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Digital transformation enabled management control capability and sustainable operational performance: the sequential roles of market sensing and green operations

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ABSTRACT

Digital transformation is reshaping how firms collect, interpret, and use information for operational and sustainability-related decisions. However, digital investments do not automatically improve sustainable operational performance. Drawing on Dynamic Capabilities Theory and management control perspectives, this study examines how digital transformation capability is associated with sustainable operational performance through a sequential pathway of management control capability, market sensing capability, and green operations capability. The model proposes that digital transformation capability strengthens management control capability by improving the availability, integration, and usefulness of information for planning, monitoring, coordination, and corrective action. Stronger management control capability is then expected to support market sensing, which enables firms to recognize changing customer, competitor, supplier, technological, and regulatory conditions. Market sensing capability subsequently supports green operations capability, including responsible sourcing, resource efficiency, waste reduction, cleaner operating practices, and environmentally conscious logistics. Using survey data from managers in Iranian manufacturing and service SMEs, the study tests the proposed relationships with partial least squares structural equation modeling. The findings support the theorized sequential pattern of associations and contribute by explaining how digital transformation capability can be translated through management control and market sensing into green operations and sustainable operational performance. The study also offers practical guidance for managers seeking to align digital systems, management control practices, market intelligence, and green operational priorities.

Introduction

Digital transformation is changing how organizations collect information, coordinate activities, monitor performance, and respond to operational uncertainty (Nambisan et al., 2019; Vial, 2019). Yet digital investments do not automatically produce sustainable operational outcomes. Their value depends on whether firms can embed digital tools within routines for decision support, control, market interpretation, and operational improvement (Poelmans et al., 2013; Yu et al., 2019). Research on humanitarian supply chains shows that digital transformation can strengthen transparency, coordination, decision-making, and adaptive capability when technological systems are integrated with human and organizational resources (Karami, 2026). However, less is known about how comparable digital capabilities support management control and sustainability-oriented operations in commercial firms, particularly small and medium-sized enterprises operating in dynamic and resource-constrained environments.

Management control capability is central to this process because it enables managers to transform operational and

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financial data into information for planning, monitoring, coordination, and corrective action. Earlier evidence from Iranian financial organizations demonstrates that the effectiveness of management accounting systems is associated with the quality and usefulness of managerial information and organizational performance (Ghasemi et al., 2019). Related research further shows that management accounting systems can transmit the effect of competitive conditions to managerial performance by providing timely, broad-scope, and decision-relevant information (Ghasemi et al., 2016). These findings suggest that management control systems should not be viewed solely as accounting tools, but as organizational capabilities that can help firms convert digital information into purposeful operational decisions (Ghasemi et al., 2019).

Market sensing capability represents a further mechanism through which firms use digitally enabled information (Grego et al., 2025; Laudon & Laudon, 2004). It involves identifying, interpreting, and disseminating intelligence about customer expectations, competitor actions, supply conditions, technological developments, and regulatory changes. Firms that can translate digital information into actionable market intelligence are better positioned to adjust priorities and align their operational practices with changing stakeholder demands (Rakthin et al., 2016). Recent research links market sensing, digital logistics, and green operations, showing that information-based capabilities can support environmentally responsive practices and superior business outcomes (Karami, 2025). Nevertheless, the role of management control capability in enabling this transition from digital information to market sensing and green operations has received limited attention (Teece, 2019).

Green operations capability includes the ability to integrate resource efficiency, waste reduction, cleaner production, responsible sourcing, and environmentally conscious logistics into routine decisions (Borah et al., 2023). These practices can improve environmental performance while also reducing operating inefficiencies and supporting resilience under uncertainty (Caliskan et al., 2021; Zaki, 2019). Although prior studies have examined digital transformation, management accounting systems, market sensing, green operations, and performance separately, the mechanisms connecting these domains remain fragmented (Hamann-Lohmer et al., 2023; Kumar et al., 2024). In particular, research has not sufficiently explained how digital transformation capability may strengthen sustainable operational performance through management control capability, market sensing, and green operations in a connected sequence (Birasnav et al., 2019; Borazon et al., 2022).

Drawing on Dynamic Capabilities Theory and management control perspectives, this study develops a sequential capability model explaining how digital transformation capability is associated with sustainable operational performance. Its novelty is not simply to link digital transformation with green outcomes, as prior capability-based research has already examined digital, market-oriented, and environmental capabilities separately. Instead, the study specifies the internal capability sequence through which digital transformation can become operationally consequential in SMEs: digital transformation capability improves the information base for management control; management control capability enables managers to convert dispersed data into coordinated planning, monitoring, and corrective-action routines; market sensing capability directs this information-processing capacity toward external changes and stakeholder demands; and green operations capability embeds the resulting insights into resource, sourcing, production, and logistics practices. This positioning identifies management control capability as the previously underexplained bridge between digital transformation and market-responsive green operational reconfiguration. The study therefore contributes a more granular explanation of how complementary capabilities operate together, rather than treating digital transformation as a direct or stand-alone source of sustainable performance.

Literature Review and Hypotheses Development

Theoretical Foundation

Dynamic Capabilities Theory explains how firms purposefully renew and reconfigure resources, routines, and competences in response to changing environments. Its core mechanisms are sensing, seizing, and reconfiguring. Sensing involves identifying and interpreting opportunities, threats, stakeholder expectations, and technological or regulatory changes. Seizing involves mobilizing resources and making coordinated decisions to capture opportunities or address emerging risks. Reconfiguring involves modifying operational routines, resource allocations, processes, and relationships so that the firm can sustain performance over time (Teece, 2007, 2019).

In the proposed model, market sensing capability corresponds most directly to the sensing mechanism because it enables firms to acquire, interpret, and disseminate information about customers, competitors, suppliers, technologies, and regulations. Management control capability corresponds primarily to the seizing mechanism because it helps managers use timely and integrated financial and non-financial information for planning, performance monitoring, coordination, resource allocation, and corrective action. Green operations capability corresponds primarily to the reconfiguring mechanism because it enables firms to embed environmental considerations into sourcing, resource use, production, waste management, and logistics routines. Digital transformation capability provides the enabling digital infrastructure, data accessibility, analytical tools, and employee skills that strengthen these sensing, seizing, and reconfiguring activities. Thus, digital transformation capability does not create sustainable operational performance automatically; it supports performance when it is translated through complementary dynamic capabilities into market-responsive and environmentally responsible operational change.

Digital Transformation Capability and Management Control Capability

Digital transformation capability refers to a firm's ability to adopt, integrate, and use digital technologies, data infrastructure, analytical tools, and digitally skilled employees to support business processes and decisions (Vial, 2019; Warner & Wäger, 2019). These capabilities can improve the availability, accuracy, timeliness, and accessibility of operational information. Management control capability refers to the ability to use financial and non-financial information for planning, performance monitoring, coordination, resource allocation, and corrective action. Digitally enabled systems can strengthen management control by integrating information across functions and providing managers with more timely and relevant evidence for decision-making. Prior research shows that effective management accounting systems improve the usefulness of managerial information and organizational performance (Ghasemi et al., 2019).

- H1: Digital transformation capability is positively associated with management control capability.

Management Control Capability and Market Sensing Capability

Management control capability can strengthen market sensing by enabling managers to organize, interpret, and distribute information concerning customer needs, competitor actions, supply conditions, and emerging risks. Market sensing capability involves systematically acquiring, interpreting, and disseminating market intelligence so that firms can recognize external changes and respond through coordinated decisions and actions (Morgan et al., 2009). While market sensing requires external intelligence, firms must also possess internal information routines that allow relevant signals to be evaluated and incorporated into strategic and operational decisions. Management accounting and control systems can provide this internal coordination function by connecting market-related information with cost, performance, and resource-allocation considerations. Evidence from Iranian financial organizations indicates that management accounting systems help managers respond to competitive conditions and improve decision quality and performance (Ghasemi et al., 2016). Firms with stronger management control capability should therefore be better positioned to develop effective market sensing (Mata et al., 2024; Teece, 2019).

- H2: Management control capability is positively associated with market sensing capability.

Market Sensing Capability and Green Operations Capability

Market sensing capability enables firms to identify changing customer preferences, stakeholder expectations, competitor practices, environmental regulations, and supply-network developments. This intelligence is especially valuable for green operations because environmental initiatives must be aligned with market demand, regulatory requirements, available technologies, and supplier capabilities. Green operations capability refers to a firm's ability to incorporate responsible sourcing, resource efficiency, waste reduction, cleaner production, and environmentally conscious logistics into routine decisions (Borah et al., 2023; Karami, 2025). Firms that systematically sense external developments are more likely to identify opportunities for sustainable sourcing, pollution prevention, energy efficiency, and environmentally responsive logistics. Prior research shows that green supply chain and operational practices can improve environmental and operational outcomes by integrating environmental concerns into sourcing, production, and logistics decisions (Ali et al., 2020; Borazon et al., 2022). Research has also linked market sensing, digital logistics, and green operations to improved business outcomes (Karami, 2025).

- H3: Market sensing capability is positively associated with green operations capability.

Green Operations Capability and Sustainable Operational Performance

Green operations capability refers to a firm's ability to embed environmentally responsible practices, such as responsible sourcing, waste-prevention routines, cleaner processes, resource-efficient operations, and environmentally conscious logistics, into its regular activities (Borah et al., 2023). Sustainable operational performance is conceptually different because it reflects the results achieved through those activities. Consistent with the multidimensional view of sustainability, sustainable operational performance encompasses interconnected economic, environmental, resource-related, and stakeholder-related outcomes. Economic outcomes include operational cost efficiency; environmental outcomes include reduced adverse environmental impacts; resource-related outcomes include improved material and energy efficiency and lower waste; and stakeholder-related outcomes include consideration of the well-being and expectations of employees, customers, suppliers, and communities (Carter et al., 2007).

These dimensions are treated as a broad operational-performance domain because sustainability-oriented operational decisions often generate related outcomes simultaneously (Cantele et al., 2023; Medne & Lapina, 2019). For example, reducing material waste and energy use may improve both environmental performance and operating efficiency, while responsible sourcing and cleaner processes may support regulatory compliance and stakeholder relationships. The study therefore does not claim that these outcomes are identical. Rather, it assesses managers' overall evaluation of whether their firm's operations are producing sustainability-related value across these related domains. This broad operational-performance perspective is appropriate for SMEs, where financial, environmental, resource, and stakeholder considerations are often managed through closely connected operational decisions.

- H4: Green operations capability is positively associated with sustainable operational performance.

Sequential Indirect Relationship

The proposed model suggests that digital transformation capability supports sustainable operational performance through a connected sequence of complementary capabilities (Kumar et al., 2024; Xing et al., 2023; Yu et al., 2025). Digital technologies enhance the availability and use of information, while management control capability converts this information into coordinated planning and monitoring routines (Borazon et al., 2022; Harsono et al., 2025). These routines strengthen market sensing by helping managers interpret external signals and align them with internal performance priorities. Market sensing then supports the development of green operations, which contribute to sustainable operational performance (Lei et al., 2026; Manzoor et al., 2022). This sequential logic extends prior research by linking digital transformation, management control, market intelligence, and green operations within a single Dynamic Capabilities Theory framework.

- H5: Management control capability, market sensing capability, and green operations capability form a sequential indirect pathway between digital transformation capability and sustainable operational performance.

Figure 1 presents the conceptual model and the proposed hypotheses.

Methodology

Research Design and Study Context

This study used a quantitative, cross-sectional survey design to examine the relationships among digital transformation capability, management control capability, market sensing capability, green operations capability, and sustainable operational performance. The firm was the unit of analysis because the proposed constructs reflect organization-level resources, routines, and operational practices. The study focused on manufacturing and service SMEs in Iran, where firms commonly face economic volatility, technological change, competitive pressure, supply uncertainty, and rising sustainability expectations. For this study, SMEs were operationally defined as independent firms employing 10 to 499 employees; this criterion was applied consistently during respondent screening and sample classification.

Iranian SMEs operate in an environment in which economic volatility, exchange-rate movements, regulatory uncertainty, technological-access constraints, and resource pressures can affect both the availability of digital technologies and the feasibility of sustainability-oriented operational change. These conditions may increase the value of management control capability because managers need timely and integrated information to allocate scarce resources and monitor changing costs and risks. They may also increase the value of market sensing capability because firms must identify changes in customer demand,

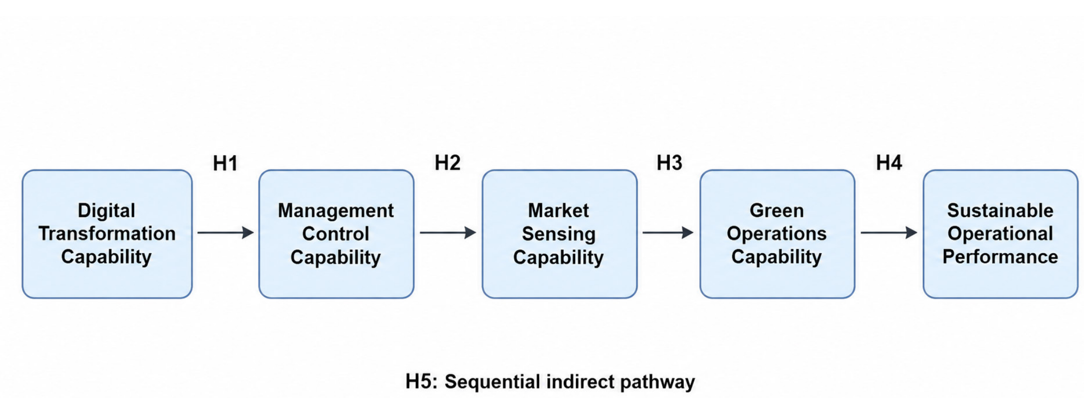

Figure 1. *Conceptual model and proposed hypotheses*
Source: *Author's own creation.*

supplier conditions, competitive actions, and regulatory expectations. Green operations may be shaped by resource costs, environmental requirements, supply constraints, and stakeholder pressures. Accordingly, the proposed relationships should be interpreted within the institutional and economic conditions of Iranian SMEs rather than assumed to operate identically in all national settings.

Data were collected from managers and senior professionals who possessed direct knowledge of their firm's digital initiatives, management-control practices, market-information activities, and operational performance. Suitable respondents included individuals with decision-making responsibilities or close involvement in financial, operational, supply chain, business-development, sustainability, or digital-transformation activities. This respondent profile was appropriate because the study examined firm-level practices that require informed assessments of cross-functional routines and outcomes. Because the design was cross-sectional, the findings indicate statistically supported associations among the constructs rather than definitive causal effects or temporal ordering.

The hypothesized sequence is grounded in theory, but it should be interpreted as an explanatory model of associations rather than evidence of a confirmed temporal or causal process. Because all focal variables were measured from the same managerial respondent at one point in time, the study cannot establish whether digital transformation capability developed before management control capability, whether management control preceded market sensing, or whether green operations occurred before subsequent performance outcomes. Reverse, reciprocal, and omitted-variable explanations remain possible. The proposed ordering should therefore be tested in future research using longitudinal, time-lagged, multi-source, or experimental research designs.

Iran provides a theoretically relevant setting because SMEs commonly operate under economic volatility, exchange-rate uncertainty, regulatory changes, resource constraints, technological-access limitations, and growing stakeholder attention to environmental responsibility. These conditions increase the importance of capabilities that help firms interpret external signals, coordinate limited resources, and adapt operational practices. The study includes both manufacturing and service SMEs because the proposed model concerns organization-level information, control, sensing, and operational-adaptation capabilities that are relevant across sectors. In manufacturing firms, green operations may be expressed through production processes, materials, energy use, waste reduction, sourcing, and logistics. In service firms, they may be expressed through service-delivery processes, procurement, facilities, energy and resource use, waste reduction, and environmentally responsible logistics. The study does not assume that the magnitude of the relationships is identical across sectors; instead, it examines whether the theorized capability pattern is observable across a heterogeneous SME sample.

Population, Sampling, and Data Collection

The target population comprised Iranian manufacturing and service SMEs with active customer, supplier, and operational relationships. Eligible respondents included owner-managers, chief executives, finance managers, operations managers, supply chain managers, business-development managers, sustainability managers, and digital-transformation managers. Purposive sampling was used because respondents must have sufficient knowledge of firm-level information systems, control practices, and operations. Survey invitations were distributed through provincial chambers of commerce, industry associations, professional networks, online business directories, LinkedIn, and direct corporate contacts. The use of purposive sampling was appropriate because the study required informed respondents who could evaluate firm-level digital initiatives, management-control routines, market-information activities, green operational practices, and performance outcomes. The sampling frame intentionally included both manufacturing and service SMEs to improve variation in organizational contexts and avoid limiting the findings to one operational setting. However, this approach does not provide a probability sample of all Iranian SMEs. Accordingly, the findings should be generalized cautiously and interpreted as evidence from the participating firms rather than as population estimates for all manufacturing and service SMEs in Iran. 1,048 invitations were successfully delivered, 381 questionnaires were returned, and 327 usable responses were retained after screening, yielding a usable response rate of 31.2%.

Sample Size and Respondent Screening

The final sample of 327 responses exceeds the minimum sample-size requirement. An a priori power analysis for a linear multiple regression model with two predictors, a medium effect size of 0.15, a significance level of 0.05, and statistical power of 0.95 indicates a minimum sample of 107 observations (Faul et al., 2009). The retained sample therefore provides sufficient statistical power for the proposed structural relationships and sequential indirect-effect analysis. The survey begins with screening questions confirming that respondents work for an Iranian SME, hold a managerial or relevant professional role, and possess adequate knowledge of digital, financial-control, and operational practices. Responses are excluded when eligibility criteria are not met, substantial data are missing, completion times are implausibly short, duplicates are identified, or straight-line response patterns are detected.

Questionnaire Development, Translation, and Pilot

Test

The questionnaire was initially developed in English and translated into Persian using translation and back-translation procedures (Brislin, 1980). The scale-adaptation process was contextual rather than substantive. Specifically, the original construct meanings, item domains, and response scale were retained, while wording was adjusted only to make items understandable and relevant for Iranian SMEs. For example, references to firm operations were interpreted to include manufacturing, service-delivery, sourcing, procurement, and logistics activities, depending on the participating firm. Five experts reviewed the questionnaire for content clarity, conceptual relevance, terminology, and potential ambiguity: two management or accounting academics, one operations or supply chain academic, and two Iranian SME managers. The instrument was then pilot tested with 23 eligible managers who were not included in the final sample. The pilot assessed wording clarity, question order, completion time, technical functionality, and contextual appropriateness. Minor wording revisions were made to improve readability and local relevance; no construct dimensions were added, removed, or substantively altered. The final questionnaire required approximately 10 to 12 minutes to complete.

Measures

All focal constructs were measured using multi-item reflective scales with a seven-point Likert response format, ranging from 1 = strongly disagree to 7 = strongly agree. The measures were adapted from established literature and contextualized for Iranian SMEs through the expert-review, translation, and pilot-testing procedures described above. Digital transformation capability refers to the firm's capacity to provide and integrate digital infrastructure, accessible data, analytical tools, digital skills, and managerial support for digitalization. It is therefore an enabling technological and informational capability, rather than a measure of how managers use information for control or how the firm performs operationally. Management control capability refers to the use of timely, integrated, broad-scope, and decision-relevant financial and non-financial information for planning, performance monitoring, coordination, resource allocation, and corrective action. It captures the internal managerial use of information, rather than the availability of digital infrastructure itself.

Market sensing capability refers to the systematic acquisition, interpretation, and cross-functional dissemination of external intelligence concerning customers, competitors, suppliers, technologies, regulations, and market developments. It is conceptually distinct from management control capability because it focuses on recognizing and interpreting external changes, whereas management control capability focuses on internal planning and control routines. Green operations capability refers to the firm's ability to embed environmental considerations in sourcing, resource use, production or service delivery, waste management, and logistics practices. In contrast, sustainable operational performance captures the results achieved through operations, including economic efficiency, reduced environmental impacts, resource-related outcomes, and stakeholder-related outcomes. Thus, green operations capability measures what the firm does, while sustainable operational performance measures the outcomes associated with those operational practices. Across the

Table 1: respondent and firm characteristics (n = 327)

Characteristic	*Category*	*Frequency*	*Percentage*
Respondent role	Operations or production manager	91	27.8
	Owner-manager or chief executive	73	22.3
	Finance or accounting manager	61	18.7
	Supply chain or logistics manager	48	14.7
	Business-development or digital-transformation manager	54	16.5
Firm size	Small: 10 to 49 employees	152	46.5
	Medium: 50 to 249 employees	138	42.2
	Larger SME: 250 to 499 employees	37	11.3
Firm sector	Manufacturing	183	56.0
	Services	144	44.0
Firm age	Less than 10 years	69	21.1
	10 to 19 years	117	35.8
	20 years or more	141	43.1

questionnaire, the term operations was used broadly to include manufacturing, service-delivery, sourcing, and logistics processes, as applicable to each participating firm.

The adaptation process did not change the conceptual boundaries of the scales. Digital transformation capability retained items related to digital infrastructure, data accessibility, employee digital skills, and managerial support for digital integration. Management control capability retained items addressing timely, integrated, broad-scope, and decision-relevant information for planning, monitoring, coordination, and corrective action. Market sensing capability retained items capturing the acquisition, interpretation, and dissemination of external market intelligence. Green operations capability retained items related to responsible sourcing, resource efficiency, waste reduction, cleaner practices, and environmentally responsible logistics. Sustainable operational performance retained items reflecting economic, environmental, resource-related, and stakeholder-related operational outcomes. The reliability, convergent-validity, and discriminant-validity results reported in Section 4 provide empirical support for the appropriateness of the adapted measures in the Iranian SME sample. Appendix A summarizes the scale-adaptation process, and Appendix B presents the full measurement items and their sources.

Common-Method Bias and Ethical Procedures

Several procedural remedies were used to reduce the risk of common-method bias. Participants were informed that their responses were anonymous and confidential, that there were no correct or incorrect answers, and that the data would be reported only in aggregate form. Predictor and outcome constructs were placed in separate questionnaire sections, item wording was concise and neutral, and respondents were not asked to provide commercially sensitive information. The questionnaire also used clear construct instructions and a consistent seven-point response format to reduce ambiguity and respondent fatigue.

Statistical checks were used as diagnostic evidence rather than as definitive proof that common-method bias was absent. First, full-collinearity variance inflation factors were examined; values below 3.3 indicate no severe collinearity concern associated with a common latent source (Kock, 2015). Second, Harman's single-factor test was conducted using an unrotated exploratory factor analysis. The first factor accounted for 34.9% of the total variance, which was below the conventional 50%

Table 2: Reliability and Convergent-Validity Results

Construct	*Items*	*Loading Range*	*Cronbach's Alpha*	*rho_A*	*Composite Reliability*	*AVE*
Digital Transformation Capability	4	0.729 to 0.847	0.851	0.856	0.899	0.691
Management Control Capability	4	0.714 to 0.838	0.842	0.847	0.894	0.679
Market Sensing Capability	4	0.738 to 0.856	0.869	0.874	0.911	0.719
Green Operations Capability	4	0.721 to 0.849	0.854	0.859	0.902	0.697
Sustainable Operational Performance	4	0.735 to 0.852	0.875	0.880	0.916	0.731

Note: AVE = average variance extracted; rho_A = Dijkstra-Henseler's rho.

Table 3: Discriminant Validity Assessment Using HTMT Ratios

Construct pair	*HTMT ratio*	*Lower 95% CI*	*Upper 95% CI*
Digital transformation capability–management control capability	0.684	0.591	0.761
Digital transformation capability–market sensing capability	0.558	0.462	0.645
Digital transformation capability–green operations capability	0.447	0.351	0.535
Digital transformation capability–sustainable operational performance	0.471	0.374	0.557
Management control capability–market sensing capability	0.719	0.633	0.793
Management control capability–green operations capability	0.586	0.491	0.671
Management control capability–sustainable operational performance	0.529	0.431	0.614
Market sensing capability–green operations capability	0.754	0.673	0.824
Market sensing capability–sustainable operational performance	0.642	0.548	0.726
Green operations capability–sustainable operational performance	0.812	0.741	0.872

Note. HTMT = heterotrait-monotrait ratio of correlations; CI = bias-corrected 95% bootstrap confidence interval. Discriminant validity is supported when HTMT values are below 0.85 and the confidence intervals do not include 1.00.

Table 4: Structural-Model Results

	Structural path	*Beta*	*Standard error*	*t-value*	*p-value*	*95% confidence interval*	*f^2*	*Decision*
H1	Digital transformation capability → Management control capability	0.441	0.054	8.167	< 0.001	[0.332, 0.541]	0.241	Supported
H2	Management control capability → Market sensing capability	0.404	0.057	7.088	< 0.001	[0.287, 0.508]	0.195	Supported
H3	Market sensing capability → Green operations capability	0.432	0.055	7.855	< 0.001	[0.323, 0.536]	0.230	Supported
H4	Green operations capability → Sustainable operational performance	0.389	0.058	6.707	< 0.001	[0.276, 0.502]	0.178	Supported
Direct effect assessed for mediation	Digital transformation capability → Sustainable operational performance	0.154	0.067	2.299	0.022	[0.026, 0.285]	0.192	Significant

Note: f^2 = effect size.

threshold. These results, together with the procedural remedies, suggest that common-method bias was unlikely to dominate the findings. Nevertheless, because the study used cross-sectional, single-source managerial responses, common-method variance cannot be completely ruled out.

Data Analysis

The proposed model is analyzed using partial least squares structural equation modeling in SmartPLS 4. PLS-SEM is appropriate because the study examines an explanatory model involving multiple latent constructs and a specific sequential indirect effect (Hair & Alamer, 2022). The reflective measurement model is assessed using indicator loadings, Cronbach's alpha, rho_A, composite reliability, average variance extracted, and heterotrait-monotrait ratios (Henseler et al., 2015). The structural model was evaluated using path coefficients, bootstrapped standard errors, t-values, p-values, bias-corrected 95% confidence intervals, direct effects, specific indirect effects, total effects, R^2, f^2, Q^2, and SRMR. To distinguish the direct association from the proposed sequential indirect association, a direct path from digital transformation capability to sustainable operational performance was included in the mediation assessment. Significance testing was conducted using 5,000 bootstrap resamples.

Results

Respondent and Firm Profile

The final sample comprised 327 valid responses from Iranian manufacturing and service SMEs. Operations and production managers represented the largest respondent

Table 5: Direct, Indirect, and Total Effects

Effect type	*Path*	*Beta*	*Standard error*	*t-value*	*p-value*	*95% confidence interval*	*Interpretation*
Direct effect	Digital transformation capability → Sustainable operational performance	0.154	0.067	2.299	0.022	[0.026, 0.285]	Significant
Specific sequential indirect effect	Digital transformation capability → Management control capability → Market sensing capability → Green operations capability → Sustainable operational performance	0.030	0.009	3.333	0.001	[0.014, 0.048]	Significant
Total effect	Digital transformation capability → Sustainable operational performance	0.184	0.064	2.875	0.004	[0.061, 0.308]	Significant

Note. The significant positive direct and sequential indirect effects indicate complementary partial mediation.

Table 6: Explanatory Power, Predictive Relevance, and Inner Collinearity

Assessment	*Management Control Capability*	*Market Sensing Capability*	*Green Operations Capability*	*Sustainable Operational Performance*
R^2	0.194	0.163	0.187	0.286
Adjusted R^2	0.192	0.160	0.184	0.281
Q^2	0.126	0.104	0.118	0.198
Inner VIF	1.000	1.000	1.000	1.180 / 1.180

Note. For sustainable operational performance, the first VIF is for green operations capability and the second is for digital transformation capability. All VIF values are below 3.3, indicating no collinearity concern.

Table 7: Model-Level Assessment

Model-level assessment	*Value*	*Interpretation*
SRMR	0.061	Acceptable approximate model fit
Full-collinearity VIF range	1.31 to 2.09	Below 3.3; no indication of severe common-method bias
Harman's single-factor variance	34.9%	Below 50%; no single factor dominates the variance
Bootstrap resamples	5,000	Bias-corrected 95% confidence intervals

group, followed by owner-managers or chief executives, finance managers, supply chain managers, and business-development managers. Manufacturing firms accounted for 56.0% of the sample, while service firms represented 44.0%. Small firms with 10 to 49 employees comprised 46.5% of the sample, medium-sized firms with 50 to 249 employees represented 42.2%, and larger SMEs with 250 to 499 employees accounted for 11.3%. The sample therefore reflects diversity in managerial roles, firm size, sector, and organizational experience. Table 1 presents the detailed respondent and firm characteristics.

Measurement Model Assessment

The reflective measurement model demonstrated satisfactory indicator reliability, internal consistency, convergent validity, and discriminant validity. All outer loadings exceeded 0.70, ranging from 0.714 to 0.856. Cronbach's alpha, rho_A, and composite reliability values were above 0.70 and below 0.95. Average variance extracted values ranged from 0.679 to 0.731, exceeding the recommended threshold of 0.50. These results indicate that the measurement items adequately represented digital transformation capability, management control capability, market sensing capability, green operations capability, and sustainable operational performance. In particular, the four sustainable operational performance items loaded between 0.735 and 0.852, with composite reliability of 0.916 and AVE of 0.731, supporting their use as a coherent broad operational-outcome construct. Table 2 reports the indicator reliability, internal-consistency reliability, and convergent-validity results for all reflective constructs.

Discriminant validity was assessed using heterotrait-monotrait ratios (HTMT) and bias-corrected 95% bootstrap confidence intervals. As shown in Table 3, all HTMT values were below the conservative threshold of 0.85, ranging from 0.447 to 0.812. In addition, none of the lower and upper confidence interval bounds included 1.00, providing further evidence that the constructs were empirically distinct. The highest HTMT value was observed between green operations capability and sustainable operational performance (HTMT = 0.812). Although these constructs are theoretically related, green operations capability captures environmentally responsible operational practices, whereas sustainable operational performance captures the economic, environmental, resource-related, and stakeholder-related outcomes achieved through operations. These findings support the discriminant validity of the five focal constructs.

Structural Model Results

Before hypothesis testing, collinearity among the structural-model predictors was assessed. Management control capability, market sensing capability, and green operations capability each had one focal predictor; sustainable operational performance had two predictors, green operations capability and digital transformation capability. All inner VIF values were below the recommended threshold of 3.3, indicating no collinearity concern. The results supported the four direct hypotheses. Digital transformation capability was positively associated with management control capability, supporting H1. Management control capability was positively associated with market sensing capability, supporting H2. Market sensing capability was positively associated with green operations capability, supporting H3. Finally, green operations capability was positively associated with

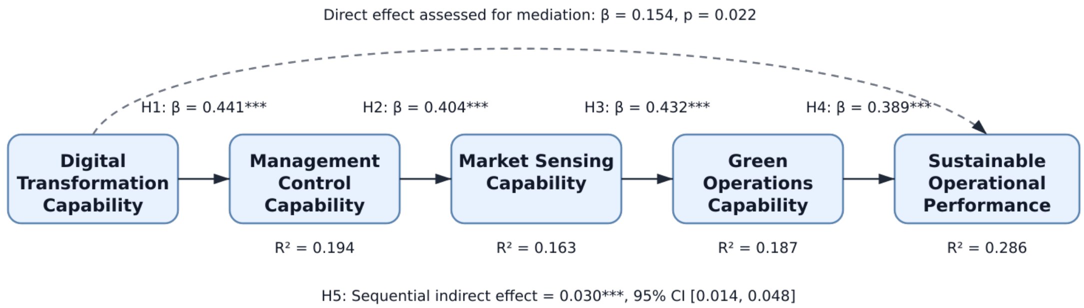

Figure 2: Validated structural model
Note: *** $p < 0.001$. The dashed path represents the direct association assessed for mediation analysis. R^2 represents explained variance.

sustainable operational performance, supporting H4. Table 4 presents the structural-path estimates, effect sizes, and hypothesis-testing decisions.

Sequential Indirect-Effect Analysis

Specific indirect effects were assessed using 5,000 bootstrap resamples and bias-corrected 95% confidence intervals. The sequential indirect association from digital transformation capability to sustainable operational performance through management control capability, market sensing capability, and green operations capability was positive and statistically significant (β = 0.030, SE = 0.009, t = 3.333, p = 0.001, 95% CI [0.014, 0.048]). The direct association between digital transformation capability and sustainable operational performance was also positive and statistically significant (β = 0.154, SE = 0.067, t = 2.299, p = 0.022, 95% CI [0.026, 0.285]). The total association was positive and statistically significant (β = 0.184, SE = 0.064, t = 2.875, p = 0.004, 95% CI [0.061, 0.308]). Because both the direct and sequential indirect associations were significant and in the same positive direction, the findings indicate complementary partial mediation. However, this interpretation concerns the statistical pattern of associations and does not establish causal mediation or temporal ordering because the study used cross-sectional data.

Explanatory Power, Predictive Relevance, and Model Fit

The model showed modest explanatory power across the endogenous constructs. Digital transformation capability explained 19.4% of the variance in management control capability; management control capability explained 16.3% of the variance in market sensing capability; market sensing capability explained 18.7% of the variance in green operations capability; and the full structural model explained 28.6% of the variance in sustainable operational performance. These R^2 values indicate that the proposed capability chain explains a meaningful but limited proportion of the variance, suggesting that sustainable operational performance is also shaped by additional organizational, market, institutional, and operational factors not included in the model. All Q^2 values were above zero, indicating in-sample predictive relevance for the endogenous constructs. However, Q^2 assesses predictive relevance within the estimation sample and does not demonstrate out-of-sample predictive accuracy. Future studies should use PLSpredict, holdout samples, or cross-validation procedures to evaluate the model's out-of-sample predictive performance. The SRMR value was 0.061, below the commonly used threshold of 0.08, indicating acceptable approximate model fit. Table 6 presents the explanatory power, adjusted explanatory power, predictive relevance, and inner collinearity results for the endogenous constructs.

As an additional diagnostic assessment, Harman's single-factor test showed that the first unrotated factor explained 34.9% of the total variance, below the 50% threshold commonly used to indicate a serious common-method-bias concern. Full-collinearity VIF values ranged from 1.31 to 2.09, below the conservative threshold of 3.3. These tests do not prove the absence of common-method variance; instead, they indicate that it was unlikely to be sufficiently severe to invalidate the observed relationships.

Table 7 summarizes the model-level assessment results, including SRMR, the full-collinearity VIF range, and the bootstrap procedure.

Discussion

Summary and Interpretation of Findings

The findings support the proposed sequential capability model. Digital transformation capability was positively associated with management control capability, indicating that firms with stronger digital infrastructure, data accessibility, analytical tools, employee skills, and managerial support may be better positioned to develop timely and integrated information routines. Management control capability was then positively associated with market sensing capability, suggesting that effective planning, monitoring, and performance-information practices may help managers identify and interpret market developments. Market sensing capability was positively associated with green operations capability, while green operations capability was positively associated with sustainable operational performance. The significant sequential indirect effect further suggests that digital transformation may be associated with sustainability-related outcomes through connected managerial, informational, sensing, and operational capabilities.

The findings should nevertheless be interpreted with appropriate caution. The R^2 value for sustainable operational performance was 0.286, indicating that the proposed capability chain accounted for a limited share of performance variation. This result is consistent with the multifaceted nature of sustainable operational performance. Other factors may influence these outcomes, including financial resources, firm size, industry characteristics, environmental regulations, customer sustainability pressure, supply chain integration, leadership, employee engagement, technological maturity, competitive intensity, and macroeconomic conditions. The results therefore support the relevance of the proposed capability pattern but do not suggest that it is the sole or dominant explanation of sustainable operational performance in Iranian SMEs.

The findings are broadly consistent with earlier research indicating that information-based managerial capabilities, environmental scanning, and sustainability-oriented operational practices are associated with improved organizational outcomes. The positive association between management control capability and market sensing is consistent with evidence that management information systems can help managers interpret competitive conditions and improve decision quality. Likewise, the positive associations involving market sensing, green operations, and sustainable operational performance are consistent with studies showing that environmental intelligence and green operational practices can support environmental and operational outcomes. However, the effect sizes and explanatory power were modest rather than dominant. This result is plausible because digital transformation and sustainability-oriented operations are complex organizational processes influenced by multiple internal and external factors. The findings therefore extend previous research by identifying a connected capability pattern, while also showing that this pattern represents only one of several explanations of sustainable operational performance in Iranian SMEs.

Theoretical Contributions

This study contributes to Dynamic Capabilities Theory by positioning digital transformation capability as an enabling organizational resource whose value is realized through complementary capabilities rather than through technology adoption alone. The findings extend the argument that digital technologies create value when they are embedded in coordinated organizational routines, information systems, and adaptive practices (Karami, 2026). Second, the study connects management accounting and control research with digital-transformation research by treating management control capability as a broader organizational mechanism for using information in planning, coordination, and corrective action. This perspective is consistent with research showing that management accounting systems influence the quality of managerial information and performance outcomes (Ghasemi et al., 2019).

More specifically, the model explains the micro-level dynamic capability logic underlying the proposed relationships. Market sensing capability represents the sensing mechanism through which firms recognize relevant external changes. Management control capability represents a seizing mechanism because it enables managers to evaluate information, coordinate priorities, allocate resources, and take corrective action. Green operations capability represents a reconfiguring mechanism because it embeds sustainability-related changes in everyday sourcing, production, resource-use, waste-reduction, and logistics routines. Digital transformation capability enables these mechanisms by improving the availability, integration, and usability of information. This explicit mapping clarifies why the constructs are treated as complementary capabilities rather than as unrelated predictors of sustainable operational performance.

A further contribution is the integration of management control capability with market sensing and green operations. Previous research has shown that management accounting systems can help managers respond to competitive conditions and improve managerial performance (Ghasemi et al., 2016). The present model extends this logic by suggesting that information-based control capability may also support market sensing, which subsequently enables environmentally responsive operational decisions. The positive association between market sensing and green operations is consistent with research linking market intelligence, digital logistics, and green operational practices to improved business outcomes (Karami, 2025). Together, these findings provide a more connected explanation of how digital information can be translated into sustainable operational value.

Managerial Implications

The findings suggest that Iranian SME managers should avoid viewing digital transformation as a narrowly technical project. Investments in software, analytics, enterprise systems, and digital communication tools are more likely to create value when they improve the timeliness, integration, and practical use of managerial information. Managers should develop routines that connect digital data with budgeting, performance monitoring, resource allocation, and corrective action. They should also ensure that operational, finance, marketing, and supply chain functions have access to relevant information and can use it collaboratively. Such integration may help firms identify changes in customer requirements, competitor actions, supplier conditions, and environmental expectations before these changes negatively affect operations.

Managers should also translate market intelligence into specific green operational priorities. Relevant actions include improving resource efficiency, reducing waste, adopting cleaner production practices, strengthening responsible sourcing, and incorporating environmental criteria into logistics and supplier decisions. These practices should be monitored through operational and non-financial performance indicators rather than treated as isolated compliance activities. By connecting digital systems, management control, market sensing, and green operations, managers may improve both operational efficiency and longer-term sustainability-related outcomes. This integrated approach is particularly relevant for SMEs that must allocate limited technological, financial, and managerial resources carefully.

Limitations and Future Research

The study has several limitations. First, the cross-sectional design does not establish temporal ordering, causality, or causal mediation. Although the model is theoretically sequenced, all variables were measured at one point in time; therefore, reverse, reciprocal, and omitted-variable explanations cannot be ruled out. Future studies should use longitudinal panel designs with measurements collected at separate time points to test whether digital transformation capability precedes management control capability, market sensing, green operations, and sustainable operational performance. Second, the use of single-source managerial perceptions may introduce recall bias, social-desirability bias, and common-method variance despite the procedural and statistical remedies used in this study. Future research should combine manager surveys with data from multiple respondents, including finance, operations, sustainability, and marketing managers, as well as archival financial records, operational indicators, environmental measures, supplier assessments, and objective digital-maturity indicators. Third, the Iranian SME context and the purposive, mixed-sector sample may limit generalizability. Manufacturing and service firms can differ in their operational processes, environmental exposures, regulatory requirements, resource use, and the forms that green operations take. Comparative research should investigate whether industry, firm size, institutional conditions, competitive intensity, environmental turbulence, and digital maturity alter the proposed relationships. Future research should use probability-based sampling where feasible and conduct sector-specific or multi-group analyses to determine whether the proposed relationships differ systematically between manufacturing and service SMEs.

Conclusion

This study advances a capability-based explanation of sustainable operational performance in Iranian manufacturing and service SMEs. It argues that digital transformation should not be treated as an isolated technological investment or as an automatic source of sustainability-related value. Instead, its organizational value depends on whether firms can convert digital infrastructure, data, analytics, and employee digital skills into practical routines for planning, monitoring, coordination, market interpretation, and environmentally responsible operations. Drawing on Dynamic Capabilities Theory and management control perspectives, the study develops a sequential model linking digital transformation capability to management control capability, market sensing capability, green operations capability, and sustainable operational performance.

The findings support the proposed sequential logic. The contribution is not simply to show that digital technologies, market intelligence, or green practices matter for performance, as these relationships are broadly recognized. Rather, the study clarifies the organizational sequence linking them. Digital transformation capability strengthens the information base available to managers; management control capability converts that information into coordinated planning, monitoring, and corrective-action routines; market sensing capability directs attention toward relevant external signals; and green operations capability translates these insights into operational changes. By identifying management control capability as the bridge between digital information and market-responsive operational adaptation, the study extends prior capability-based research that has generally examined these domains separately or assumed a more direct digital transformation–performance relationship.

The study makes a theoretical contribution by connecting research streams that are commonly examined separately. Digital-transformation research often emphasizes technology adoption and digital capability, whereas management accounting research focuses on the usefulness of information for control and managerial performance. Similarly, market-sensing and green-operations research frequently examines external intelligence and environmental practices without fully explaining the internal information and control mechanisms that connect them. By integrating these perspectives, the study positions management control capability as a bridge between digital transformation and market-oriented operational adaptation. It also extends

Dynamic Capabilities Theory by showing how sensing and reconfiguring activities can be supported by digitally enabled information and control routines.

The managerial implications are especially relevant for Iranian SMEs operating under economic volatility, competitive pressure, technological constraints, and changing stakeholder expectations. Managers should invest not only in digital tools, but also in the routines and employee capabilities needed to use digital information effectively. Practical priorities include integrating operational, financial, customer, supplier, and environmental information; using performance dashboards for timely monitoring; establishing cross-functional review routines; and translating market intelligence into clear actions on sourcing, waste reduction, energy efficiency, production processes, and logistics. Green operations should be managed as a source of efficiency, learning, risk reduction, and stakeholder value rather than as a stand-alone compliance requirement.

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Appendix

Table 1: Appendix A. Scale Adaptation and Contextual Validation

Construct	*Source(s)*	*Nature of adaptation*	*Contextual validation*
Digital Transformation Capability	Vial (2019); Warner and Wäger (2019)	Items were worded for firm-level digital infrastructure, data accessibility, employee skills, and managerial support in SMEs.	Persian translation and back-translation; expert review; pilot test with 23 Iranian SME managers.
Management Control Capability	Ghasemi et al. (2019)	Items were worded to capture planning, monitoring, coordination, and corrective action using financial and non-financial information.	Persian translation and back-translation; expert review; pilot test with 23 Iranian SME managers.
Market Sensing Capability	Morgan et al. (2009)	Items were worded to include customer, competitor, supplier, and market information relevant to SMEs.	Persian translation and back-translation; expert review; pilot test with 23 Iranian SME managers.
Green Operations Capability	Ali et al. (2020); Borazon et al. (2022)	Items were worded to apply to sourcing, resource use, waste, cleaner practices, and logistics in manufacturing and service firms.	Persian translation and back-translation; expert review; pilot test with 23 Iranian SME managers.
Sustainable Operational Performance	Ali et al. (2020); Borazon et al. (2022)	Items were worded to capture operational economic, environmental, resource-related, and stakeholder-related outcomes.	Persian translation and back-translation; expert review; pilot test with 23 Iranian SME managers.

Table 2: Appendix B. Measurement Items and Sources

Construct and Sources	*Item code*	*Measurement item*
Digital Transformation Capability (Vial, 2019; Warner & Wäger, 2019)	DTC1	Our firm has adequate digital infrastructure to support its core operational activities.
	DTC2	Relevant data are readily accessible to managers and employees when making operational decisions.
	DTC3	Our employees possess the digital skills needed to use digital technologies effectively.
	DTC4	Top management actively supports the integration of digital technologies into business processes.
Management Control Capability (Ghasemi et al., 2019)	MCC1	Our firm provides timely information for planning, monitoring, and operational decision-making.
	MCC2	Our firm's performance-information systems integrate information across relevant functions.
	MCC3	Managers receive broad-scope information that includes financial and non-financial performance indicators.
	MCC4	Our firm uses performance information to identify deviations and take corrective action.

Market Sensing Capability Morgan et al., 2009	MSC1	Our firm regularly collects information about changes in customer needs and expectations.
	MSC2	Our firm systematically monitors competitor actions and market developments.
	MSC3	Our firm actively gathers information about supplier conditions and supply-market changes.
	MSC4	Relevant market information is shared across functions to support managerial decisions.
Green Operations Capability (Ali et al., 2020; Borazon et al., 2022)	GOC1	Our firm incorporates environmental considerations into sourcing and supplier-selection decisions.
	GOC2	Our firm actively reduces material waste and inefficient resource use in operations.
	GOC3	Our firm adopts cleaner production practices and energy-efficient operational procedures.
	GOC4	Our firm considers environmental impacts in packaging, transportation, and logistics decisions.
Sustainable Operational Performance (Ali et al., 2020; Borazon et al., 2022)	SOP1	Our firm has improved operational cost efficiency through its operational practices.
	SOP2	Our firm has reduced the environmental impacts of its operational activities.
	SOP3	Our firm has improved resource efficiency and reduced waste across its operations.
	SOP4	Our firm considers the well-being of employees, customers, suppliers, and communities in its operational activities.

Note: All items are measured on a seven-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree. The wording must match the questionnaire actually administered.

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