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Strategic enablers of digital transformation: A quantitative study on SMEs in Vietnam

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Abstract In the modern business context, digital transformation (DX) has emerged as an increasingly critical factor, profoundly influencing all dimensions of business operations. In particular, for small and medium-sized enterprises (SMEs), the DX roadmap is not merely a trend but a vital determinant of competitiveness and sustainable development in the global economy. Vietnamese SMEs play an essential role in promoting balanced development and facilitating regional economic restructuring. However, these enterprises face numerous challenges in adopting digital technologies, ranging from inadequate technological infrastructure and limited financial resources to a shortage of digital skills among employees. This study investigates the key factors influencing the DX process of Vietnamese SMEs and proposes practical implications to enhance the effectiveness of their digital initiatives. Utilizing survey data from 610 SMEs across 16 industry sectors, the study adopts a quantitative research approach, incorporating Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and multiple linear regression to validate the conceptual framework. The findings identify four primary factors that significantly contribute to DX process: (1) customer experience and supply chain integration, (2) technological infrastructure and data governance, (3) human capital and organizational structure, and (4) enterprise leaders' strategic orientation. The proposed model demonstrates strong explanatory power (R^2 = 0.905), affirming the relevance and applicability of the identified factors. Based on the research results, we provide recommendations for leaders of SMEs and relevant Vietnamese government agencies to formulate DX strategies tailored to the unique characteristics of enterprises in Vietnam.

Keywords: Digital technology, CFA, DX, EFA, Vietnamese SMEs

1. Introduction

In the modern business context, DX has emerged as an increasingly critical factor, profoundly influencing all dimensions of business operations. For SMEs, the DX roadmap is not merely a trend but a strategic imperative, shaping competitiveness and sustainable development in the global economy. Across countries, SMEs play a vital role in economic systems, significantly contributing to gross domestic product and employment generation (Reena et al., 2023).

The growing ubiquity of digital technologies has transitioned from an option to an essential requirement for SMEs to remain competitive, particularly amidst rapid technological advancement and ever-evolving customer expectations. This necessity became more evident during the COVID-19 pandemic, where firms with more robust digital infrastructure demonstrated greater resilience to economic disruptions (Holl & Rama, 2024; Petropoulou et al., 2024). These observations suggest a strong causal relationship between firms' digital capabilities and their ability to sustain operations during times of crisis (Surahman, 2023).

Our review of academic literature indicates that researchers have employed diverse methodologies to measure the level of digitalization in enterprises. Common approaches include surveys, case studies, bibliometric analysis, and the development of digital maturity models (Almeida et al., 2022; Petropoulou et al., 2024). In addition, both quantitative and qualitative methods are used in the literature, including regression analysis, cluster analysis, interviews, and content analysis (Nessrine et al., 2022). Some studies adopt mixed-methods approaches, combining quantitative and qualitative techniques, to yield a more holistic and reliable understanding of DX (Chen et al., 2022).

Studies on the application of digital maturity models often assess the progress of the DX process in enterprises in aspects such as technology adoption, organizational capabilities, strategic orientation, data governance, and corporate culture

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(Syahrial et al., 2024; Kahveci, 2025). Nevertheless, accurately assessing the degree of enterprise digitalization remains challenging due to the complexity and dynamic nature of the process (Zou et al., 2024).

In in-depth studies on the factors influencing the DX process of enterprises, Werth et al. (2020) proposed four groups of factors affecting DX in the financial sector: (1) political factors; (2) economic factors; (3) social factors; and (4) technological factors. Among these, the primary determinants are those shaping the development orientation of enterprises. The study by Gouveia & Mamede (2022) on DX in SMEs in the retail sector in Portugal also emphasized that strategic orientation has a substantial impact on the DX process of SMEs. In addition, the authors highlighted that aspects of customer experience through distribution channels and technological capabilities are major factors influencing DX.

Mohamad & Muhammad (2024) found that there are three pillars influencing the DX process in Malaysian SMEs: digital strategy, technical capability, and managerial capability. Similarly, Kusuma et al. (2024), when examining factors affecting the DX process in sales organizations in Indonesia, identified the leadership model, organizational citizenship behavior, and sales management control as key drivers of both DX and business performance.

In Vietnam, over the past five years, most studies have focused on the impact of DX on firm performance or financial performance across different business sectors (Dam et al., 2025). Consequently, empirical research analyzing the factors affecting the DX process in SMEs has been limited, primarily due to data-related constraints. In reviewing the literature, we identified two notable studies by Nguyen et al. (2023) and Minh et al. (2024). However, both are restricted to SMEs in Hanoi and do not encompass data from SMEs nationwide. This represents a research gap that our study aims to address, leveraging our advantage in collecting data from SMEs with the support of the Ministry of Planning and Investment.

According to statistics from the Ministry of Planning and Investment, In Vietnam, SMEs comprise more than 98% of all enterprises, contribute approximately 45% of GDP, and generate over 50% of employment. However, Vietnamese SMEs face numerous challenges in adopting technology and implementing DX, ranging from inadequate technological infrastructure and limited financial resources to a shortage of digital skills among employees (MPI, 2024).

Despite these challenges, SMEs in Vietnam have consistently played a vital role in promoting balanced regional development and facilitating structural economic transitions across territories. In contrast, large enterprises are typically concentrated in urban centers and major industrial zones, leading to disparities in economic, cultural, and social development between urban and rural areas, as well as among regions. Consequently, the development of SMEs is critical to fostering regional equity and advancing sustainable socio-economic growth. In particular, expanding SMEs in rural areas has the potential to absorb unemployed or underemployed labor, as well as to engage seasonal workers during agricultural off-seasons in productive business activities. This transition helps gradually shift the labor force from agriculture to industry and services, thereby contributing to long-term, stable, and sustainable economic development in Vietnam (Le & Do, 2024).

DX is a key driver of competitiveness for Vietnamese SMEs and a prerequisite for integration into the global economy. However, successful DX requires a thorough understanding of the factors influencing digital readiness. These include technological infrastructure, strategic leadership, financial capacity, operational processes, digital competencies, and an organizational culture that supports transformation. Investigating these factors is essential for SMEs to formulate effective DX strategies and to leverage new opportunities for sustainable development in the digital era.

The paper is structured into five parts, including Section 1, which introduces the research context; Section 2, which outlines the theoretical basis and research methods; Section 3, which presents the main results; Section 4, which discusses the findings of the study; and Section 5, which summarizes the main research findings and provides policy implications for the DX strategy of SMEs in Vietnam.

2. Materials and Methods

2.1. Concept of digital transformation

In the context of the rapidly evolving Fourth Industrial Revolution, DX has become an inevitable trend - a matter of survival for countries, organizations, enterprises, and consumers alike. Within enterprises, DX goes beyond the mere digitization of existing processes; it entails fundamental changes to business models, operational workflows, and customer interactions to generate new value (Kane et al., 2015; Nnenna et al., 2024).

It is essential to distinguish among three levels of DX in enterprises: digitization, digitalization, and digital transformation. Digitization refers to the conversion of information from analog to digital formats. Digitalization involves applying digital technologies to optimize existing workflows. In contrast, digital transformation represents the most advanced stage, characterized by the emergence of entirely new business models and transformative impacts on all facets of the enterprise (Costa Melo et al., 2023). This distinction is critical, as digital transformation encompasses not only the adoption of technology but also the strategic integration of digital capabilities to enhance overall performance and foster innovation.

The core pillars of enterprise DX include technology adoption, organizational restructuring, and strategic alignment (Nnenna et al., 2024). To ensure successful transformation, organizations must invest not only in digital infrastructure but also in cultural change, leadership development, workforce upskilling, and operational redesign to realize business value (Interreg Europe, 2022; Syahrial et al., 2024).

Thus, DX constitutes a comprehensive organizational endeavor that requires a fundamental shift in mindset and operational frameworks, far beyond the implementation of new technological tools.

2.2. Factors affecting the digital transformation process

It is essential to understand the factors that influence the DX process of enterprises. These factors can be broadly categorized into two groups: internal and external. Among the internal factors, three key elements stand out.

First, leadership and strategic direction are critical. According to Kane et al. (2015), one of the most important determinants of successful DX is the commitment and vision of organizational leaders. Leaders must clearly understand the value of DX and develop coherent strategies for effective technology deployment (Dam et al., 2025).

Second, corporate culture plays a pivotal role. Bharadwaj et al. (2013) believe that a culture that fosters innovation and experimentation is essential for DX. Organizations that cultivate open environments encouraging innovation and tolerance for failure are more likely to succeed in their transformation efforts (Kahveci, 2025).

Third, the quality of human resources is fundamental. Research by Haffke et al. (2016) and Leso et al. (2023) suggests that investing in new technologies and training employees to use them proficiently is a core enabler of successful DX.

Regarding external factors, three prominent influences can be identified.

First, technological advancement presents both opportunities and challenges. Chen et al. (2022) highlight that the pace of technological development requires businesses to rapidly adapt to emerging trends. To successfully pursue digitalization, enterprises must integrate technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data (Mazzei & Noble, 2017).

Second, national policies, legal frameworks, and institutional environments exert significant influence. According to De Reuver et al. (2018), regulations concerning data privacy, security, and digital infrastructure strongly affect the extent to which enterprises can engage in DX.

Third, competitive pressures and market dynamics are key external drivers. In a globalized economy, increasing competition and evolving customer expectations compel businesses to embrace DX to sustain their competitive advantage (Porter & Heppelmann, 2014). Continuous improvement and innovation are thus essential for enhancing customer experiences (Naim et al., 2024).

2.3. Developing hypotheses and research models

Nowaday, enterprises aiming to survive and grow tend to adopt a digital approach integrated into their overall business strategies (Stoianova et al., 2020). Digital strategies outline the company's vision in the context of digitalization, including the necessary strategic measures to achieve this vision. Such strategies set clear digitalization goals and initiatives for short-term, mid-term, and long-term horizons, impacting product offerings, value creation, organizational structure, and corporate culture (Gouveia & Mamede, 2022).

DX begins with leadership that formulates and supports the implementation of the strategy. According to Korachi & Bounabat (2020), to maintain competitiveness in the digital era and address DX challenges, SMEs need a comprehensive DX strategy to manage digital change and drive operational excellence. Based on these arguments, the study proposes the following hypothesis:

Hypothesis H1: Strategic orientation in an enterprise has a positive impact on digital transformation process.

The objective of all investment decisions, including investments in DX, is to enhance the enterprise's operational efficiency. Customers are the ones who determine the effectiveness of these efforts through the number of orders, level of support, and revenue growth of the enterprise. Thus, the top priority for DX should be customer-centric, focusing on improving the customer experience (Kusuma et al., 2024).

A positive customer experience determines whether customers will return to continue purchasing products or be willing to recommend the products or enterprise to others. This directly affects the company's growth. Moreover, as consumers become more technologically savvy, they increasingly expect enhanced digital experiences. Whether shopping online or at traditional stores, consumers expect to have digital interactions (Naim et al., 2024). From these points, the study proposes the following hypothesis:

Hypothesis H2: Customer experience in a enterprise has a positive impact on digital transformation process.

Research by Ning & Yao (2023) explored the impact of DX on the sustainable competitiveness of supply chains. The authors found that DX not only improves supply chain capabilities but also positively affects sustainable competitive performance. These findings provide evidence that DX is a crucial factor in creating a competitive advantage for firms in the modern enterprise environment.

In addition, Catlin et al. (2017) highlighted that adopting digital technologies in supply chains enhances decision-making processes and improves operational efficiency. The research emphasized the importance of deploying digital solutions for processing information and data automatically, enabling supply chain managers to make timely and accurate decisions. Hence, the following hypothesis is proposed:

Hypothesis H3: The erprise supply chain has a positive impact on digital transformation process.

A firm's DX process is dependent on how operations are managed, as they provide the necessary foundation for integrating digital technologies and facilitating the transformation process. In the fields of finance and accounting, the application of digital technology can significantly enhance operational efficiency. Technologies such as AI, robotics, and cloud-based ERP systems have been used to automate processes and improve decision-making (Gonçalves et al., 2022).

Employee-related issues can hinder DX readiness in various ways. One of the major challenges is the lack of digital skills among employees, and upskilling often requires considerable effort and can be met with resistance, particularly if employees feel inadequately supported during the transformation (Ning & Yao, 2023). Legal regulations to ensure compliance with new technology-related standards, especially in data management and information protection, can also pose a barrier to DX process (Ahmad et al., 2024). From these points, the study proposes:

Hypothesis H4: Operational management capabilities in a enterprise have a negative impact on digital transformation process.

In today's business context, characterized by rapid technological advancements and fierce competition, the IT systems and data management capabilities of each enterprise have become essential. To achieve sustainable growth and maintain competitiveness, firms must continuously develop and enhance their technological capabilities to generate both internal and external business impacts (Sahlman & Haapasalo, 2009). Enterprise performance and sustainability are closely linked to technological innovation, which plays a vital role in creating economic value. Furthermore, IT and data management capabilities are increasingly seen as catalysts for the DX of business models, enabling companies to adapt to the ever-changing environment (Unsal & Cetindamar, 2015). Thus, the study proposes the following hypothesis:

Hypothesis H5: IT and data management capabilities in a enterprise have a positive impact on digital transformation process.

Risk management and cybersecurity significantly affect a enterprise's DX process. Organizations often face challenges in balancing the adoption of new technologies and ensuring information security. Implementing an effective cybersecurity and risk management strategy not only protects businesses from threats but also enhances adaptability and innovation in the digital environment. Leading global companies are employing risk-based management approaches instead of maturity-based approaches to achieve greater effectiveness in cybersecurity management (Ahmad, 2024).

Furthermore, integrating cybersecurity strategies with a company's overall business strategy is essential. Enterprises must view cybersecurity not merely as a technical requirement but as a part of a comprehensive enterprise strategy that protects corporate value and facilitates DX (Möller, 2023). Thus, we propose:

Hypothesis H6: Risk management and cybersecurity in a enterprise have a positive impact on digital transformation process.

Human and organizational factors play a critical role in shaping an enterprise's DX process. Elements such as organizational culture, management structure, and employee readiness can either facilitate or hinder the transformation. In particular, organizational culture is a decisive factor in DX. A culture that fosters innovation and flexibility is more likely to embrace digital changes (Leso et al., 2023). Therefore, the final hypothesis is:

Hypothesis H7: Human and organizational factors have a positive impact on digital transformation process.

Based on the theory of internal and external factors influencing the DX process of enterprises, along with empirical studies by Werth et al. (2020), Nguyen et al. (2023), Kusuma et al. (2024), Minh et al. (2024), Mohamad & Muhammad (2024), and taking into account the seven hypotheses (H1–H7) presented above, we propose a model to analyze the factors affecting the DX process in SMEs in Vietnam, as illustrated in Figure 1 below.

2.4. Variables and scales used in research

The empirical study by Nguyen et al. (2023) employed six latent variables: (1) perceived usability, (2) perceived behavioral control, (3) social influence, (4) expected efficiency, (5) convenient conditions, and (6) risks associated with DX, along with 30 indicators representing 30 observed variables, to analyze factors influencing the DX process of SMEs in Hanoi. In the same research context, Minh et al. (2024) utilized six latent variables: (1) DX strategy, (2) managers' attitudes and capabilities, (3) employees' capabilities, (4) corporate culture, (5) technological infrastructure, and (6) DX pressures, with 36 indicators to evaluate the DX process of SMEs. Similarly, Mohamad and Muhammad (2024) applied only three latent variables: (1) digital strategy, (2) managerial capability, and (3) technical capability with 11 indicators to assess the DX process of SMEs in Malaysia.

We contend that the approach of Mohamad and Muhammad (2024) is incomplete, as it focuses solely on variables reflecting internal factors of the enterprise, excluding external factors, and notably omitting those related to DX culture within the organization. The scale construction in Nguyen et al. (2023) leans heavily toward qualitative factors, which may pose difficulties for SMEs in providing accurate responses. Meanwhile, the approach of Minh et al. (2024) shares several similarities with ours; however, we seek to further clarify variable groups related to "information systems and data management" and "risk management." Consequently, we have expanded the model to include seven pillars, adding one additional pillar compared to Minh et al. (2024). In contrast to the 36 indicators used by Minh et al. (2024), we have reduced the number to 34, having

identified overlap between certain indicators within the “DX strategy” and “managers’ attitudes and capabilities” pillars, which allowed for consolidation and improved convenience.

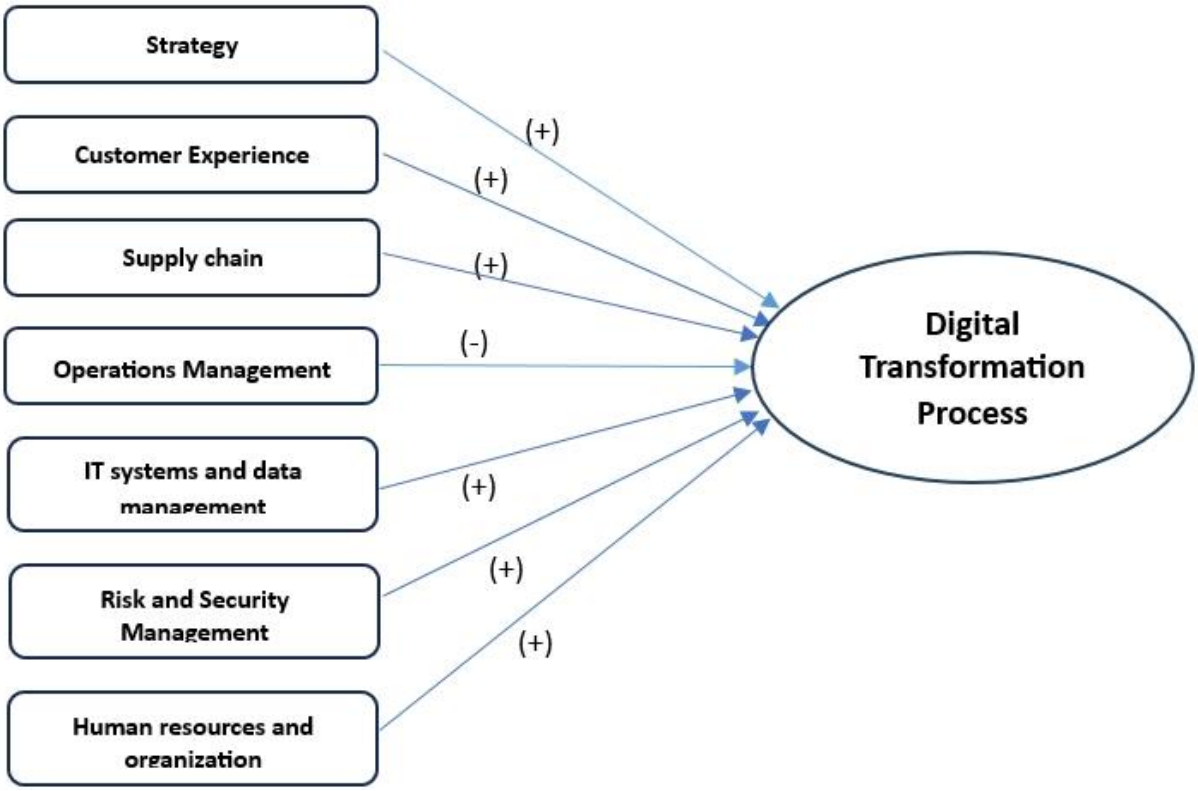

Figure 1 Conceptual framework of factors affecting digital transformation process.

Notably, Decision No. 2158/QD-BTTT (2023) issued by the Vietnamese Ministry of Information and Communications, comprising seven pillars (strategic orientation; customer experience and multi-channel sales; supply chain; information systems and data management; risk management and cybersecurity; people and organizational factors; and financial, accounting, planning, legal, and human resource management) aligns closely with the framework proposed in our study. The indicators in our model have also been implemented on the official website “https://digital.business.gov.vn” to facilitate ongoing surveys and evaluations of SMEs’ DX processes in Vietnam. Table 1 presents the details of these 34 indicators.

2.5. Data collection

In this study, we rely on the number of questions to calculate a sample size that is both appropriate and reliable (Hair et al., 1998). Therefore, with a questionnaire containing content related to the research model comprising 34 observed variables, the minimum number of valid responses should be 170 or, ideally, 340 valid responses.

To conduct this study, we received support from the Agency of Enterprise Development in surveying SMEs across 16 industry sectors in Vietnam. The data collection process was carried out through the official online platform at https://digital.business.gov.vn. Based on sample size requirements, 750 survey forms were sent to SMEs in Vietnam by direct contact and meeting. The result was 610 valid entries (more than 340 required). The response rate reached 81.33%, which confirms that representatives of SMEs in Vietnam are very open when participating in the survey, and the answers are serious and trustworthy (Neuman, 2014). The detailed breakdown of the valid responses is shown in Table 2.

There are 34 indicators to collect valid responses using a Likert scale, ranging from one (1) representing strong disagreement to five (5) representing strong agreement. The results of the assessment score of each enterprise's DX process are determined according to Table 3 below.

Table 1 Criteria for assessing digital transformation process.

Pillars	Code	Component criteria	References
Strategic Orientation	CL1	Enterprise leaders are knowledgeable about DX trends related to markets, customers, and competitors	Werth et al. (2020); Mohamad & Muhammad (2024); Minh et al. (2024)
	CL2	Enterprise leaders incorporate DX initiatives into the strategic orientation of the enterprise	
	CL3	The enterprise regularly pays attention to and invests in technological initiatives to improve business performance	

	CL4	The enterprise has a strategy to apply Information Technology (IT) systems and big data analytics to support business operations	
Customer Experience	TN1	The enterprise employs digital technologies in marketing, distribution, and omni-channel strategies to enhance customer experience	Gouveia & Mamede (2022); Nguyen et al. (2023)
	TN2	The enterprise applies digital technologies in customer service to deliver differentiated customer experiences	
	TN3	The enterprise's customer relationship management (CRM) system can be integrated with other systems and is easily upgradeable	
	TN4	The enterprise utilizes IT systems to measure the performance of marketing, sales, and customer service activities	
	TN5	The enterprise applies data analytics to adjust marketing, sales, and customer service strategies	
Supply Chain	CU1	The enterprise uses IT systems to compare its supply capabilities with customer demand	Chen et al. (2022); Ning & Yao (2023)
	CU2	The enterprise uses IT systems to connect information across customers, suppliers, and production	
	CU3	The enterprise has adopted software to support planning and budgeting activities	
	CU4	The supply chain components of the enterprise are adaptable to changes in the business and technological environment	
	CU5	The enterprise has automated and digitally transformed its production processes	
	CU6	The enterprise has automated several core processes such as procurement and inventory management	
	CU7	The enterprise conducts data analysis related to procurement, production, and sales to support decision-making and action planning	
Operational Management	QL1	The finance and accounting department supports cost-benefit analysis of digital technology adoption in business operations	Leso et al. (2023); Mohamad & Muhammad (2024).
	QL2	The enterprise has implemented IT software for financial management, accounting, human resources, and other administrative functions...	
	QL3	The enterprise is aware of legal risks associated with the use of emerging technologies	
Information systems & data management	CN1	The enterprise regularly updates itself on the latest technological solutions offered by vendors	Mohamad & Muhammad (2024); Minh et al. (2024)
	CN2	The enterprise has adopted new technologies to reduce costs and improve the efficiency of IT systems	
	CN3	The enterprise's current IT solutions are easily integrable with new technologies	
	CN4	The enterprise has plans and resources available to upgrade and innovate IT systems as needed	
	CN5	The enterprise has established processes for collecting, storing, and analyzing data to support business decision-making	
Risk management	AN1	The enterprise has a clear understanding of the risks associated with DX	Gouveia & Mamede (2022); Minh et al. (2024)
	AN2	The enterprise uses IT to identify, assess, and manage risks arising during operations	
	AN3	The enterprise conducts regular reviews and inspections to detect vulnerabilities in IT systems	
	AN4	The enterprise has established procedures to handle IT incidents and cybersecurity breaches	
Organizational & human resources	TC1	Employees are capable of quickly and positively adapting to organizational changes	Leso et al. (2023); Minh et al. (2024)
	TC2	The organizational structure is flexible and ready to accommodate DX	
	TC3	Employees possess sufficient knowledge, skills, and experience to meet the demands of DX	
	TC4	The enterprise implements programs to attract and recruit talent in the field of IT	
	TC5	The enterprise has mechanisms to promptly and efficiently share knowledge and experience across the organization	

TC6	The enterprise utilizes IT systems to facilitate information sharing and workflow coordination among departments and units	

Table 2 Survey sample structure.

Criteria		Number of Responses	Percentage (%)
By business sector	Manufacturing	151	24.75
	Mining	12	1.97
	Agriculture, forestry and fisheries	80	13.11
	Accommodation and food services	37	6.07
	Financial, banking and insurance activities	16	2.62
	Production and distribution of electricity, gas, hot water, steam and air conditioning	16	2.62
	Construction	24	3.93
	Transportation and warehousing	25	4.10
	Information and communication	39	6.39
	Real estate	12	1.97
	Professional, scientific and technological activities	32	5.25
	Education and training	73	11.97
	Health and social assistance activities	17	2.79
	Arts, entertainment and recreation	21	3.44
	Wholesale and retail trade, repair of automobiles, motorcycles, motorbikes and other motor vehicles	49	8.03
	Administrative activities and service support	6	0.98
By region of SMEs headquarters	Northern region	241	39.51
	Central region	179	29.34
	Southern region	190	31.15
By enterprise size	Small enterprise	456	74.75
	Medium enterprise	154	25.25
By survey method	Online	53	8.69
	Face-to-face interview	557	91.31

Table 3 Criteria for assessing digital transformation process.

Scoring scale based on each criterion	Pillar Evaluation	The enterprise readiness for digital transformation
Less than 10% of the maximum score for each pillar	Not Initiated (level 0)	Assign a score of 0 if less than 4 pillars have a level 1
From 10% to 20% of the maximum score for each pillar	Initiated (level 1)	Assign a score of 1 if at least four pillars have a level 1
From over 20% to 40% of the maximum score for each pillar	Beginning (level 2)	Assign a score of 2 if at least four pillars have a level 2
From over 40% to 60% of the maximum score for each pillar	Forming (level 3)	Assign a score of 3 if at least four pillars have a level 3
From over 60% to 80% of the maximum score for each pillar	Enhancing (level 4)	Assign a score of 4 if at least four pillars have a level 4
From over 80% to 100% of the maximum score for each pillar	Leading (level 5)	All pillars at level 5

3. Results

3.1. Evaluation using Cronbach's Alpha and Exploratory Factor Analysis

The results of the reliability analysis using Cronbach's Alpha indicate that all constructs exhibit strong internal consistency, with alpha values ranging from 0.842 to 0.912, well above the commonly accepted threshold of 0.8. The item-total correlation coefficients for all items also exceed 0.6, specifically ranging from 0.633 to 0.749. These results confirm that the measurement items are suitable for inclusion in the subsequent Exploratory Factor Analysis (EFA).

To assess the suitability of the dataset for factor analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were conducted. The high KMO value suggests a strong level of shared variance among the observed variables, thereby supporting the appropriateness of factor analysis. Furthermore, the statistically significant result of Bartlett's test confirms that the correlation matrix is not an identity matrix, indicating that sufficient intercorrelations exist among the variables to justify factor extraction and the identification of latent structures.

From the results of testing the suitability of the data using the KMO coefficient and Bartlett's test in Table 4 above, we continued to perform EFA to determine the number of potential factors that can be extracted from the data set. The factor extraction process was performed using the Principal Component Analysis (PCA) method with the criterion Eigenvalue > 1.

Table 4 KMO and Bartlett test.

Kaiser-Mayer-Olkin Measure of Sampling Adequacy		.978
Bartlett's Test of Sphericity	Approx. Chi-Square	14362.505
	Df	.378
	Sig.	.000

Table 5 Rotation matrix when performing EFA.

Observation variable	Group 1	Group 2	Group 3	Group 4
TN4	0.747			
TN3	0.727			
TN5	0.713			
CU1	0.675			
CU2	0.608			
TN1	0.604			
CU5	0.598			
TN2	0.590			
CU7	0.570			
CU6	0.567			
AN3		0.768		
AN4		0.741		
AN2		0.676		
AN1		0.654		
CN3		0.637		
CN2		0.620		
CN1		0.592		
CN5		0.568		
CN4		0.530		
TC2			0.780	
TC4			0.769	
TC3			0.731	
TC5			0.698	
TC1			0.660	
TC6			0.577	
CL1				0.772
CL2				0.739
CL3				0.646
KMO	0.975	Sig	0.000	
Eigenvalue	1.001	Variance Explained	70.719%	

The results presented in Table 5 indicate that four principal factors were extracted from the dataset, satisfying the eigenvalue criterion (eigenvalue > 1) and collectively explaining 70.719% of the total variance. This suggests that the extracted factors adequately represent the underlying structure of the data.

The first factor group demonstrates the highest item loadings on a single component and reflects the linkage between customer experience and supply chain performance. This relationship is theoretically grounded, as supply chain efficiency significantly contributes to customer experience by influencing delivery speed, product quality, operating costs, and customer satisfaction. Accordingly, this factor is labeled CE (Customer Experience and Supply Chain).

The second factor group comprises variables related to both risk management and cybersecurity and technology systems and data management, highlighting the intrinsic connection between system operations and data security. In the context of DX, enterprise IT systems must be reinforced by robust cybersecurity measures to prevent breaches and mitigate cyber risks. This factor is labeled RC (Risk and Cybersecurity).

The third factor group includes observed variables associated with human and organizational dimensions, emphasizing the pivotal role of human capital in facilitating DX. This group captures organizational readiness to embrace new technologies, employee adaptability, and the cultivation of an innovation-oriented culture. Thus, this factor is labeled HO (Human and Organization).

The fourth factor group consists of variables related to strategic orientation, underscoring the importance of clear digital strategies and leadership commitment in successfully implementing digital initiatives, resource allocation, and long-term sustainability. This factor is labeled SO (Strategic Orientation).

These four factor groups will be employed in subsequent Confirmatory Factor Analysis (CFA) and multiple linear regression to examine their respective impacts on the dependent variable representing the DX process.

3.2. Confirmatory Factor Analysis

After conducting the initial CFA, the model identified three main factors, with the following model fit indices: χ^2 = 1124.739, df = 272, $p < 0.001$, $\chi^2/df = 4.135$, GFI = 0.862, TLI = 0.927, CFI = 0.933, and RMSEA = 0.072. These indices indicate a moderate model fit, although the overall fit had not yet reached an optimal level. Notably, several observed variables exhibited ambiguous loadings, suggesting that the factor structure did not fully or accurately capture the relationships among the latent constructs. This necessitated further model refinement to improve fit and enhance the robustness and validity of the results.

A second CFA was subsequently performed using a revised factor structure better aligned with the empirical data. The results revealed four latent factors, and the model fit indices demonstrated improvements, as presented in Figure 2 below.

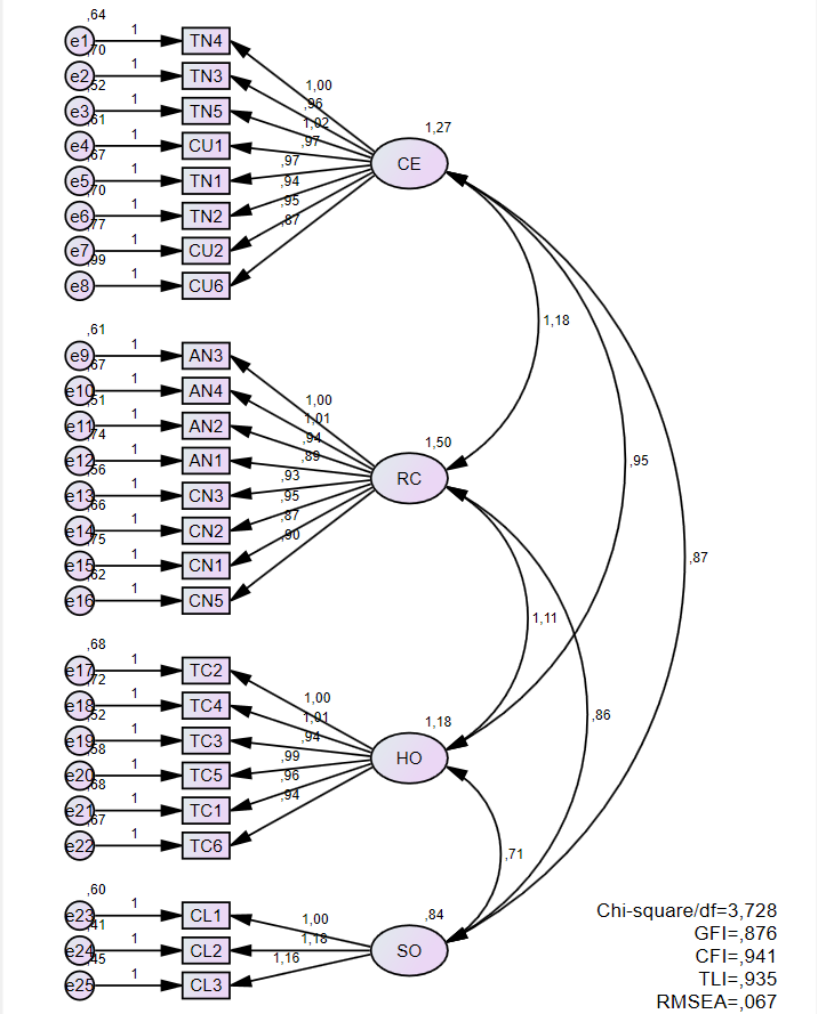

Figure 2 Measurement model diagram with 4 factors.

The second CFA, conducted with a four-factor structure, enabled a clearer identification of key constructs, ensuring that each observed variable exhibited high factor loadings on its most relevant factor while reducing cross-loadings and enhancing discriminant validity. The transition from a three-factor to a four-factor model not only improved overall model fit but also enhanced the theoretical clarity and practical relevance of the findings in the context of enterprise DX.

The identified factors: Customer Experience, Enterprise Technology System, People and Organization, and Strategic Orientation - each represent distinct dimensions within the DX process. This refined four-factor structure allowed the model to more accurately capture the underlying components that influence DX in enterprises.

3.3. Regression analysis

We continue to use SPSS 20 to analyze the regression model. Some basic indicators are satisfied, ensuring that there is no autocorrelation in the model as shown in Table 6 and Table 7 below.

Table 6 Summary of first regression results.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.952[a]	.906	.905	.297	.906	1450.587	4	605	<.001	1.976

a. Predictors: (Constant), CE, RC, HO, SO.
b. Dependent Variable: DX.

Table 7 Results of the first regression analysis.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.883	.045		19.681	<.001					
	CE	.325	.022	.374	14.990	<.001	.899	.520	.187	.251	3.987
	RC	.297	.021	.361	14.002	<.001	.903	.495	.175	.234	4.267
	HO	.174	.018	.200	9.518	<.001	.826	.361	.119	.354	2.821
	SO	.091	.017	.103	5.404	<.001	.759	.215	.068	.426	2.347

a. Dependent Variable: DX.

Table 7 shows that all independent variables have p-values less than 0.001, indicating that each factor has a statistically significant effect on the dependent variable. Although the model demonstrates strong explanatory power ($R^2 = 0.906$), two main issues warrant adjustment: multicollinearity, as indicated by relatively high variance inflation factors (VIFs), and heteroskedasticity, evidenced by the scatterplot of standardized residuals, which reveals non-random patterns.

In response to these concerns, and following the approach of MacKinnon and White (1985), we applied the HC3 robust standard errors estimator (Heteroskedasticity-Consistent Covariance Matrix Estimator Type 3). The adjusted results confirm that all independent variables remain statistically significant ($p < 0.001$), with regression coefficients falling within the 95% confidence intervals that do not include zero. The application of robust standard errors enhances the reliability of the parameter estimates, confirming the model's appropriateness and the practical explanatory power of the included variables.

Table 8 Parameter Estimates with Robust Standard Errors.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	3.761	.012		312.316	.000					
	CE	.515	.012	.535	42.750	<.001	.535	.867	.535	1.000	1.000
	RC	.508	.012	.527	42.138	<.001	.527	.864	.527	1.000	1.000
	HO	.441	.012	.458	36.580	<.001	.458	.830	.458	1.000	1.000
	SO	.350	.012	.363	29.028	<.001	.365	.763	.363	1.000	1.000

a. Dependent Variable: DX.

Table 8 shows that all independent variables: CE, RC, HO, and SO have p-values less than 0.001, indicating statistically significant effects on the dependent variable. The VIFs for all variables were 1.000, confirming that the model no longer suffers from multicollinearity, thereby effectively resolving the issue observed in the initial regression model.

Accordingly, the revised regression model with standardized coefficients is specified as follows:

$$DX = 0.535*CE + 0.527*RC + 0.458*HO + 0.363*SO + e \quad (1)$$

These results suggest that the adjusted model has successfully addressed the problem of heteroskedasticity, thereby enhancing the stability and reliability of the coefficient estimates in the regression analysis.

4. Discussion

The regression analysis results indicate that all four factors: Customer Experience and Supply Chain (CE); Enterprise Risk and Cybersecurity System (RC); People and Organization (HO); and Strategic Orientation (SO), are statistically significant and positively influence the DX process of SMEs in Vietnam. These findings are consistent with the initial hypotheses proposed in the research model and align with recent international studies (Chen et al., 2022; Ning & Yao, 2023; Leso et al., 2023; Mohamad & Muhammad, 2024; Syahrial et al., 2024).

Among these, Customer Experience and Supply Chain (CE) was found to have the most substantial impact on DX process. This result is intuitive, as customer experience today is shaped not only by the product itself but also by the entire delivery process. Firms must integrate technologies to optimize their supply chains, from inventory management and distribution to customer communication and service (Ning & Yao, 2023). As technology increasingly connects all parts of a business, enhancing supply chain efficiency becomes a strategic advantage (Syahrial et al., 2024). The use of technologies such as IoT and blockchain to track products throughout the supply process not only improves operational efficiency but also adds value for customers, thereby driving DX.

The Enterprise Risk and Cybersecurity System (RC) also plays a foundational role. This includes software for management, data storage and analytics, and security infrastructure. A robust, flexible IT system enables business continuity and enhances communication with customers and partners (Chen et al., 2022). One major challenge for SMEs in Vietnam, as in other Southeast Asian developing countries such as Malaysia (Mohamad & Muhammad, 2024), is the limited financial capacity to invest in such systems. However, the availability of cloud-based services allows firms to adopt advanced technological solutions at reduced initial costs, thereby supporting DX efforts.

The third key factor, People and Organization (HO), highlights the human dimension of transformation. Digitally literate employees and flexible organizational structures are essential for innovation and change. Leaders must foster a culture of adaptability and learning. As Fitzgerald et al. (2014) suggest, firms with strong employee and leadership engagement are more likely to succeed in transformation initiatives, as human and cultural factors are critical for technology adoption. Developing employees' digital skills, raising awareness about the benefits of transformation, and cultivating a dynamic work environment are all essential for long-term competitiveness.

Finally, Strategic Orientation (SO) reflects the importance of a clear digital vision. A coherent strategy supported by leadership commitment ensures the successful implementation of technology across business functions (Leso et al., 2023). DX is not solely about technology, it also requires shifts in mindset, leadership behavior, and strategic governance.

Overall, the research findings are not only consistent with established theoretical frameworks but also provide empirical evidence to guide managerial decision-making. This contribution is particularly valuable for Vietnamese SMEs seeking to accelerate DX amid increasingly intense global competition.

5. Conclusions and policy implications

This study demonstrates that the DX process of SMEs in Vietnam is strongly influenced by four key groups of factors: Customer Experience and Supply Chain (CE), Enterprise Risk and Cybersecurity System (RC), People and Organization (HO), and Strategic Orientation (SO). Quantitative analysis confirms that all four factors are positively associated with the level of DX, with Customer Experience and Supply Chain exerting the strongest influence. These findings provide a practical foundation that enables managers to develop a more comprehensive understanding of how to formulate DX strategies tailored to the specific characteristics of Vietnamese enterprises. In light of these results, the study offers the following policy and managerial recommendations to enhance SMEs' adaptability in an increasingly competitive environment:

First, Customer Experience and Supply Chain are critical in enhancing customer engagement and optimizing operations. SMEs should develop and refine digital platforms that deliver seamless customer experiences, from product delivery to after-sales service. This requires the integration of advanced technologies such as big data analytics and predictive modeling to improve demand forecasting and operational efficiency. Implementing smart supply chain management (SCM) systems integrated with big data platforms can reduce costs and increase responsiveness. Furthermore, leveraging multi-platform communication and personalized services based on data analytics can improve customer satisfaction and loyalty, thereby strengthening competitive advantage.

Second, Enterprise Risk and Cybersecurity Systems are foundational to the success of DX. Vietnamese SMEs should invest in ERP and CRM software to streamline internal operations and customer engagement. Additionally, technologies such as A), cloud computing, and the IoT should be adopted to enhance risk management, cost control, and real-time responsiveness. To ensure data security, enterprises must implement robust cybersecurity measures and foster a security-conscious organizational culture. Training employees in digital and cybersecurity skills is essential to maintaining operational stability in the digital environment.

Third, People and Organizational Culture play a decisive role in enabling DX. Enterprises must cultivate a workforce that is digitally literate, innovative, and adaptable. This entails investing in training programs, fostering interdepartmental collaboration, and promoting a workplace culture that values creativity and flexibility. A shift toward a more open and agile organizational culture is essential to fully embracing technological change and sustaining innovation.

Fourth, Strategic Orientation is necessary to guide SMEs in building a long-term and adaptive DX roadmap. Effective strategies should be grounded in a deep understanding of market trends, customer needs, and financial capacity. SMEs are encouraged to adopt a phased approach: start with clearly defined goals and gradually implement transformation initiatives aligned with available resources. Given the dynamic nature of DX, strategic plans must remain flexible and responsive to change. Enterprises should also include digital marketing and service delivery strategies, leveraging digital platforms to provide

fast, personalized, and consistent customer experiences. Once digital capabilities are firmly established, SMEs can expand into new markets and explore innovative business models, thereby fostering sustainable growth.

Fifth, to accelerate the DX of SMEs, the Vietnamese government must serve as a key enabler by creating a supportive environment and offering preferential policies that facilitate technology adoption and transformation. Such policies may include financial support packages, workforce development initiatives, legal and regulatory reforms, and mechanisms to foster collaboration between SMEs and technology providers. Among these, financial assistance is particularly crucial—especially during the early stages of DX. Providing access to preferential loans, subsidized interest rates, or tax incentives for businesses undertaking DX initiatives can substantially reduce financial burdens. Additionally, grants or subsidies for software acquisition and technology infrastructure are essential to help SMEs initiate transformation efforts without incurring excessive upfront investment costs.

Sixth, the Vietnamese government should actively promote training programs aimed at enhancing digital skills among enterprise personnel. These programs should target not only managerial staff but also employees at all levels, equipping them with the knowledge and capabilities to operate effectively in digital environments, thereby improving work efficiency and labor productivity. Importantly, the government can collaborate with educational institutions and technology firms to deliver free or low-cost training courses, thereby facilitating broader SME access to essential digital competencies.

Finally, building a conducive legal and institutional framework is equally critical. The government must strengthen regulations concerning information security, intellectual property rights, and personal data protection to ensure SMEs feel confident in adopting digital technologies while enhancing consumer trust in their products and services. Furthermore, the government should promote collaboration between SMEs and large technology companies through seminars, networking events, and digital collaboration platforms. Such initiatives offer SMEs valuable opportunities to learn from industry leaders and access advanced technologies without the need for heavy investment in infrastructure or in-house R&D.

In summary, developing a comprehensive DX strategy for Vietnamese SMEs is not solely the responsibility of individual enterprises; it also necessitates strong institutional support from the government. Only through close coordination between the public and private sectors can the DX process of SMEs proceed effectively and sustainably.

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Ethical considerations

The authors declare that the research was conducted in accordance with ethical standards. All participants provided informed consent prior to their involvement in the study. Data were collected and analyzed with the utmost respect for privacy and confidentiality, ensuring that no personal identifiers were disclosed without explicit consent.

Conflict of Interest

The authors declare no conflicts of interest.

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