary to expectations, this study found no statistically significant effect of top management support on the CCA (*H6*). This finding diverges from a broad literature that considers top management support as one of the key determinants of technology adoption (AlBar & Hoque, 2019; Lawan et al., 2021; Atuah et al., 2023). Indeed, Ayoobkhan and Kaldeen's (2020) study on the Sri Lankan hospitality industry found that top management support had a significant and positive effect on CCA.

This study's different outcome can be explained by organisational and sectoral dynamics specific to the Turkish context. In Turkish hospitality

enterprises, decisions regarding technology are mostly taken at the operational level by IT departments or field managers; senior management is involved in the process indirectly, mainly through budget approval and the overall strategic framework. Particularly in Turkish accommodation businesses at the SME level, senior management's limited grasp of the technical details of technological infrastructure investments may lead to support being perceived as weak by employees and implementers. Furthermore, intense competition, seasonality, and cost pressures in the Turkish tourism sector cause technology investments to be viewed as a tool for daily operational efficiency rather than strategic transformation; this situation also limits the prominence of senior management support as a decisive factor in the adoption process. In this respect, the findings are consistent with recent studies showing that top management support may not be equally effective in every national and sectoral context (Amini & Bakri, 2015; Sithole & Ruhode, 2021; KardanMoghaddam et al., 2021; Aligarh et al., 2023).

Although the effect of organisational resources on CCA is positive, it is not statistically significant (*H7*). This indicates that the financial, human, and technological resources possessed by organisations do not, on their own, directly determine the CCA. For a successful technology implementation, it is not only the presence of these resources that is required, but also their strategic direction and continuous reinforcement with support (Aligarh et al., 2023). The findings reveal that resource adequacy has a limited effect on the adoption process in the hospitality sector, whereas technological readiness plays a more decisive role. This is because technological readiness encompasses not only the availability of resources but also the business's ability to manage its existing infrastructure and its capacity to use technology in a manner consistent with strategic objectives. Therefore, in an adaptation requiring technical expertise, such as CC, the level of technological readiness emerges as a more critical factor than general resource adequacy.

In academic literature, competitive pressure is generally considered a key determinant of technology adoption (Alkhater et al., 2015; Amini & Bakri, 2015) and even a strategic necessity in market competition (Gamage, 2019; Mokhtar & Mahomed, 2025). Numerous studies supporting this view have demonstrated that competitive pressure positively influences the CCA (Lawan et

al., 2021; Atuah et al., 2023; Matias & Hernandez, 2021; Al Hadwer et al., 2021). However, the findings of this study indicate that competitive pressure does not have a statistically significant effect on CCA (*H8*). This result is consistent with some studies that do not view competitive pressure as one of the key determinants of CCA (Priyadarshinee et al., 2017; Job, 2016; Skafi et al., 2020). However, it diverges from the findings of Ayoobkhan and Kaldeen (2020), which reveal a significant effect of competitive pressure on CCA in the Sri Lankan hospitality sector. In the Turkish context, this difference can be explained by accommodation businesses perceiving competition more in terms of elements that directly affect the customer, such as customer experience, service quality and pricing, and not viewing technological investments that remain in the background, such as CC, as strategic tools that create a competitive advantage in the short term. This finding demonstrates that the impact of competitive pressure on technology adoption may vary depending on the national, sectoral, and organisational context.

Within the investigation's scope, the effect of CCA on business performance was identified as the strongest and most significant relationship (*H11*). This finding demonstrates that CC provide a significant and positive contribution to performance by optimising workflows. This result aligns with the general literature (Chen et al., 2022; Khayer et al., 2020; Garrison et al., 2015; Rawashdeh & Rawashdeh, 2023; Ahmad et al., 2025) and studies specific to the hospitality sector (Hui & Mohammadi, 2024; Mansour et al., 2020). For accommodation businesses, CC significantly enhances financial performance by providing benefits such as operational improvement, increased efficiency, data access, and accelerated decision-making processes (Ionescu & Andronie, 2021). Consequently, CCA offers cost-effectiveness, flexibility and time savings in critical areas such as reservation management, customer relations and inventory tracking, thereby enhancing service quality and customer satisfaction. This demonstrates that it is a strategic investment that supports competitiveness and sustainable growth.

Additionally, the effects of other control variables included in the framework (star rating, corporate structure) on CCA and business performance were not found to be statistically significant. This indicates that technological adaptation can be explained more comprehensively

not only by structural elements but also by contextual and organisational determinants. Among the control variables, only business classification (particularly 4- and 5-star hotels) had a positive and significant effect on business performance. This finding highlights the direct relationship between service quality and performance, suggesting that business performance improves as the classification level increases. This situation can be attributed to high-standard accommodation businesses having more advanced operational workflows and management practices. This observation is consistent with studies such as Chen et al. (2022) and Zhang et al. (2016), which show that business size affects performance.

5. Conclusion

This study examined the factors shaping the CCA in accommodation businesses operating in Türkiye. The findings reveal that compatibility has the strongest and most positive effect on adoption; conversely, perceived complexity and security and privacy concerns negatively affect adoption. Furthermore, while external support and technological readiness were found to increase adoption, factors frequently emphasised in the literature, such as relative advantage, top management support, organisational resources, and competitive pressure, were not found to be significant in this study. This indicates that technology adoption decisions in Turkish accommodation businesses are shaped more by operational feasibility and perceived risks. This situation is particularly evident in SME-scale businesses. Another important finding of the study is that CC has a positive and significant impact on business performance. The fact that this effect is stronger in four- and five-star hotels reveals that CC is a strategic tool for businesses with high digital maturity, while also showing that small-scale businesses need supportive mechanisms to benefit effectively from this technology.

When evaluated from an application perspective, the findings provide concrete and actionable recommendations for accommodation businesses, particularly SME-scale hotels. The findings indicate that CC strategies should be built not only on the premise of cost savings, but also on compatibility with existing business processes, ease of use, and the systematic development of employees' digital competencies. In this context, adopting gradual transition strategies rather than sudden and comprehensive shifts, implementing

pilot applications, and implementing continuous training programmes targeting operational staff can significantly reduce perceived complexity and resistance to technology. Furthermore, managers need to approach the digital transformation process from a long-term perspective of increased efficiency and performance, rather than short-term operational pressures.

From the perspective of technology providers, the findings highlight the importance of solutions featuring user-friendly interfaces tailored to the hospitality sector's needs, high data security standards, and transparent and predictable pricing models. In particular, 24/7 technical support, trial versions, and scalable service packages can accelerate the adoption process by reducing the risks perceived by SMEs. For policymakers, the study shows that clear and reassuring legal regulations on data security and privacy, financial incentives for CC, and the development of digital transformation roadmaps specific to the accommodation sector are of critical importance. Such support mechanisms will facilitate the inclusion of small and medium-sized enterprises in the digital transformation process.

From an academic perspective, this study provides strong empirical evidence for the debate that technology adoption factors are not universal and context-independent, but rather shaped by national, cultural, and sectoral dynamics. The integration of the TOE framework with DOI theory and the testing of the model with data from 609 accommodation businesses has increased its analytical robustness. In this respect, the study offers a flexible, comparable, and context-sensitive analytical framework not only for CC but also for future research examining the adoption of other digital innovations. Overall, the research presents important theoretical and practical implications for managing digital transformation processes in Türkiye's accommodation sector in a more strategic, sustainable, and effective manner.

5.1. Limitations and Suggestions for Future Research

This study has certain limitations. Firstly, the fact that the research is limited to accommodation businesses in Türkiye indicates that the findings may have been shaped by national economic conditions, institutional structures and sectoral dynamics. Comparative or multi-group analyses conducted by applying the model in different countries could reveal how cultural and economic factors shape the determinants of technology

adoption. Secondly, the cross-sectional research design cannot reflect the adoption dynamics of CC over time. Future longitudinal studies could provide deeper theoretical insights into how adoption factors change as organisational learning and experience increase. Finally, due to the study's limitation to the DOI and TOE frameworks, the use of additional contextual variables such as organisational culture or macroeconomic uncertainty, along with qualitative methods, could enhance the explanatory power of future research.

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Appendix.1. Measurement items

Variable	References
Relative Advantage 1.Cloud computing allows us to manage business operations efficiently. 2.The use of cloud computing services improves the quality of operations. 3.Using cloud computing enables us to perform specific tasks more quickly. 4.The use of cloud computing offers new opportunities. 5.Using cloud computing enhances business productivity.	Oliveira vd., 2014; Pathan vd., 2017; Tashkandi ve Al-Jabri, 2015; Al-Jabri, 2015
Compatibility 1.The use of cloud computing is compatible with the way our hotel operates. 2.The use of cloud computing is fully compatible with our current business operations. 3.The use of cloud computing is consistent with our hotel's corporate culture and value system 4.The use of cloud computing is compatible with our hotel's existing hardware and software.	Oliveira vd., 2014; Alharbi vd., 2016; Yadegaridehkordi vd., 2020; Lian vd. 2014; Pathan vd., 2017; Tashkandi ve Al-Jabri, 2015
Complexity 1.Using cloud computing requires too much mental effort. 2.The use of cloud computing is too complex for business operations. 3.The skills required to adopt cloud computing are too complex for our hotel employees. 4.It is difficult to migrate our existing systems to cloud computing.	Lian vd. 2014; Oliveira vd., 2014; Yadegaridehkordi vd., 2020; Pathan vd., 2017; Tashkandi ve Al-Jabri, 2015
Security and Privacy Concerns 1.Our hotel has concerns about data security in cloud computing. 2.Our customers have concerns about data security in cloud computing. 3.There are concerns regarding privacy in cloud computing.	Oliveira vd., 2014
Cost Savings 1.The benefits gained from cloud computing outweigh the costs incurred. 2.The use of cloud computing reduces energy and environmental costs. 3.The maintenance costs of cloud computing are very low.	Oliveira vd., 2014
Top Management Support 1.Hotel management supports the adoption of cloud computing. 2.Hotel management believes this technology has potential strategic value. 3.Hotel management is willing to take financial and organizational risks related to the adoption of cloud computing.	Oliveira vd., 2014; Yadegaridehkordi vd., 2020; Pathan vd., 2017
Competitive Pressure 1.The adoption of cloud computing influences competition in the industry. 2.Our hotel feels pressure from competitors to adopt cloud computing. 3.Most of our competitors have adopted cloud computing.	Oliveira vd., 2014; Pathan vd., 2017; Al-Jabri, 2015
Organizational Resources 1.Our hotel has the technological resources to adopt cloud computing. 2.Our hotel has the financial resources to adopt cloud computing. 3.Our hotel does not face difficulties in obtaining the necessary resources to adopt cloud computing. 4.Our hotel has employees who can quickly learn and apply new information technologies.	Yadegaridehkordi vd., 2020
External Support 1.Suppliers encourage our hotel to adopt cloud computing by offering free training sessions. 2.Adequate technical support will be provided by suppliers for the adoption of cloud computing. 3.Suppliers and business partners actively promote the use of cloud computing. 4.Public policies established by the government encourage the adoption of cloud computing.	Alharbi vd., 2016; Yadegaridehkordi vd., 2020; Tashkandi ve Al-Jabri, 2015
Technological Readiness 1.Our hotel provides Internet access to all employees. 2.Our hotel understands how information technologies can be used to support business operations. 3.Our hotel makes good use of information technologies to achieve its goals.	Oliveira vd., 2014; Alharbi vd., 2016
Cloud Computing Adoption 1.At what stage is your hotel currently regarding the adoption of cloud computing? - We are not considering adoption. - We are currently evaluating it (e.g., in a pilot project). - Evaluated but not planning to adopt. - Evaluated and planning to adopt. - We have already adopted cloud computing services. 2.If you foresee your hotel adopting cloud computing in the future, when do you think it will happen? - We are not considering adoption. - In more than 5 years.- Between 2 and 5 years.- Between 1 and 2 years.- In less than 1 year. - We have already adopted cloud computing services.	Oliveira vd., 2014
Business Performance 1.I believe cloud computing can provide us with more accurate data. 2.I believe cloud computing can increase our hotel's profitability. 3.I believe cloud computing can improve our financial performance. 4.I believe cloud computing can enhance our hotel's operational performance.	Garrison vd., 2015; Yadegaridehkordi vd., 2020

Entrepreneurial Orientation and Business Performance: Evidence from Hungarian SMEs

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Abstract

Background: Entrepreneurial orientation (EO) is a central concept in strategic management research; however empirical evidence on its performance implications remains context dependent. In particular, studies from Central and Eastern Europe are scarce despite the economic significance of small and medium-sized enterprises in the region.

Purpose: This study examines the relationship between entrepreneurial orientation and business performance in Hungarian small and medium-sized enterprises. This study also explores whether firm performance and entrepreneurial orientation vary across managerial gender, industry affiliation, and geographic location.

Study design/methodology/approach: This research is based on a cross-sectional survey of 415 Hungarian SMEs conducted in 2024. Entrepreneurial orientation was measured using multi-item Likert scales for the three sub-dimensions, while firm performance was assessed through self-reported indicators. Linear regression and chi-square tests were used to analyze the relationships and contextual differences.

Findings/conclusions: The findings show a positive relationship between entrepreneurial orientation and firm performance. Innovation and proactivity are strongly associated with performance outcomes, whereas risk-taking exhibits a comparatively weaker relationship. Significant differences in entrepreneurial orientation and performance are observed across gender, industry and regional contexts.

Limitations/future research: This study contributes to entrepreneurial orientation research by providing evidence from a Central and Eastern European transition economy and reinforcing the multidimensional nature of entrepreneurial orientation. The results highlight the importance of contextual factors in shaping the performance of entrepreneurial behavior.

Keywords

entrepreneurial orientation, innovation, proactivity, risk-taking, firm performance, Central and Eastern Europe

Introduction

Small and medium-sized enterprises (SMEs) operate in an increasingly turbulent economic environment, characterized by technological transformation, global competition, and rapidly changing market conditions. These developments place considerable pressure on firms, especially SMEs, to continuously adapt, innovate, and refine their strategic posture to sustain growth and competitiveness (Meirinhos et al., 2023; Freihat, 2020). In this context, managerial behavior and leadership decisions become especially critical, as SMEs typically rely on limited internal resources and depend heavily on the owner-manager's

strategic orientation (Roffia et al., 2022). This is particularly relevant in emerging and transition economies, where constitutional shifts and resource constraints shape firms' ability to respond effectively to environmental challenges.

Entrepreneurial orientation (EO) has long been recognized as a central strategic construct that captures a firm's propensity to innovate, proactively pursue opportunities, and engage in calculated risk-taking (Miller, 1983). Previous studies have confirmed that EO contributes to superior firm performance by fostering opportunity recognition, enhancing adaptability, and enabling firms to leverage internal capabilities more effectively (Molote et al., 2025; Sekyere & Jalali,

2024; Yahaya & Nadarajah, 2023). While a substantial body of research documents the EO-performance relationship, most empirical evidence originates from Western economies and advanced technological markets. Much less is known about how EO functions in Central and Eastern Europe (CEE), where SMEs operate under different institutional, cultural, and competitive conditions.

Despite the growing academic interest, empirical evidence on EO within the Hungarian SME sector remains scarce, and the mechanisms through which EO affects performance in this specific socio-economic environment are not yet well understood. Moreover, the potential heterogeneity of the EO-performance link across different managerial, industrial, and regional contexts has received limited scholarly attention in CEE countries to date. Existing studies rarely examine how gender, industry affiliation, or geographic location may influence either the level of EO or its effectiveness in driving firm performance, despite indications that structural and demographic factors play a significant role in shaping entrepreneurial behavior. Consequently, a systematic examination of EO in Hungary can extend the theoretical understanding and address an important empirical gap.

To address these limitations, this study investigates the following research questions:

Q1: What is the relationship between entrepreneurial orientation and the organizational performance of Hungarian SMEs?

Q2: How do managerial gender, industry classification, and geographical location influence both EO and SME performance?

This study makes several contributions to the literature. First, it provides empirical evidence from Hungary, a transition economy where EO research is still underrepresented, thereby contributing to regional diversification in EO studies. Second, by examining multiple contextual moderations (managerial gender, industry, and regional location), it extends the theoretical discussion on the contingent nature of EO, responding to recent calls for more contextualized EO research. Third, it offers practical implications for SME managers and policymakers by identifying the specific dimensions of EO that strongly influence performance within the Hungarian business environment.

The remainder of this paper is organized as follows. Section 1 reviews the theoretical foundations of EO and develops hypotheses. Section 2 outlines the methodology, data collection

process, and analytical techniques. Section 3 presents the empirical results, followed by a discussion in Section 4. Finally, the conclusion contains the theoretical and practical implications, limitations, and future research directions.

1. Literature Review

1.1. Entrepreneurial Orientation as a strategic orientation

Entrepreneurial orientation (EO) is widely regarded as a core construct in strategic management that captures the strategic posture through which firms identify, evaluate and exploit entrepreneurial opportunities. One of the earliest conceptualizations of EO was provided by Miller (1983), who defined entrepreneurial firms as those that engage in innovation, proactive market behavior, and risk-taking. Covin and Slevin (1989) further developed this approach by conceptualizing EO as a firm-level strategic orientation that reflects managerial preferences and decision-making practices under conditions of uncertainty. Their seminal work demonstrated that EO is particularly critical for small firms operating in hostile or dynamic environments, where entrepreneurial behavior can compensate for limited resources and structural constraints.

A major theoretical advance was introduced by Lumpkin and Dess (1996), who emphasized the multidimensional and context-dependent nature of EO. They argued that EO consists of distinct dimensions, most notably innovation, proactivity, and risk-taking, which may vary independently and whose effects on performance depend on environmental and organizational contingencies. This perspective shifted EO research away from purely additive logic and highlighted the importance of contextual factors, such as dynamism, competitive intensity, and organizational structure.

Building on these foundations, Wiklund and Shephard (2005) proposed a configurational approach to EO, demonstrating that entrepreneurial orientation enhances small business performance by enabling firms to leverage internal resources, pursue growth opportunities, and engage in strategic learning. Their findings underscore that EO operates as part of a broader strategic system rather than an isolated determinant of performance. Together, these classical contributions establish EO as a strategic orientation linking managerial behavior, organizational capabilities, and

environmental conditions, particularly in the context of SMEs.

1.2. Entrepreneurial Orientation and SME performance

A substantial body of empirical research confirms a generally positive relationship between EO and firm performance, especially in small- and medium-sized enterprises (SMEs). Firms exhibiting higher levels of EO tend to outperform their less entrepreneurial counterparts in terms of growth, profitability, and competitive positioning (Rauch et al., 2009; Wiklund & Shepherd, 2005). EO contributes to performance by fostering innovation-driven strategies, proactive market engagement, and strategic flexibility (Octavia et al., 2020; Williams et al., 2020).

However, the EO-performance relationship is not consistent across contexts. Empirical studies indicate that its strength depends on internal resources, managerial capabilities and environmental conditions (Zarrouk et al., 2020; Rochiyati et al., 2022). In SMEs, where resource constraints are pronounced, EO often functions as a mechanism for mobilizing intangible assets such as knowledge, learning orientation, and managerial competence (Mantok et al., 2019; Meekaewkunchorn et al., 2021). Recent empirical evidence by Islam et al. (2024) confirms the positive impact of EO on SME performance, while also showing that EO dimensions contribute unevenly, with innovation and proactivity typically exerting stronger effects than risk-taking.

These findings are particularly relevant for transition economies, where SMEs face institutional volatility and have limited access to capital. In such contexts, EO may play a decisive role in sustaining competitiveness and performance; however empirical evidence from Central and Eastern Europe (and Hungary in particular) remains relatively scarce.

1.3. Entrepreneurial Orientation and SME performance in the Hungarian context

Hungarian SMEs operate in a business environment characterized by resource constraints, evolving institutional conditions, and significant regional disparities. Prior Hungarian research emphasizes that firm competitiveness and performance are strongly linked to managerial competencies, strategic decision-making and internal organizational practices (Rideg, 2017; Kurath et al., 2024). These findings suggest that EO-related behaviors may be particularly

consequential in the Hungarian SME sector, where managerial discretion is high and organizational structures are relatively flexible.

Empirical evidence highlights the importance of internal organizational factors in shaping performance outcomes. Balogh et al. (2021) demonstrate that incentive systems, managerial practices and internal governance mechanisms significantly influence SME competitiveness and performance. Their results align closely with EO theory, which conceptualizes entrepreneurial orientation as a behavioral and organizational phenomenon embedded in firm-level practices rather than merely an abstract strategic intention.

Adaptation to change is also a critical managerial challenge in the Hungarian context. Change management research stresses that successful adaptation requires deliberate behavioral and organizational adjustments (Takacs, 2015), conceptually aligning with EO dimensions such as innovation and proactivity. Together, these streams of Hungarian research support the relevance of EO as a theoretical lens for explaining performance differences among SMEs and motivate the need for an empirical analysis that integrates international EO theory with local contextual insights.

1.4. Core dimensions of Entrepreneurial Orientation

1.4.1. Innovation

Innovation reflects a firm's tendency to support creativity, experimentation, and the development of new products, services, or organizational practices (Covin & Slevin, 1989). In SMEs, innovation plays a central role in differentiation, adaptability, and long-term competitiveness (Meekaewkunchorn et al., 2021; Kusa et al., 2021). Innovation enables firms to respond effectively to changing customer needs and technological developments, thereby enhancing their performance (Beltrame et al., 2022; William et al., 2020).

At the same time, innovation involves substantial costs and uncertainty. Empirical evidence suggests that innovation alone does not guarantee superior performance unless complemented by proactive behavior and effective risk management (Pisar & Tomaskova, 2020; Islam et al., 2024).

1.4.2. Proactivity

Proactivity refers to a forward-looking strategic posture aimed at anticipating future market opportunities and acting before competitors (Lumpkin & Dess, 1996). Proactive firms shape their competitive environments by introducing new products, services or processes before their rivals, thereby achieving a first-mover advantage.

In the SME context, proactivity is particularly important because of limited resources and high environmental uncertainty. Prior studies show that proactive behavior strengthens performance by improving market responsiveness and strategic alignment (Meedkaewkunchorn et al., 2021; Kusa et al., 2022). Wiklund and Shepherd (2005) further emphasized that proactivity enables SMEs to capitalize on growth opportunities more effectively than reactive competitors.

1.4.3. Risk-taking

Risk-taking reflects a firm's willingness to commit resources to uncertain initiatives that have potentially high returns (Covin & Slevin, 1989). While risk-taking is a defining element of entrepreneurial behavior, its relationship with performance is more ambiguous than of innovation and proactivity.

Empirical research reports mixed findings regarding the risk-taking – performance relationship, particularly in SMEs facing financial constraints (Dvorsky et al., 2021; Kusa et al., 2021). Recent evidence by Islam et al. (2024) suggests that risk-taking often exhibits weaker or inconsistent effects on performance, highlighting the importance of strategic moderation and contextual alignment.

1.5. Contextual and contingency perspectives on entrepreneurial orientation

Consistent with the contingency logic proposed by Lumpkin and Dess (1996) and the configurational approach of Wiklund and Shepherd (2005), contemporary EO research increasingly emphasizes the role of contextual factors in shaping entrepreneurial behavior. Managerial characteristics, industry dynamics, and regional environments influence both the level of EO and its effectiveness in driving performance (Wales et al., 2011; Arzubagi et al., 2018).

Leadership-related factors play a particularly important role in SMEs, where decision-making authority is highly centralized. A recent systematic review and meta-analysis by Qandeel and Kurath (2025) demonstrated that leadership style and

perceptions of interactional justice significantly affect employee attitudes and performance. These findings support the argument that EO-related behaviors, such as innovation and proactivity, are influenced not only by strategic intent but also by leadership practices and organizational climate.

Industry structure and regional embeddedness further influence EO effects. Borgulya and Balogh (2019) highlight the strategic role of industrial clusters and inter-organizational communication in enhancing firms' adaptive capacity and competitiveness. Therefore, firms embedded in stronger networks and knowledge-sharing environments may experience amplified EO-performance effects. Extending this perspective, Hahn, Civera, and Cavallo (2025) demonstrate that entrepreneurial orientation can be activated in response to exogenous shocks, emphasizing the contingent role of entrepreneurial exposure in shaping EO behaviors.

From a country-specific perspective, Hungarian evidence suggests that managerial competence and strategic choices are closely associated with SME competitiveness, implying that the effects of EO may vary systematically across decision-makers, industries, and regions (Rideg, 2017; Kurath et al., 2024).

1.6. Hypotheses development

Drawing on classical EO theory (Covin & Slevin, 1989; Lumpkin & Dess, 1996) configurational approaches (Wiklund & Shepherd, 2005), and recent empirical evidence (Islam et al., 2024; Hahn et al., 2025), the following hypotheses are proposed:

Hypothesis 1: Entrepreneurial orientation positively affects firm performance.

Hypothesis 2: Innovation positively affects firm performance.

Hypothesis 3: Proactivity positively affects firm performance.

Hypothesis 4: Risk-taking ability positively affects firm performance.

Hypothesis 5: Managerial gender influences firm performance and entrepreneurial orientation.

Hypothesis 6: The industrial classification affects firm performance and entrepreneurial orientation.

Hypothesis 7: Geographical location influences firm performance and entrepreneurial orientation.

In conclusion, the overarching theoretical framework of this study is depicted in Figure 1.

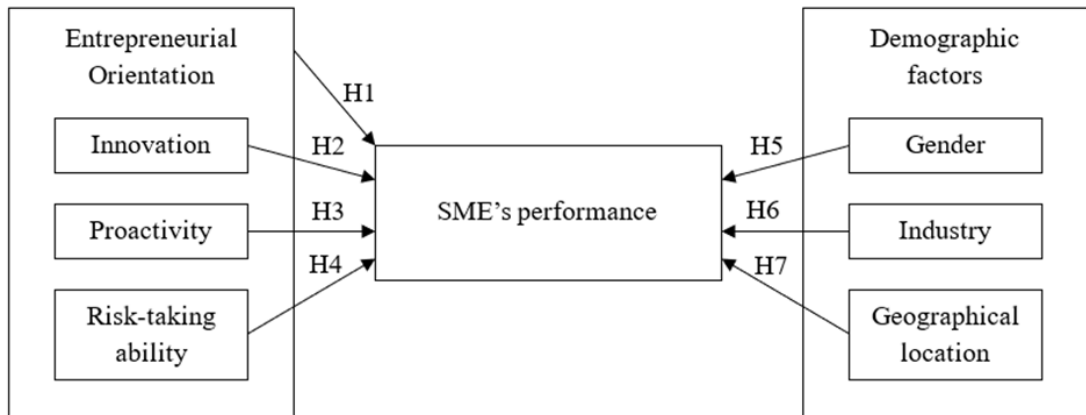


Figure 1 Theoretical framework
Source: the author

2. Methodology

2.1. Research Design

This study employs a quantitative, cross-sectional research design to examine the relationship between entrepreneurial orientation and firm performance among Hungarian small and medium-sized enterprises (SMEs). A survey-based approach was selected as being well suited for capturing managerial perceptions, strategic orientations, and organizational characteristics across a relatively large sample of firms, and it is widely used in EO research (Covin & Slevin, 1989; Wiklund & Shepherd, 2005).

The research design is explanatory in nature, aiming to test theoretically derived hypotheses concerning the impact of EO and its core dimensions (innovation, proactivity, and risk-taking) on organizational performance. In addition, this study adopts a contingency-oriented perspective by examining whether this relationship varies across contextual characteristics, including managerial gender, industry affiliation, and geographical location. This approach is consistent with prior EO research that emphasizes the context-dependent nature of entrepreneurial behavior (Lumpkin & Dess, 1996).

Data were collected at a single point in time, which allowed for the identification of statistical associations between key constructs but did not permit causal inference. This limitation is acknowledged and addressed in the discussion of the methodological constraints and future research directions. Nevertheless, the cross-sectional design is appropriate for the study's objectives, which focus on identifying patterns and relationships

within the Hungarian SME sector, rather than tracking longitudinal dynamics.

2.2. Population and sample

The study population consisted of Hungarian small and medium-sized enterprises (SMEs). Industry classification was based on the industrial ecosystem framework defined by the European Commission. The final sample includes 415 enterprises distributed across multiple industries, firm sizes, and geographical regions.

Table 1 presents the distribution of enterprises by industry and size. The sample is dominated by small enterprises (286 firms), followed by medium-sized (95 firms) and micro-enterprises (34 firms). Construction represents the largest industry in the sample (128 firms), followed by freight and passenger transport, including the automotive industry (66 firms), and the agri-food sector (49 firms). Several industries, such as digital devices, electronics-related industries, renewable energy, and cultural and creative industries, are represented by smaller numbers of firms, while a few sectors (e.g., textile, defense and space, proximity-based/social economy) include only one enterprise each.

Table 1 Industry classification of enterprises by size category (number of enterprises)

Industry	Micro-enterprise	Small enterprise	Medium-sized enterprise	Total
agri-food industry	3	25	21	49
freight and passenger transport, automotive industry	3	51	12	66
digital devices industry	3	8	3	14
healthcare industry	2	26	6	34

electronics-related industries	0	9	4	13
energy intensive industries	4	14	7	25
construction industry	8	99	20	128
retail industry	8	23	6	37
cultural and creative industries	1	4	6	11
renewable energy sources	1	17	2	20
proximity-based economy / social economy	1	0	0	1
textile industry	0	0	1	1
tourism	0	9	6	15
defense and space industry	0	0	1	1
Total	34	286	95	415

Source: the author

Overall, the industry distribution indicates substantial heterogeneity, ensuring that no single sector exclusively drives the empirical results. At the same time, industries with very low representation are interpreted with caution in subsequent analysis.

Table 2 reports the geographical distribution of participating enterprises by firm size at the NUTS 3 (county) level. The sample shows a clear territorial concentration, with Budapest (87 firms) and Pest County (58 firms) accounting for a substantial share of observations. Other counties, such as Fejér, Győr-Moson-Sopron, Baranya, Bács-Kiskun, and Csongrád-Csanád, each contributed between 20 and 23 firms, and several counties were represented by fewer than 15 enterprises.

Table 2 The participating enterprises by size and county (NUTS 3) level

NUTS 3	Micro-enterprise	Small enterprise	Medium-sized enterprise	Total
Bács-Kiskun	1	16	3	20
Baranya	0	14	6	20
Békés	1	10	7	18
B.-A.-Z.	0	16	1	17
Budapest	9	55	23	87
Csongrád-Csanád	0	14	6	20
Fejér	3	16	4	23
Gy.-M.-S.	0	22	1	23
Hajdú-Bihar	4	13	4	21
Heves	1	9	3	13
J.-N.-Sz.	0	3	5	8
Komárom-Esztergom	0	9	3	12
Nógrád	0	1	0	1
Pest	6	41	11	58
Somogy	2	7	1	10
Sz.-Sz.-B.	2	10	2	14
Tolna	1	9	1	11
Vas	0	4	5	9
Veszprém	2	11	3	15
Zala	2	6	5	13
Total	34	286	95	415

Source: the author

Across regions, small enterprises constitute the largest share of firms, followed by medium-sized enterprises, with micro-enterprises appearing less frequently. This regional structure reflects the broader spatial concentration of economic activity in Hungary and provides sufficient variation for examining geographical differences in entrepreneurial orientation and performance.

With regard to managerial characteristics, the sample is predominantly male-led; 306 firms (74%) are managed by men and 109 firms (26%) by women. Gender representation varies across industries, firm age categories, and regions, supporting the inclusion of gender as a contextual factor in the empirical analysis. Detailed comparisons related to gender, industry, and regional patterns are addressed in the Results and Discussion sections.

2.3. Measures and variable operationalization

This section describes the operationalization of the main study variables, entrepreneurial orientation and firm performance, and explains how abstract theoretical constructs were translated into measurable indicators that are suitable for empirical analysis.

2.3.1. Entrepreneurial orientation

Entrepreneurial orientation (EO) was operationalized as a multidimensional construct reflecting firms’ strategic attitudes and behavioral tendencies toward entrepreneurial activity. Consistent with classical EO theory (Covin & Slevin, 1989; Lumpkin & Dess 1996), the EO scale captures three core dimensions: innovation, proactivity, and risk-taking.

The measurement items were adapted from established empirical studies that examined the relationship between entrepreneurial orientation and firm performance in different contexts (Mantok et al., 2019; Oni et al., 2019; Nuryakin, 2021; Kim, 2022; Kusa et al., 2022; Rochiyati et al., 2022). Rather than adopting a single standardized scale, the questionnaire was constructed by selecting and adapting relevant items that reflect the conceptual content of EO while aligning with the specific characteristics of Hungarian SMEs.

The original items were translated into Hungarian using a direct translation approach, with particular attention to conceptual equivalence, linguistic clarity, and managerial relevance. During the adaptation process, terminology was

adjusted to fit the Hungarian business context and ensure that items were easily interpretable by SME managers. All EO items were measured on a five-point Likert scale (1=strongly disagree, 5=strongly agree). Separate indices were calculated for innovation, proactivity, and risk-taking, as well as an aggregated EO index representing overall entrepreneurial orientation.

Table 3 presents the operationalization of the EO dimensions, illustrating the specific behavioral and strategic aspects captured under innovation, proactivity and risk-taking.

Table 3 Aspects of entrepreneurial orientation (innovation, proactivity, risk-taking ability)

Aspects of innovation	Aspects of proactivity	Aspects of risk-taking
search for new opportunities	time of new programs, services	tolerating failure
new programs / services / administrative techniques	time of new administration technologies	undertaking high-risk projects
creative operation	taking advantage of opportunities provided for businesses	employee attitude towards risk
new tasks	analysis of the external environment	taking risks for above-average profits
new developments, innovations	identification of market needs	encouraging employees to take risks
	initiative skills	exploring opportunities, experimenting

Source: the author

2.3.2. Firm performance

Firm performance was measured using a subjective performance index reflecting managers' self-assessment of their firms' competitive outcomes. The use of subjective performance measures is well-established in SME research, particularly when objective financial data are difficult to obtain or firms are reluctant to disclose sensitive information (Wiklund & Shepherd, 2005; Rauch et al., 2009).

The performance measurement instrument was not based on a single standardized scale but was constructed by adapting performance-related dimensions commonly used in international EO performance studies (Mantok et al., 2019; Oni et al., 2019; Nuryakin, 2021; Kim, 2022; Kusa et al., 2022; Rochiyati et al., 2022). The selected items capture multiple aspects of firm performance, including growth, profitability, market position, and overall competitive performance, thereby enabling a comprehensive assessment of organizational outcomes.

The items were translated and adapted to the Hungarian SME context following the same principles applied to the EO scale, ensuring conceptual clarity and contextual relevance of the

translation. Respondents evaluated each statement using a five-point Likert scale (1=strongly disagree, 5=strongly agree). Based on the responses, a composite performance index was constructed by aggregating the individual items with equal weighting across dimensions. This approach allows for a meaningful comparison across firms while maintaining consistency with prior empirical research.

The performance-related indicators included in Table 4 illustrate how firm performance was conceptualized as a multidimensional construct, enabling a comprehensive assessment of organizational outcomes beyond purely financial measures.

Table 4 Aspects of performance

Aspects of performance
profitability
productivity
customer base
brand awareness
products and services
supports

Source: the author

2.4. Reliability and validity tests

The reliability of the measurement instruments was assessed using Cronbach's alpha coefficients, which evaluate the internal consistency of multi-item scales. Reliability analyses were conducted separately for the firm performance scale and the entrepreneurial orientation (EO) scale, including its three core dimensions: innovation, proactivity, and risk-taking.

The firm performance construct was measured using nine-item scale that captures multiple aspects of business operations. The reliability analysis yielded a Cronbach's alpha value of 0.835 (Table 5), indicating strong internal consistency. This value exceeds the commonly accepted threshold of 0.70 and suggests that the items form a coherent and reliable performance index. This result supports the use of an aggregated performance measure in subsequent analyses and indicates that the respondents interpreted the performance-related items consistently.

Table 5 Testing the reliability of questions on performance and entrepreneurial orientation

Dimension	Cronbach α
Performance	0.835
Innovation	0.873
Proactivity	0.821
Risk-taking	0.644

Source: the author

The reliability of the entrepreneurial orientation measurement was examined at the overall construct level and the level of its individual dimensions (Table 5). The overall entrepreneurial orientation scale demonstrated acceptable internal consistency, with a Cronbach's alpha value of 0.779, supporting its suitability for empirical analysis.

At the dimensional level, the reliability results varied across the EO components. The innovation dimension exhibited very high internal consistency (Cronbach's alpha=0.873), while the proactivity dimension also demonstrated excellent reliability (Cronbach's alpha=0.821). These values indicate that the items associated with innovation and proactivity reliably capture the coherent underlying constructs. The risk-taking dimension yielded a lower Cronbach's alpha value (0.644), which is slightly below the conventional 0.70 threshold but still within the range considered acceptable in exploratory and SME-focused research. Given the conceptual complexity of risk-taking and its context-dependent manifestation in SMEs, this level of internal consistency is consistent with prior EO studies and does not preclude the scale's use in future analyses.

The content validity of the measurement instruments is supported using items adapted from established EO-performance studies and by grounding the constructs in well-established theoretical frameworks. Construct validity is reinforced by the multidimensional operationalization of EO, which aligns with classical and contemporary EO theory. Given the cross-sectional survey design and the use of established scales, reliability and validity were primarily ensured through careful scale construction and internal consistency assessment rather than through additional factor-analytic procedures.

2.5. Regression Assumption

Prior to estimating the regression models, the main assumption of linear regression was systematically assessed to ensure the robustness and interpretability of the empirical results. Diagnostics were conducted separately for the aggregated entrepreneurial orientation (EO) model and the dimension-level EO model, including innovation, proactivity, and risk-taking. A summary of the diagnostic results is provided in Table 6.

Table 6 Summary of Regression Assumption Diagnostics

Assumption	Diagnostic Method	Model A: EO → performance	Model B: Innovation, Proactivity, Risk-taking - → performance
Multicollinearity	Variance Inflation Factor (VIF)	VIF = 1.000	VIF = 1.23 – 1.94
Autocorrelation of residuals	Durbin-Watson test	DW = 1.856	DW = 1.901
Normality of residuals	Histogram, Normal P-P plot	Approximately normal distribution	Approximately normal distribution
Homoscedasticity	Scatterplot of standardized residuals vs. predicted values	Nonsystematic pattern observed	Nonsystematic pattern observed
Influential outliers	Standardized residuals	No influential outliers detected	Standard residuals
Sample size adequacy	Number of observations	N = 415	N = 415

Source: the author

As shown in Table 6, multicollinearity was not a concern in either model. In the aggregated EO model, the VIF value was 1.000, reflecting the absence of linear dependency among the predictors. In the dimension-level model, the VIF values ranged between 1.23 and 1.94, which are well below the commonly accepted threshold levels, indicating that the EO dimensions can be jointly included in the regression without distorting coefficient estimates.

The autocorrelation of the residuals was assessed using the Durbin-Watson test. The obtained values (1.856 for Model A and 1.94 for Model B) fell within the acceptable range, suggesting that the residuals were not serially correlated.

The normality assumption was evaluated through graphical inspection of standardized residual histograms and normal probability plots. In both models, the residuals displayed an approximately normal distribution with mean values close to zero and standard deviations close to one. Given the relatively large sample size (N=415), minor deviations from normality were not considered problematic.

Homoscedasticity was examined by plotting the standardized residuals against the standardized predicted values. No systematic patterns or funnel-shaped distributions were observed, indicating that the assumption of a constant error variance was reasonably satisfied in both models.

Finally, the influential outliers were assessed using standardized residuals. Although a small

number of observations approached the conventional threshold of [3], no cases exceeded the critical values to a degree that would justify exclusion. Therefore, all observations were retained for subsequent analyses.

Overall, the diagnostic results summarized in Table 6 indicate that the key assumptions of linear regression were adequately met for both estimated models. This supports the reliability of the regression estimates reported in the next section.

2.6. Analysis method

To test the proposed hypotheses, a combination of linear regression analysis and categorical association tests was applied. This mixed analytical approach allows for the examination of both the performance effects of entrepreneurial orientation and the structural differences across firm characteristics.

2.6.1. Linear regression analysis

Linear regression models were used to examine the relationship between entrepreneurial orientation and firm performance. Two complementary model specifications were applied to capture both the overall and dimension-level effects of entrepreneurial orientation.

First, the aggregated entrepreneurial orientation Model A was estimated, in which firm performance served as the dependent variable, and the aggregated entrepreneurial orientation index was included as the main explanatory variable. This specification captures the overall strategic orientation of the firm toward entrepreneurial behavior.

Second, a dimension-level entrepreneurial orientation model (Model B) was estimated to assess the relative contributions of individual EO dimensions. In this model, innovation, proactivity, and risk-taking were simultaneously included as independent variables, with firm performance as the dependent variable. This approach allows for identifying which specific entrepreneurial behaviors are most strongly associated with performance outcomes while controlling for the remaining dimensions.

The estimated regression models can be expressed in the following general form:

Model A (aggregated entrepreneurial orientation):

$$Performance_i = \beta_0 + \beta_1 EO_i + \varepsilon_i$$

Model B (dimensions of entrepreneurial orientation):

$$Performance_i = \beta_0 + \beta_1 Innovation_i + \beta_2 Proactivity_i + \beta_3 Risk-taking_i + \varepsilon_i$$

where ε_i denotes the error.

All regression models were estimated using the Enter method. Standardized regression coefficients were reported to facilitate the comparison of effect sizes across explanatory variables. Model fit was evaluated using R^2 and adjusted R^2 values, while statistical significance was assessed at the conventional threshold level. Prior to interpretation, regression assumptions were systematically tested, as reported in Section 2.5.

2.6.2. Chi-square test and effect size measures

In addition to regression analysis, chi-square test (χ^2) of independence was conducted to examine associations between entrepreneurial orientation variables and selected categorical firm characteristics, including the gender of the manager, industry affiliation, and regional location. These analyses were applied to explore whether entrepreneurial orientation and its dimensions differ systematically across the structural firm attributes.

Cramer's V was calculated as an effect size measure to assess the strength of statistically significant associations. Cramer's V provides a standardized interpretation of association strength and allows for comparison across contingency tables of different sizes, complementing the result of the χ^2 tests.

2.6.3. Additional analytical considerations

The empirical analysis focuses on the direct effect of entrepreneurial orientation on firm performance. Although moderation effects (e.g., by firm size, firm age, industry, or region) were not formally estimated using interaction terms in the present study, the applied analytical framework allows for such extensions in future research.

Overall, the combined use of regression analysis and categorical association tests provides a robust and methodologically consistent basis for evaluating the proposed hypotheses and aligns with the established empirical practices in entrepreneurship and strategic management research.

3. Results

This section presents the study’s empirical findings. First, the results related to the relationship between entrepreneurial orientation and firm performance are discussed. Second, the role of selected contextual factors, including gender, industry, and regional location, is examined.

3.1. Main results for Q1: Relationship between entrepreneurial orientation and firm performance

This subsection reports the results of the regression analyses conducted to examine the relationship between entrepreneurial orientation and firm performance at the aggregated level and across individual EO dimensions.

3.1.1. Aggregated entrepreneurial orientation (H1)

Table 7 reports the linear regression examining the relationship between aggregated entrepreneurial orientation and firm performance. The results indicate a positive and statistically significant relationship between the two variables ($\beta=0.593$; $p<0.001$). The model explains 23.2% of the variance in firm performance ($R^2=0.232$). Consequently, Hypothesis 1 was accepted.

Table 7 Linear regression calculation of the relationship between entrepreneurial orientation and SME performance

Aspects	Significance level	Beta	R ²
entrepreneurial orientation x performance	<0.001	0.593	0.232

Source: the author

3.1.2. Entrepreneurial orientation dimensions (H2-H4)

Tables 8-10 present the results of separate regression analyses examining the relationship between individual EO dimensions and firm performance.

Innovation exhibits a positive and statistically significant effect on firm performance ($\beta=0.436$; $p<0.001$) (Table 8), explaining 24.1% of the performance variance ($R^2=0.241$). Consequently, Hypothesis 2 was accepted.

Table 8 Linear regression analysis of the relationship between innovation and SME performance

Aspects	Significance level	Beta	R ²
innovation x performance	<0.001	0.436	0.241

Source: the author

Proactivity is also positively and significantly associated with firm performance ($\beta=0.466$;

$p<0.001$) (Table 9), with an explanatory power of $R^2=0.220$. Therefore, based on these results, Hypothesis 3 was accepted.

Table 9 Linear regression analysis of the relationship between proactivity and SME performance

Aspects	Significance level	Beta	R ²
proactivity x performance	<0.001	0.466	0.220

Source: the author

Risk-taking shows a positive but relatively weak relationship with firm performance ($\beta=0.215$; $p<0.001$) (Table 10). The explanatory power of the model was limited ($R^2=0.032$), indicating a modest association. Nevertheless, the relationship is statistically significant; therefore, H4 is accepted.

Table 10 Linear regression analysis of the relationship between risk-taking and SME performance

Aspects	Significance level	Beta	R ²
risk-taking x performance	<0.001	0.215	0.032

Source: the author

3.2. Main results for Q2: Contextual factors

The analysis presented in subsection 3.2. provides an answer to the second research question by examining whether entrepreneurial orientation and firm performance differ across the gender of the managers, the industry classification of the enterprise, and geographical location.

3.2.1. Gender

The chi-square test results indicate a statistically significant association between managerial gender and firm performance ($p<0.001$) (Table 11). The corresponding Cramer’s V value (0.709) suggests a strong association.

Table 11 Gender of respondents and business performance

Pearson’s Chi-square test				Cramer’s V test		
<0.001				0.709		
Gender	0 – 19%	20 – 39%	40 – 59%	60 – 79%	80 – 100%	Total
Female	7	15	16	20	50	108
Male	13	30	46	62	156	307
Total	20	45	62	82	206	415

Source: the author

A similarly strong and statistically significant relationship was observed between gender and entrepreneurial orientation ($p<0.001$; Cramer’s $V=0.713$) (Table 12).

Table 12 Gender of respondents and entrepreneurial orientation

Pearson's Chi-square test				Cramer's V test		
<0.001				0.713		
Gender	0 – 19%	20 – 39%	40 – 59%	60 – 79%	80 – 100%	Total
Female	8	21	37	27	15	108
Male	17	56	72	103	59	307
Total	25	77	109	130	74	415

Source: the author

Therefore, H5 is accepted.

3.2.2. Industry

Tables 13 and 14 present the distribution of firm performance and entrepreneurial orientation across industries. Pearson's chi-square test indicates statistically significant associations between industry classification and both firm performance ($p < 0.001$; Cramer's $V = 0.482$) and entrepreneurial orientation ($p < 0.001$; Cramer's $V = 0.488$)

Table 13. Industry classification and business performance

Pearson's Chi-square test				Cramer's V test		
<0.001				0.482		
Industry	0 – 19%	20 – 39%	40 – 59%	60 – 79%	80 – 100%	Total
agri-food industry	4	8	11	12	14	49
freight and passenger transport, automotive industry	3	5	13	15	30	66
digital devices industry	1	2	3	3	5	14
healthcare industry	3	2	3	7	19	34
electronics-related industries	1	3	0	1	8	13
energy intensive industries	1	7	5	2	10	25
construction industry	4	13	20	24	67	128
retail industry	1	2	2	8	24	37
cultural and creative industries	1	1	2	1	6	11
renewable energy sources	0	1	1	7	11	20
proximity-based economy / social economy	0	0	0	0	1	1
textile industry	1	0	0	0	0	1
tourism	0	1	2	2	10	15
defense and space industry	0	0	0	0	1	1
Total	20	45	62	82	206	415

Source: the author

Table 14 Industry classification and entrepreneurial orientation

Pearson's Chi-square test				Cramer's V test		
<0.001				0.488		
Industry	0 – 19%	20 – 39%	40 – 59%	60 – 79%	80 – 100%	Total
agri-food industry	8	12	8	17	4	49
freight and passenger transport, automotive industry	5	9	20	21	11	66
digital devices industry	0	5	2	3	4	14
healthcare industry	3	1	10	11	9	34
electronics-related industries	0	2	4	5	2	13
energy intensive industries	3	5	6	9	2	25
construction industry	5	21	31	36	24	128
retail industry	0	4	15	10	8	37
cultural and creative industries	0	3	3	4	1	11
renewable energy sources	0	2	6	5	7	20
proximity-based economy / social economy	0	0	1	0	0	1
textile industry	1	0	0	0	0	1
tourism	0	2	3	9	2	15
defense and space industry	0	0	0	0	1	1
Total	20	45	62	82	206	415

Source: the author

These values have moderate effect sizes, suggesting that the industry context is related to variations in performance and entrepreneurial orientation.

Accordingly, H6 is accepted.

3.2.3. NUTS 3

Table 15 reports the regional differences in firm performance. Pearson's chi-square test results indicated a statistically significant association between geographic location and performance ($p < 0.001$), with a moderate effect size (Cramer's $V = 0.485$).

Table 15 Geographical location and business performance

Pearson's Chi-square test				Cramer's V test		
<0.001				0.485		
NUTS 3	0 – 19%	20 – 39%	40 – 59%	60 – 79%	80 – 100%	Total
Bács-Kiskun	1	2	2	3	12	20
Baranya	0	1	1	5	13	20
Békés	1	1	3	5	8	18

Borsod-Abaúj-Zemplén	0	2	2	4	9	17
Budapest	2	6	14	19	46	87
Csongrád-Csanád	1	3	2	5	9	20
Fejér	2	5	2	4	10	23
Győr-Moson-Sopron	2	0	1	5	15	23
Hajdú-Bihar	2	3	6	1	9	21
Heves	0	0	3	1	9	13
Jász-Nagykun-Szolnok	0	1	1	2	4	8
Komárom-Esztergom	0	0	3	3	6	12
Nógrád	0	0	0	0	1	1
Pest	4	9	11	10	24	58
Somogy	1	2	1	3	3	10
Szabolcs-Szatmár-Bereg	0	2	2	1	10	15
Tolna	1	1	2	4	3	11
Vas	2	4	1	2	0	9
Veszprém	1	2	3	4	6	16
Zala	0	1	2	1	9	13
Total	20	45	62	802	206	415

Source: the author

Table 16 shows a similar pattern for entrepreneurial orientation, with significant regional differences ($p<0.001$) and Cramér's V (0.487).

Table 16 Geographical location of the enterprise and entrepreneurial orientation

	Pearson's Chi-square test				Cramer's V test	
	<0.001				0.487	
NUTS 3	0 – 19%	20 – 39%	40 – 59%	60 – 79%	80 – 100%	Total
Bács-Kiskun	1	5	4	5	5	20
Baranya	1	1	6	10	2	20
Békés	0	3	6	7	2	18
Borsod-Abaúj-Zemplén	0	5	4	6	2	17
Budapest	2	13	21	34	17	87
Csongrád-Csanád	1	2	7	6	4	20
Fejér	1	3	5	9	5	23
Győr-Moson-Sopron	3	4	2	7	7	23
Hajdú-Bihar	2	3	8	6	2	21
Heves	1	3	3	4	2	13
Jász-Nagykun-Szolnok	0	1	2	4	1	8
Komárom-Esztergom	2	0	3	3	4	12
Nógrád	0	0	0	1	0	0
Pest	5	19	18	8	8	58
Somogy	0	3	3	4	0	10
Szabolcs-Szatmár-Bereg	1	1	5	5	3	15
Tolna	1	2	4	2	2	11
Vas	3	3	1	1	1	9
Veszprém	1	2	5	4	4	16
Zala	0	4	2	4	3	13
Total	25	77	109	130	74	415

Source: the author

Accordingly, H7 is also accepted.

4. Discussion

This study investigates the relationship between entrepreneurial orientation and firm performance in Hungarian SMEs, emphasizing its multidimensional structure and contextual embeddedness. The results extend existing EO research by offering empirical evidence from a Central and Eastern European (CEE) transition economy.

4.1. Interpretation of main findings

The results confirm a positive and statistically significant relationship between aggregated entrepreneurial orientation and firm performance. This finding supports the core EO theory, which conceptualizes entrepreneurial orientation as a strategic posture that enhances opportunity recognition and exploitation (Covin & Slevin, 1989; Lumpkin & Dess, 1996). This aligns with prior empirical evidence from small business research (Wiklund & Shepherd, 2005; Rauch et al., 2009).

At the dimensional level, innovation and proactivity exhibit strong and positive associations with firm performance. These findings highlight that innovation and proactivity are key drivers of competitive advantage in resource-constrained SME. Consistent with the multidimensional EO framework (Lumpkin & Dess, 1996), the dimensions do not equally contribute to performance. These effects are dimension-specific and context-dependent.

Overall, the results support the view that entrepreneurial orientation functions as a strategic capability rather than a uniform behavioral bundle. Firms that actively pursue innovation and proactivity and anticipate market changes are better positioned to translate entrepreneurial intent into tangible performance gains.

4.2. Context-specific findings

A key finding is the comparatively weak relationship between risk-taking and firm performance. Although statistically significant, its explanatory power was substantially lower than that of innovation and proactivity. While classical EO studies emphasize risk-taking (Covin & Slevin, 1989), recent research indicates that its performance impact may be context-dependent.

In the Hungarian SME context, cautious strategic behavior may reflect economic volatility, financing constraints and regulatory uncertainty. Under such conditions, excessive risk-taking may

generate a disproportionate downside risk. Therefore, SMEs may benefit more from calculated innovation and proactive market positioning than aggressive risk-taking strategies. This finding underscores the importance of contextualizing EO dimensions rather than assuming their universal effectiveness in institutional settings.

4.3. Contribution to entrepreneurial orientation theory

This study makes three main contributions to the EO literature. First, it provides evidence from a CEE transition economy, a region that is still underrepresented in EO research. By focusing on Hungarian SMEs, this analysis highlights how entrepreneurial orientation operates in a post-transition economy characterized by evolving institutions and heterogeneous market conditions.

Second, the findings reinforce the multidimensional interpretation of the EO construct. The differential effects of innovation, proactivity, and risk-taking abilities provide empirical support for the argument that EO dimensions should be analyzed separately rather than aggregated indiscriminately. This aligns with theoretical debates emphasizing configurational and contingency-based interpretations of EO (Lumpkin & Dess, 1996; Wiklund & Shepherd, 2005).

Third, the results show that EO and performance vary across gender, industry, and region, underscoring the contextual embeddedness of EO. Although these variables were not modelled as formal statistical moderators, the observed associations indicate that EO-performance relationships are embedded in broader organizational and institutional contexts. This insight opens avenues for future research employing interaction models or multilevel approaches to explore these contingencies further.

4.4. Practical implications

The findings have direct implications for SME managers operating in Hungary and the broader Central and Eastern European (CEE) region. First, the results indicate that performance gains are more strongly associated with innovation and proactivity than with heightened risk-taking. In practical terms, SME leaders should institutionalize opportunity-recognition routines such as regular market-scanning meetings, structured customer feedback analysis, and internal idea-generation mechanisms. Establishing simple

but formalized evaluation criteria for new projects can help balance innovation initiatives with financial stability, which is particularly important in resource-constrained environments.

Second, given the comparatively weaker performance impact of risk-taking, SME managers in CEE economies should adopt a calculated, rather than an aggressive, risk posture. Instead of pursuing high-risk expansion strategies, firms may benefit from incremental innovation, pilot testing new products and services, and phased market entry approaches. This is especially relevant in transition economies, which are characterized by regulatory volatility, limited access to external financing, and uneven regional development.

Third, the observed gender, industry, and regional differences suggest that entrepreneurial strategies should not be applied uniformly. SME leaders are encouraged to align innovation practices with industry-specific dynamics and regional market conditions. Firms from peripheral regions may benefit from inter-firm collaboration, cluster participation, and knowledge-sharing networks to compensate for their structural disadvantages.

From a policy perspective, the results underline the importance of targeted and context-sensitive SME-support instruments. Policymakers in Hungary and the broader CEE region should prioritize innovation vouchers, regional incubation programs, digitalization grants, and accessible micro-financing schemes that lower the perceived costs of entrepreneurial experimentation. Special attention should be paid to female-led enterprises and firms in less developed regions to reduce structural disparities. By strengthening innovation ecosystems and improving access to financial and advisory support, policymakers can enhance SMEs' ability to translate entrepreneurial orientation into sustainable-performance outcomes.

Conclusions

This study examines the relationship between entrepreneurial orientation and firm performance among Hungarian SMEs, with particular attention to the multidimensional structure of EO and the roles of gender, industry, and geographical location. By combining regression and categorical analyses, this study provides empirical evidence on how entrepreneurial orientation relates to performance outcomes in a Central and Eastern European context.

Summary of the findings

The results confirm a positive and statistically significant relationship between aggregated entrepreneurial orientation and firm performance. At the dimension level, innovation and proactivity emerge as the primary drivers, whereas risk-taking shows a positive, but comparatively weak, effect. The findings also reveal significant variations in EO and performance across gender, industry, and regional location, underscoring contextual heterogeneity.

Overall, entrepreneurial orientation contributes to SME performance in Hungary; however, its effects are uneven across dimensions and are embedded in structural and institutional contexts.

Theoretical contributions

This study makes three main theoretical contributions to the literature. First, it extends EO research to a CEE transition economy, addressing a geographical gap in the literature on EO. The Hungarian context illustrates how EO operate under heterogeneous institutional and market contributions.

Second, the findings reinforce the multidimensional conceptualization of entrepreneurial orientation. The strong effects of innovation and proactivity, combined with the weak role of risk-taking, provide empirical support for contingency-based and configurational perspectives of EO.

Third, the variation across gender, industry, and region highlights the contextual embeddedness of the EO. These results suggest that EO should be understood not only as a firm-level strategic posture but also as context-sensitive capability.

Practical implications

From a management perspective, the findings indicate that SME performance gains are more likely to result from innovation-oriented and proactive strategies than from increased risk-taking alone. SME leaders should prioritize opportunity recognition, structured innovation practices and balanced risk management.

For policymakers, the findings emphasize the need for context-sensitive SME support instruments. Initiatives aimed at strengthening innovation capabilities, reducing financing constraints, and supporting proactive market engagement may be particularly effective in enhancing SME competitiveness. Regional disparities indicate the need for targeted

development programs in peripheral areas.

Limitations

Despite these contributions, this study has several limitations. First, the analysis relies on cross-sectional survey data, which limits the ability to draw causal inferences. Second, firm performance was measured using subjective indicators that may have introduced respondent bias. Third, the contextual differences were not tested using formal interaction models. Finally, this study focused on a single national context, which may limit the generalizability of the findings.

Future research directions

Future research should employ longitudinal designs to capture the causal dynamics between EO and performance. The use of objective performance indicators strengthens empirical robustness. Future studies should model moderation and mediation effects, such as firm size, age, digitalization level, and institutional support. Comparative cross-country analyses within the CEE region would clarify whether the observed patterns are context-specific or generalizable to other nations.

Declarations

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Conflict of Interest

The author declares no conflict of interest.

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Designing Efficient Algorithms for Logistics Management: Optimizing Time-Constrained Vehicle Routing

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Abstract

Background: City logistics is a critical component of urban economic development, as it optimizes supply chains, enhances customer satisfaction through reliable deliveries, and minimizes environmental impacts in densely populated areas. This field addresses various challenges, including traffic congestion, environmental concerns, noise pollution, and the crucial need for timely deliveries. Routing and scheduling are central to logistics operations, with modern software integrating time windows to meet precise scheduling demands driven by detailed customer requirements and operational efficiencies. Furthermore, advanced vehicle routing models now effectively simulate real-world factors such as traffic congestion, stochastic travel times, and dynamic product demands.

Purpose: This paper aims to develop an algorithm that addresses the routing decisions. Our approach extends to the time dimension, considering travel times and customer service times within predefined time windows.

Study design/methodology/approach: The proposed algorithm is structured to execute in iterative phases, aiming to optimize key logistical objectives. In order to generate competitive solutions, we seek to minimize the number of vehicles utilized and overall travel costs. The evaluation of solution space was conducted via Simulated Annealing.

Findings/conclusions: The performance of the proposed algorithm, evaluated using the Gehring and Homberger benchmark instances for 200 customers, demonstrates its effectiveness. The algorithm successfully meets the target number of vehicles required, and the associated travel costs are on average within 1% of the best solutions reported in the relevant literature.

Limitations/future research: Given the ongoing need for timely solutions from decision-makers, future research endeavors will focus on enhancing the computational efficiency of the algorithm. Additionally, incorporating more time-related features, such as stochastic travel times, could further improve the algorithm's real-time applicability.

Keywords

City logistics, Vehicle routing, Scheduling, Time windows, Simulated annealing

Introduction

City logistics plays an important role in sustaining urban economies by optimizing supply chain efficiency, improving customer satisfaction through dependable delivery services, and mitigating the environmental repercussions of freight transportation in densely populated areas. This field encompasses the management of challenges like traffic congestion, spatial constraints on roads, environmental impacts, noise pollution, and the critical requirement for punctual deliveries. Among the crucial models considered in applications and research is multi-echelon vehicle routing.

The Vehicle Routing Problem (VRP) representing a critical logistical challenge is extensively studied in Operations Research. Originating in 1959 with Dantzig and Ramser's formulation of the Truck Dispatching Problem, it aimed to minimize travel distances for a homogeneous fleet delivering to gas stations from a central depot. This seminal work laid the groundwork for subsequent research into optimizing delivery routes. In 1964, Clarke and Wright expanded on this concept by formulating a generalized linear optimization problem. This advancement enabled the efficient distribution of goods from a central depot to geographically dispersed consumers using vehicles with varying capacities. Known today as the VRP, this problem has become fundamental in logistics and transportation research, guiding strategies to minimize costs and improve efficiency in delivering goods to diverse locations.

Since its inception, the VRP has evolved to handle complexities like varying vehicle capacities, strict time constraints, multiple depots, and other practical challenges in logistics. Route optimization is crucial in transportation, logistics, and supply chain management, serving sectors such as public transit, postal services, food delivery, cash logistics, and waste management. Designing efficient transport routes involves considering factors like vehicle characteristics, capacities, travel costs, service time windows, and other variables. These elements determine the feasibility and effectiveness of tailored route plans for specific operational needs.

Reducing the number of vehicles and travel distance is key to cutting vehicle costs, lowering

product prices, and reducing greenhouse gas emissions. Various real-world routing problems aim to minimize total logistics expenses while maintaining high service levels. Transportation costs are a significant part of product expenses, split into fixed (like driver wages and vehicle maintenance) and variable costs (like fuel expenses, which depend on route duration and specific factors). Efficient vehicle routing not only improves economic efficiency but also promotes environmental sustainability by minimizing emissions and operational impacts.

Lenstra and Rinnooy Kan proved in 1981 that the VRP is NP-hard, indicating that exact algorithms are efficient only for small-scale instances. Therefore, heuristic and metaheuristic algorithms are more suitable for solving real-world problems of significant size. Modern approaches in VRP algorithms emphasize both exact and approximate solutions. Exact algorithms are constrained to smaller problems due to the problem's complexity. In contrast, approximate algorithms offer quick but not necessarily optimal solutions, and are a primary focus of algorithmic research. Metaheuristics like simulated annealing, tabu search, ant colony optimization, genetic algorithms, and memetic algorithms are widely used for tackling VRP and related optimization challenges.

Today's vehicle routing models have advanced significantly, integrating complex real-world factors such as stochastic travel times to simulate traffic congestion, time windows for precise product collection and delivery scheduling, and varying dynamic demands for products. Each of these enhancements introduces substantial intricacy into the optimization process. In contemporary vehicle routing models, routes are typically planned for specific time periods, often daily. This can translate into different operational scenarios: routes may be recalculated iteratively with updated data inputs, or a single route plan may repeat over an extended timeframe. The Vehicle Routing Problem with Time Windows (VRPTW) is a critical variant where each customer requires service within a designated time slot. For instance, some customers may specify deliveries only between 9 AM and 10 AM. The integration of time windows into modern logistics software has gained significant traction over the past decades, driven by increasingly detailed customer needs and

operational efficiencies. As logistics challenges continue to evolve, new variations and enhancements to routing algorithms and software solutions will undoubtedly remain at the forefront of research and development in city logistics and broader transportation management.

Real-world logistics rely on precise algorithms within routing software to optimize delivery routes amidst complex constraints. For instance, in fast parcel delivery, algorithms ensure efficient routes, uniform delivery schedules, and minimal customer-driver interactions, boosting service quality and operational efficiency. Similar optimizations benefit diverse sectors like newspaper delivery, school bus routing, waste management, postal services, and security patrols, addressing challenges such as variable travel times and fluctuating demand. In today's competitive landscape, advanced routing systems are critical for meeting customer expectations and maintaining a strategic edge in logistics.

The rest of the paper is organized as follows. Section 1 contains the overview of literature on VRP and related time variations. In Section 2 we give a problem description and mathematical model. Section 3 is devoted to presentation of the algorithm, followed by the results in Section 4.

1. Related literature

Literature on VRP and related variations is very rich. We will emphasize several papers related to time-constrained versions. For a more detailed overview, one can see for instance Bräysy and Gendreau (2005a and 2005b) or Konstantakopoulos et al. (2022).

Solomon's (1985) paper addresses vehicle routing and scheduling problems with time window constraints by developing and analyzing tour-building algorithms for the VRPTW. He extends existing VRP heuristics to integrate both distance and time dimensions into the heuristic process, resulting in more adaptable methods capable of handling time window constraints. Initially, he adapted Clarke and Wright (1964) savings heuristic for the VRPTW to enhance route optimization effectiveness. Additionally, Solomon explores sequential tour-building algorithms and insertion heuristics that initialize routes based on various criteria. These methods iteratively insert customers into partial routes, optimizing tour efficiency within specified time constraints. Li and Wang's study (2025) addresses the capacitated vehicle routing problem in the context of omnichannel retailing, accounting for multiple

types of time windows and products simultaneously.

Exact methods often exhibit considerable inefficiencies, sometimes taking days or more to find even moderately satisfactory, let alone optimal, solutions for relatively small problem instances. A comprehensive analysis of well-known exact algorithms for VRP can be found in Laporte (1992). Fisher et al. (1997) introduce an algorithm that solves the VRPTW optimally, formulating the problem as a K-tree with a degree of 2K at the depot. Kohl and Madsen (1997) present a shortest path approach with side constraints, followed by Lagrange relaxation. This method relaxes constraints to ensure each customer is served exactly once. Desrosiers et al. (1984) pioneer the use of the column generation approach for solving VRPTW, and a more effective version incorporating valid inequalities achieves optimality in Desrosiers et al. (1992). The dynamic programming approach for VRPTW is first presented by Kolen et al. (1987), while Christofides and Beasley (1984) utilize the dynamic programming paradigm to solve the VRP. Hoogeboom et al. (2020) propose an exact polynomial-time algorithm that can efficiently identify the optimal start time for serving each customer in the vehicle routing problem with multiple time windows.

Mathematical formulations for the cumulative vehicle routing problem with soft and hard time window constraints were presented by Fernández Gil et al. (2023). Their approach integrates CO2 emissions into routing decisions, achieving a balance between environmental impact and time window compliance. Ulmer et al. (2024) demonstrate how companies can provide reliable, narrow time windows despite arrival time uncertainty by decoupling time window decisions from routing. Assuming specific arrival time distributions, they reduce a complex stochastic optimization problem to a one-dimensional root-finding task, enabling a practical heuristic for broader applications. Köhler et al. (2020) propose customer acceptance mechanisms for flexible time window management in attended home deliveries. Through a computational study using demand scenarios, including real data from a German online supermarket, they assess the approaches' effectiveness in offering short time windows while serving many customers.

Metaheuristic algorithms can be seen as versatile strategies applicable across diverse problem domains, offering iterative guidance and

adjustment of subordinate heuristics. These methods intelligently blend various techniques to explore and exploit solution spaces, adapting heuristics to specific challenges. At each iteration, metaheuristics can manipulate either a single complete or incomplete solution, or a collection of solutions. Typical representatives of these algorithms are simulated annealing, tabu search, genetic algorithms, Variable Neighborhood Search (VNS) and Greedy Randomized Adaptive Search Procedure (GRASP). Simulated annealing is a robust optimization technique utilized across various problem domains. It draws inspiration from thermodynamics, specifically the gradual cooling process akin to metal cooling. This approach mimics the transformation of liquid metal into a crystal through slower cooling, symbolizing the exploration of the solution space from feasibility to discovering global optima. The seminal works by Kirkpatrick et al. (1983) and Černý (1985) introduced simulated annealing as a powerful algorithm for addressing challenging optimization problems. Notably, both studies applied simulated annealing to tackle the Traveling Salesman Problem in combinatorial optimization.

In 1995, Kontoravdis and Bard introduced a greedy randomized adaptive search procedure (GRASP) for solving the Vehicle Routing Problem with Time Windows (VRPTW). The approach minimizes the number of vehicles used and the total distance traveled. Lau et al. (2003) present a tabu search approach for the m-VRPTW, where a limited number of vehicles is given. The method uses a holding list, forces dense packing within routes, and allows time window relaxation through penalties. Computational results show competitive solutions for VRPTW and near-optimal results for m-VRPTW. Baños et al. (2013) proposed a multiobjective approach using simulated annealing and multiple-temperature Pareto simulated annealing to tackle the VRPTW, incorporating travel distance and route balance considerations. Adewumi and Adeleke (2018) review four most-addressed vehicle routing problem variations: capacitated, time windows, periodic, and dynamic, and examine their formulations, solution methods, and applications. A multi-objective approach combined with genetic algorithms is used by Ombuki and Hanshar (2006). The authors applied a multi-objective genetic algorithm to solve the VRPTW, optimizing both the number of vehicles and total cost without the need for predetermined weights. Their method produced competitive solutions compared to existing approaches and

found new solutions that were not biased towards either the number of vehicles or cost. Schneider (2016) introduced a tailored tabu search algorithm for VRP with time windows, accommodating driver-specific familiarity with customers. Wang et al. (2015) focused on the Heterogeneous Multi-type Fleet Vehicle Routing Problem with time windows and incompatible loading constraints, developing heuristic and tabu search methods. In 2019, Marinakis et al. introduced a Multi-Adaptive Particle Swarm Optimization (MAPSO) algorithm to solve the VRPTW. The algorithm incorporates three adaptive strategies: using GRASP for initial solutions and iterations, an Adaptive Combinatorial Neighborhood Topology for particle movement, and dynamic parameter adaptation during execution. MAPSO was tested on benchmark instances and compared with other PSO versions and top algorithms, showing competitive performance in solving VRPTW instances with 100 to 1000 nodes.

Furthermore, Gehring and Homberger (2011) presented a cooperative parallel strategy using two-phase metaheuristics, combining evolutionary approaches to minimize vehicles followed by tabu search to optimize travel distance. Additionally, a cooperative parallel metaheuristic for VRPTW utilizes a solution warehouse strategy, facilitating the asynchronous exchange of best solution information among search threads (le Bouthillier and Crainic, 2005). Feng, Wei, and Hu (2023) proposed an Adaptive Large Neighborhood Search (ALNS) algorithm to solve the Vehicle Routing Problem with Multiple Time Windows (VRPMTW). This method uses an adaptive strategy to select neighborhoods and a local search based on destroy and repair operators to avoid local optima. Infeasible solutions are incorporated into the search, expanding the solution space, and an archive stores high-quality feasible solutions. In the study by Wang et al. (2024), an adaptive large neighborhood search (ALNS) algorithm for the multi-depot dynamic vehicle routing problem with time windows (MD-DVRPTW), where customer requests emerge stochastically, is developed. The ALNS includes novel removal operators and a time window compatibility-based insertion method, proving effective for dynamic problems requiring fast re-optimization. The study also highlights that vehicle fixed costs affect route planning, and that speeding up responsiveness can increase costs rather than improve the solution.

Agra et al. (2013) tackled the robust vehicle routing problem with time windows, focusing on

maritime transportation where delays are common. It presents two new formulations based on different robust approaches: one using adjustable robust optimization and another based on path inequalities. Both approaches incorporate techniques to reduce the complexity of uncertainty. Comparative results show that the new formulations are faster than previous methods, achieving similar solution times while addressing the uncertainty in travel times effectively. Hu et al. (2018) examined a more realistic variation of VRPTW that involves demand and travel time uncertainty. To tackle large instances, they designed a two-stage method based on a modified variable neighborhood search heuristic. In Jabali et al. (2012) the authors introduce a new variant of VRP that accounts for travel time, fuel, and CO2 emissions. They incorporate CO2 emissions in routing decisions, relating CO2 to vehicle speed and fuel consumption, which changes during the day with respect to congestion. The conclusion is that it is important to control vehicle speed from a total cost point of view. Authors study the trade-off between minimizing CO2 emissions and minimizing total travel times. In his thesis, Souza (2024) introduces Flexi-VNS, a General Variable Neighborhood Search (GVNS) algorithm for solving three electric vehicle routing problems: EVRP, BSS-EV-LRP, and E-VRPTW. It employs a Randomized Variable Neighborhood Descent (RVND) method for local search and is shown to improve several best-known solutions. Flexi-VNS performs competitively, surpassing existing algorithms in multiple instances, including reducing battery swap stations and achieving high success rates.

Cattaruzza et al. (2017) review urban vehicle routing challenges in goods distribution, analyzing logistics flows and highlighting key issues: time-dependency, multi-level and multi-trip distribution, and dynamic information management. In Zhou et al. (2022), the authors investigate a novel variant of the two-echelon VRP incorporating time windows, pickup, and delivery, demonstrating its applicability in multimodal urban distribution, particularly for critical sectors such as medical supplies. The paper by Gutierrez et al. (2024) explores a two-echelon VRP incorporating time-dependent travel times to address urban traffic congestion. They employ a blend of soft and hard time windows to enhance customer service quality. The body of research on the Location-routing Problem is expanding. In their study, Mara et al. (2021) conducted a review

of LRP literature, examining factors such as publication trends, problem characteristics, solution approaches, and application domains. A mixed-integer linear program was developed by Tian and Hu (2023) to minimize the distribution costs for a two-echelon location routing problem with recommended satellite facilities. A two-echelon LRP model was developed by Chen et al. (2024) to minimize total costs for a perishable food distribution network, accounting for the different needs of in-store pickup and delivery customers. In Bala et al. (2017), the authors investigate synchronization between production times and customer time windows to optimize service levels effectively. The approach was tested for a newspaper delivery problem. Yildiz et al. (2023), integrate location decisions into a two-echelon VRP that includes pickup and delivery operations. They apply this approach to a two-echelon supermarket chain, demonstrating its suitability for addressing real-world logistics challenges effectively. Escobar-Varbas and Crainic (2024) tackle a two-echelon location routing incorporating time-dependent multicommodity origin-to-destination demand, time windows, limited storage at intermediate facilities, and synchronization of fleets across echelons. This new problem, involves selecting facilities, routing vehicles, scheduling synchronized operations at intermediate sites, and allocating demands using time-sensitive routes.

2. Problem formulation

In this section we will introduce VRPTW in more details. Let $\mathcal{C} = \{1, \dots, n\}$ be a set of customers and r_i a request of a customer i in $\mathcal{C}$, that has to be served within time window $[t_i^a, t_i^d]$ with a serving time t_i^s . The time dimension besides the customers is also associated with depot, so that D has also defined window $[t_D^d, t_D^a]$. Service is carried with a homogenous fleet $\mathcal{V}$ of capacity Q . Each vehicle leaving the depot, starts distribution in time t_D^d and returns before the closing time t_D^a . At customers, vehicle cannot start service before the start of time window t_i^a and if arrives sonner than t_i^a it has to wait. The arrival time at customer i cannot be after the end time t_i^d . The serving time t_i^s defines holding time at customer i .

Let $G = (N, A)$ be an oriented graph defined on a set of vertices $N = \{0, 1, \dots, n, n + 1\}$ so that vertices 0 and $n + 1$ represent depot, and $1, \dots, n$ is the customer set $\mathcal{C}$. Arcs A of the graph are generated by connections between customers $\mathcal{C}$, while arcs with depot are modelled so that vertex

$0 \rightarrow \{1, \dots, n\}$ and represents leaving arcs from depot, while $\{1, \dots, n\} \rightarrow n+1$ and represents arcs entering the depot. For $i \in N$, O_i represents the outset $O_i = \{j : (i, j) \in A\}$, and I_i is the inset $I_i = \{j : (j, i) \in A\}$.

In the presented model we have two types of variables: binary x_{ij}^V and continuous ω_i^V . Binary

$$\min \left\{ \sum_{V \in \mathcal{V}} \sum_{j \in O(0)} x_{0j}^V, \sum_{V \in \mathcal{V}} \sum_{(i,j) \in A} c_{ij} x_{ij}^V \right\} \quad (1)$$

$$\sum_{V \in \mathcal{V}} \sum_{j \in N} x_{ij}^V = 1 \quad \forall i \in N \setminus \{0, n+1\} \quad (2)$$

$$\sum_{j \in O(0)} x_{0j}^V \leq 1 \quad \forall V \in \mathcal{V} \quad (3)$$

$$\sum_{j \in O(i)} x_{ij}^V - \sum_{j \in I(i)} x_{ji}^V = 0 \quad \forall V \in \mathcal{V}, i \in N \setminus \{0, n+1\} \quad (4)$$

$$\sum_{j \in O(0)} x_{0j}^V - \sum_{j \in I(n+1)} x_{jn+1}^V = 0 \quad \forall V \in \mathcal{V} \quad (5)$$

$$x_{ij}^V (\omega_i^V + t_i^s + t_{ij} - \omega_j^V) \leq 0 \quad \forall V \in \mathcal{V}, (i, j) \in A \quad (6)$$

$$t_i^a \sum_{j \in O(i)} x_{ij}^V \leq \omega_i^V - t_i^d \sum_{j \in O(i)} x_{ij}^V \quad \forall V \in \mathcal{V}, i \in N \setminus \{0, n+1\} \quad (7)$$

$$t_i^d \leq \omega_i^V \leq t_i^a \quad \forall V \in \mathcal{V}, i \in \{0, n+1\} \quad (8)$$

$$\sum_{i \in N \setminus \{0, n+1\}} r_i \sum_{j \in O(i)} x_{ij}^V \leq Q \quad \forall V \in \mathcal{V} \quad (9)$$

$$x_{ij}^V \in \{0, 1\} \quad \forall V \in \mathcal{V}, (i, j) \in A \quad (10)$$

$$\omega_i^V \geq 0 \quad \forall V \in \mathcal{V}, i \in N \quad (11)$$

The objective function (1) contemplates two objectives: number of vehicles and travel costs. With (2) we assure that each customer is visited exactly once. Inequality (3) implies that each vehicle is used exactly once, and combined with (4) and (5) defines the route of vehicle $V \in \mathcal{V}$. With (6)-(8) and (9) we follow the time constraints and capacity constraint, respectively. For a vehicle $V \in \mathcal{V}$ (7) implies $\omega_i^V = 0$ if customer i is not served by a vehicle V . Finally, (10) and (11) are variable constraints.

3. The algorithm

In this section, we present an algorithm for VRPTW that runs in predefined time blocks. Within each block, our primary objective is to evaluate the total travel costs. However, some blocks are treated as “special”, where the algorithm randomly selects a route s to focus on. Let m be the number of customers on route s , and w the cumulative quantity of all customers on s . Additional evaluation calculates the logarithm of m and average of w . The evaluation function is

variable is defined as 1 if a vehicle V uses the arc (i, j) , and 0 otherwise. Continuous variable ω_i^V represents time, more precisely start of serving time at customer i by a vehicle V . Time window associated with depot, that corresponds to vertices 0 and $n+1$, is $[t_0^d, t_0^a] = [t_{n+1}^d, t_{n+1}^a] = [t_D^d, t_D^a]$.

structured to prioritize moving customers away from the route by the means of a logarithmic function. The average of quantities tends to keep customers with smaller requests.

With appropriate term hierarchy, the algorithm will prioritize removing customers from the route first; if that's not possible, it will retain customers of smaller quantities who have a greater number of potential positions. If the number of customers reaches zero, and the running time for the block hasn't elapsed, the new route is chosen randomly. As the running time of the algorithm increases, we decrease the probability of declaring the special blocks, and gradually focus only on travel costs.

Let F_1 be the number of vehicles and F_2 the travel costs. Then the integral form of the evaluation function can be written as: $E(\cdot) = \alpha \cdot F_1 + \beta \cdot F_2 + \gamma \cdot \log(m+1) + \delta \frac{w}{m+1}$. If a block is not special, $\gamma = \delta = 0$. Otherwise, $\delta > 0$.

Exploration of the solution space is executed using the simulated annealing technique. As it is shown in several papers, for instance see Chiang and Russell (1996), Wang et al. (2015), Baños et

al. (2013), Bala et al. (2024), this metaheuristic can return solutions of high quality. In the review by Konstantakopoulos et al. (2022) the method is emphasized as one of the approaches that can effectively overcome the algorithm being stuck in local optimum. In this research we decided to apply the simulated annealing because of its robustness and relatively easy manipulation of the evaluation function. Another feature that we apply is guiding the search through infeasibility regions. During the special blocks, we accept solutions with minor time window or vehicle capacity violations. The idea is simple: to overcome local minima.

Generation of potential neighboring solutions is carried out via four transformations. To give a brief explanation, we will use the oriented graph described in a previous section. More comprehensive overview can be found in Bräysy and Gendreau (2005a).

1. Move: choose vertex $u \in M$ and $v \in \{0\} \cup M$, and move u after v . See Figure 1.
2. Swap: choose vertices $u, v \in M$, and swap their positions. See Figure 2.
3. 2-opt: choose vertices $u, v \in M$ on the same route and change the direction in the sub-route that they define. See figure 3.
4. Cross: choose vertices $u, v \in M$ on different routes and swap their remaining tails. See figure 4.

The Figures 1 – 4 are graphical presentations of transformation 1 – 4, respectively. The square indicates Depot, the start and the end of the routes, while circles represent customers. Direction of routes are indicated with arrows.

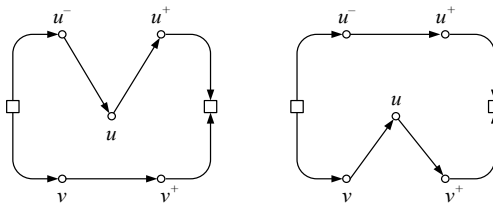


Figure 1 Move transformation
Source: the authors

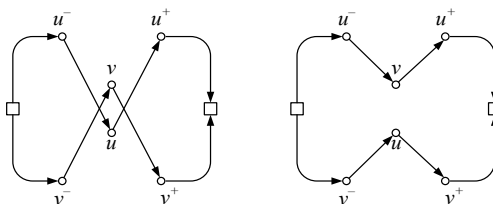


Figure 2 Swap transformation
Source: the authors

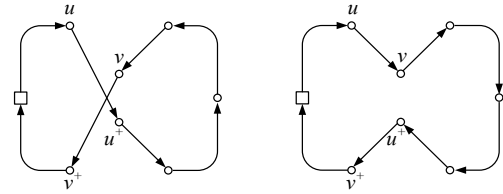


Figure 3 2-opt transformation
Source: the authors

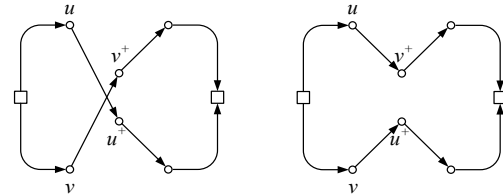


Figure 4 Cross transformation
Source: the authors

4. Results

This section contains the results of the proposed algorithm. We evaluated its performance using the Gehring and Homberger benchmark instances designed for 200 customers (<https://www.sintef.no/projectweb/top/vrptw/200-customers/>). These test instances are extensions of the well-known Solomon test problems for VRPTW and follow the same topology differentiation: clustered (C), random (R), and mixture (RC), and time scheduling horizon: short (1) and long (2). Each class (topology, horizon) contains 10 instances, resulting in 60 test instances.

For simulated annealing we define start and end temperatures of 20, and 0,5 respectively, with a cooling factor 0,999999. Each block lasts for 5 seconds, and applying the cooling rule $T := T \cdot 0,999999$ leads to the running time of the algorithm to being approximately 15 minutes (915 seconds).

For each problem instance, the algorithm is executed 10 times. In Table 1 we present a summary of the test results categorized by instance group. The first column denotes the problem group, followed by the deviation of the best-solution (bs) found from the best known solution (bks). The deviation is calculated as $(bs - bks)/bks$ and reported as percentage. Then we take the best among the whole group. The third column contains the average of deviations for each obtained solution after 10 runs. We report the average over the respective group.

Motivated by practitioner evaluation of results, where the tradeoff between execution time and

solution quality, or commonly small improvements that the algorithm makes in the latest part of execution, we introduce the measure “class” for each solution. If the deviation from the best-known solution is less than $(p + 1)\%$, we call the solution to be of class p . Average class for test results are given in the third column.

Table 1 Summary of the results across problem groups

Problem group	Minimum (%)	Average (%)	Average class
c1	0,0000	0,2256	0,1
c2	0,0005	0,1747	0,1
r1	0,0000	0,6244	0,2
r2	0,0005	0,5697	0,1
rc1	0,4579	2,3313	1,9
rc2	0,0351	1,1484	0,7
Total	0,0000	0,8457	0,5

Source: the authors

From the final row, we can see that our algorithm creates solutions that are on average 0,8457% behind the best solutions reported in the literature. This average is calculated across 600 test cases. The algorithm matches the best solutions in 23 tests, and in Table 2 we give a distribution of test cases among the classes. Specifically, 414 or 69% of test cases are within 1% of the best-known solution. Moreover, in 572 or 95,33% of cases our results lag by no more than 3%, demonstrating the algorithm's consistency and robustness.

Table 2 Class distribution

Class	Relative frequency (%)
1	69,00
2	18,83
3	7,50
4	2,83
5	1,17
6	0,33
7	0,33
Total	100,00

Source: the authors

Time consumption is presented in Table 3, with averages calculated within each respective group. The second column details the average time required to reach the minimum number of vehicles. In the third column, we report the average time taken to achieve the best solution for each test instance. Finally, the fourth column shows the average time required to attain the class for each test.

Table 3 Time consumption

Problem group	Average time (vehicles)	Average time (best)	Average time (class)
c1	26,3	650,8	449,7
c2	18,0	750,9	506,2
r1	21,1	692,3	547,4
r2	24,5	737,1	560,4
rc1	34,6	798,4	624,9
rc2	34,4	822,9	641,7
Total	26,5	742,1	555,0

Source: the authors

Note that although the algorithm reaches the minimum number of vehicles relatively quickly, it continues to periodically run in special blocks. That is not optimal behavior from a running time perspective. Furthermore, from Table 3, we can see that the algorithm spends on average an additional 187 seconds in making small progress in transportation costs from its class to the best solution. There is potential to make further improvements in running time efficiency in this area.

Conclusion

In this paper, we address the Vehicle Routing Problem with Time Windows (VRPTW), a critical component of logistics models. We present an algorithm for VRPTW designed to operate in predefined time blocks. Within each block, our primary objective is to minimize travel costs. Additionally, in certain blocks, we focus on reducing the number of vehicles involved by randomly selecting routes and including the number of requests and their quantities as part of our evaluation strategy. In overcoming the local optimum, we let algorithm explore the infeasible regions, from time and capacity perspective.

Our approach has demonstrated high quality solutions on Gehring and Homberger benchmark instances featuring 200 customers. Across all instances, we achieve the minimum number of vehicles reported in the literature. With travel costs averaging 0,8457% from the best-known solutions, we affirm the effectiveness of our algorithm.

Given the integral role of VRPTW in logistics software, we analyze solutions also from a practical standpoint. Our approach emphasizes achieving reasonably good solutions within feasible time frames, categorizing solutions into performance classes. Specifically, 69% of test cases are within 1% of the best-known solution, and 95% are within 3%.

While our method excels in solution quality, time efficiency remains a challenge. We find that 20% of execution time is spent on marginal improvements, indicating space for enhancing runtime efficiency. Future research will focus on refining our algorithm through advanced transformations, parallelization, and additional experimentation in evaluation functions to achieve faster execution times and further improve solution quality.

Declarations

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Dimitrijević, M. (2007). *Customer relationship management* (6th ed.). Faculty of Economics in Subotica.

➤ **Book, two authors.**

Ljubojević, K., Dimitrijević, M. (2007). *The enterprise knowledge portal and its architecture*. Faculty of Economics in Subotica.

➤ **Book, three to six authors.**

Ljubojević, K., Dimitrijević, M., Mirković, D., Tanasijević, V., & Perić, O. (2006). *Importance of software testing*. Faculty of Economics in Subotica.

➤ **Book, more than six authors.**

Mirković, D., Tanasijević, V., Perić, O., Jovanov, N., Boškov, T., Strakić, F., et al. (2007). *Supply chain management*. Faculty of Economics in Subotica.

➤ **Book, no author or editor.**

Web user interface (10th ed.). (2003). Faculty of Economics.

➤ **Group, corporate, or government author.**

Statistical office of the Republic of Serbia. (1978). *Statistical abstract of the Republic of Serbia*. Ministry of community and social services.

➤ **Edited book.**

Dimitrijević, M., & Tanasijević, V. (Eds.). (2004). *Data warehouse architecture*. Faculty of Economics.

➤ **Chapter in an edited book.**

Repa, V. (2019). Deriving Key Performance Indicators from Business Process Model. In M. Pańkowska & K. Sandkuhl (Eds.), *Perspectives in Business Informatics Research. BIR 2019. Lecture Notes in Business Information Processing, vol 365*. (pp. 148–162). Springer.
https://doi.org/10.1007/978-3-030-31143-8_11

➞ **Encyclopedia entry.**

Mirković, D. (2006). History and the world of mathematicians. In *The new mathematics encyclopedia* (Vol. 56, pp. 23-45). Faculty of Economics.

C. UNPUBLISHED WORKS

➞ **Paper presented at a meeting or a conference.**

Ljubojević, K., Tanasijević, V., Dimitrijević, M. (2003). *Designing a web form without tables*. Paper presented at the annual meeting of the Serbian computer alliance, Beograd.

➞ **Paper or manuscript.**

Boškov, T., Strakić, F., Ljubojević, K., Dimitrijević, M., & Perić, O. (2007. May). *First steps in visual basic for applications*. Unpublished paper, Faculty of Economics Subotica, Subotica.

➞ **Doctoral dissertation.**

Strakić, F. (2000). *Managing network services: Managing DNS servers*. Unpublished doctoral dissertation, Faculty of Economics Subotica.

➞ **Master's thesis.**

Dimitrijević, M. (2003). *Structural modeling: Class and object diagrams*. Unpublished master's thesis, Faculty of Economics Subotica.

D. ELECTRONIC MEDIA

The same guidelines apply for online articles as for printed articles. All the information that the online host makes available must be listed, including an issue number in parentheses:

Author, A. A., & Author, B. B. (Publication date). Title of article. *Title of Online Periodical, volume number* (issue number if available). <https://www.anyaddress.com/full/url/>

➞ **Article in an internet-only journal**

Tanasijević, V. (2003, March). Putting the user at the center of software testing activity. *Strategic Management*, 8 (4). <https://www.ef.uns.ac.rs/sm2024>

➞ **Document from an organization**

Faculty of Economics. (2008, March 5). *A new approach to CRM*. <https://www.ef.uns.ac.rs/papers/acrm.html>

➞ **Article from an online periodical with DOI assigned.**

Jovanov, N., & Boškov, T. A PHP project test-driven end to end. *Management Information Systems*, 2 (2), 45-54. <https://doi.org/10.5937/StraMan213302003S>

➞ Article from an online periodical without DOI assigned.

Online journal articles without a DOI require a URL.

Author, A. A., & Author, B. B. (Publication date). Title of article. *Title of Journal*, volume number. <https://www.anyaddress.com/full/url/>

Jovanov, N., & Boškov, T. A PHP project test-driven end to end. *Management Information Systems*, 2 (2), 45-54. <https://www.ef.uns.ac.rs/mis/TestDriven.html>

REFERENCE QUOTATIONS IN THE TEXT

➞ Quotations

If a work is directly quoted from, then the author, year of publication and the page reference (preceded by “p.”) must be included. The quotation is introduced with an introductory phrase including the author’s last name followed by publication date in parentheses.

According to Mirković (2001, p. 201), “The use of data warehouses may be limited, especially if they contain confidential data”.

Mirković (2001, p. 201), found that “the use of data warehouses may be limited”. What unexpected impact does this have on the range of availability?

If the author is not named in the introductory phrase, the author's last name, publication year, and the page number in parentheses must be placed at the end of the quotation, e.g.

He stated, “The use of data warehouses may be limited,” but he did not fully explain the possible impact (Mirković, 2001, p. 201).

➞ Summary or paraphrase

According to Mirković (1991, p. 201), limitations on the use of databases can be external and software-based, or temporary and even discretion-based.

Limitations on the use of databases can be external and software-based, or temporary and even discretion-based (Mirković, 1991, p. 201).

➞ One author

Boškov (2005) compared the access range...

In an early study of access range (Boškov, 2005), it was found...

➞ When there are **two authors**, both names are always cited:

Another study (Mirković & Boškov, 2006) concluded that...

➞ If there are **three or more authors** the abbreviation "et al." (Latin for "and others") is employed in APA in-text citations when referencing works with three or more authors. The format is to include only the first author's last name, followed by "et al.," a comma, and the year of publication. For instance, (Dakic et al., 2024) would be used as an example.

➞ **Unknown author**

If the work does not have an author, the source is cited by its title in the introductory phrase, or the first 1-2 words are placed in the parentheses. Book and report titles must be italicized or underlined, while titles of articles and chapters are placed in quotation marks:

A similar survey was conducted on a number of organizations employing database managers (*Limiting database access*, 2005).

If work (such as a newspaper editorial) has no author, the first few words of the title are cited, followed by the year: (*The Objectives of Access Delegation*, 2007)

Note: In the rare cases when the word "Anonymous" is used for the author, it is treated as the author's name (Anonymous, 2008). The name Anonymous must then be used as the author in the reference list.

➞ **Organization as an Author**

If the author is an organization or a government agency, the organization must be mentioned in the introductory phrase or in the parenthetical citation the first time the source is cited:

According to the Statistical Office of the Republic of Serbia (1978), ...

Also, the full name of corporate authors must be listed in the first reference, with an abbreviation in brackets. The abbreviated name will then be used for subsequent references:

The overview is limited to towns with 10,000 inhabitants and up (Statistical Office of the Republic of Serbia [SORS], 1978).

The list does not include schools that were listed as closed down in the previous statistical overview (SORS, 1978).

➞ When citing **more than one reference from the same author**: (Bezjak, 1999, 2002)

➞ When several **used works by the same author were published in the same year**, they must be cited adding a, b, c, and so on, to the publication date:

(Griffith, 2002a, 2002b, 2004)

➞ **Two or more works in the same parentheses**

When two or more manuscripts are cited parenthetically, they must be cited in the same order as they appear in the reference list, separated by a semicolon.

(Bezjak, 1999; Griffith, 2004)

➞ **Two or more works by the same author in the same year**

If two or more sources used in the submission were published by the same author in the same year, the entries in the reference list must be ordered using lower-case letters (a, b, c...) with the year. Lower-case letters will also be used with the year in the in-text citation as well:

Survey results published in Theissen (2004a) show that...

- ➞ To **credit an author for discovering a work** when you have not read the original:

Bergson's research (as cited in Mirković & Boškov, 2006)...

Here, Mirković & Boškov (2006) will appear in the reference list, while Bergson will not.

- ➞ When **citing more than one author**, the authors must be listed alphabetically:

(Britten, 2001; Sturlasson, 2002; Wasserwandt, 1997)

- ➞ When there is **no publication date**: (Hessenberg, n.d.)

- ➞ **Page numbers must always be given for quotations:**

(Mirković & Boškov, 2006, p.12)

Mirković & Boškov (2006, p. 12) propose the approach by which “the initial viewpoint...

- ➞ **Referring to a specific part of a work:**

(Theissen, 2004a, chap. 3) (Keaton, 1997, pp. 85-94)

- ➞ **Personal communications, including interviews, letters, memos, e-mails, and telephone conversations**, are cited as below. (These are *not* included in the reference list.)

(K. Ljubojević, personal communication, May 5, 2008).

FOOTNOTES AND ENDNOTES

A few footnotes may be necessary when elaborating on an issue raised in the text, adding something that is in indirect connection, or providing supplementary technical information. Footnotes and endnotes are numbered with superscript Arabic numerals at the end of the sentence, like this.¹ Endnotes begin on a separate page, after the end of the text. However, *Strategic Management* **does not recommend the use of footnotes or endnotes.**

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