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Digital transformation strategies in supply chain management for Vietnamese SMEs: A sustainable development approach using SWOT-AHP-TOWS

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ABSTRACT

This study focuses on digital transformation (DT) in supply chain management among Vietnamese SMEs, an area that remains underexplored compared to large enterprises. Using a hybrid SWOT-AHP-TOWS framework and evaluations from 20 experts, the study identifies key influencing factors and prioritizes strategic responses. Twelve feasible strategies are identified, with five emerging as top priorities: leveraging government policies and international funding (WO1, weight = 0.014379), developing a skilled digital workforce (WT2, 0.009865), adopting advanced technologies such as AI and IoT (SO1, 0.006036), enhancing organizational flexibility and financial efficiency (ST2, 0.005323), and strengthening system security and operational safety (ST3, 0.005323). These findings offer actionable guidance for SMEs in planning DT while providing evidence-based insights for policymakers to support sustainable and resilient digital supply chains.

Keywords: digital transformation, SMEs, supply chain management, SWOT-AHP-TOWS, sustainable strategies

INTRODUCTION

The Fourth Industrial Revolution has made digital transformation (DT) a key factor in helping businesses stay competitive and resilient (Vial, 2019). New technologies such as AI, big data, IoT, blockchain, and cloud computing are changing how companies run operations, manage supply chains, and interact with customers. According to Adhikari and Chanda (2024), nearly half of global supply chain companies now use advanced analytics to improve forecasting and logistics, and around 60% of executives consider real-time data essential for making decisions in uncertain environments. Beyond improving efficiency, DT also supports sustainable development (SD) by reducing resource use and boosting overall system performance. Despite these advances, applying DT effectively in diverse supply chain networks, especially among SMEs, is still a challenge. This highlights the need for research on tailored strategies that consider specific business contexts.

In this context, supply chain management (SCM) has gained strategic importance, especially following the disruptions caused by the COVID-19 pandemic. According to Li et al. (2024), more than half of firms have already implemented digital tools in logistics, while another 55% plan to expand their digital initiatives over the next three years. These changes have led to tangible improvements, including about a 15% reduction in logistics costs, a 35% drop in inventory levels, and service improvements of up to 65% (Knut Alicke, 2021). Taken together, these results indicate that DT is not just a short-term measure but a critical long-term approach for enhancing flexibility, resilience, and sustainable growth in global value chains.

In Vietnam, DT has been identified as a national development pillar through decision no. 749 on the national digital transformation program to 2025 with orientation toward 2030 (Government of Vietnam, 2020). Small and medium-sized enterprises (SMEs) account for nearly 98% of all businesses, contribute 45% to GDP, and generate over 60% of employment (Linh, 2024; Uyen, 2025), thereby holding a central role in this process. According to Ha Anh (2025), in 2024 the total value of e-commerce transactions reached approximately US$13.82 billion, a 40% increase compared to 2023, and the market size is estimated to exceed US$25 billion, accounting for about 9% of the total retail sales nationwide Vietnam Financial Times (2025). This shows that e-commerce is becoming an important distribution channel helping SMEs expand their market and participate more deeply in the digital supply chain. However, Vietnamese SMEs face numerous barriers, including financial constraints, underdeveloped

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digital infrastructure, shortages of digital talent, and fragmented strategic orientations. Recent surveys reveal that fewer than 4% of SMEs have achieved advanced levels of DT, while most remain confined to basic tools such as email, office software, or social media (V. A. T. Nguyen et al., 2023). This reality highlights that digitalization in Vietnam is still in its nascent stage, lacking governance frameworks and clear strategic roadmaps.

Recent scholarship has increasingly adopted integrated methodologies such as the SWOT framework and the analytic hierarchy process (AHP) in strategic management research. For example, Thuyen (2023) applied an AHP-SWOT approach to assess the drivers of green innovation, Dinh (2024) proposed a SWOT-AHP-GROUP framework for socio-economic development planning, and Tuan and Canh (2022) demonstrated the applicability of the SWOT-AHP-TOWS model in agricultural strategy formulation under drought conditions. These studies collectively highlight the value of hybrid methods in bridging qualitative insights with quantitative rigor.

However, prior reviews (Le et al., 2024; T. Nguyen et al., 2024) have largely concentrated on the general adoption of digital technologies in Vietnamese SMEs, focusing on descriptive patterns, adoption barriers, or policy-oriented discussions. While these studies provide valuable insights, they rarely move beyond fragmented analyses and do not offer an integrated, decision-oriented framework that systematically supports strategic prioritization in SCM. More importantly, despite the widespread use of SWOT or AHP as standalone tools, empirical studies that integrate SWOT-AHP-TOWS into a coherent decision-making framework tailored specifically to Vietnamese SMEs remain scarce. Existing applications of hybrid multi-criteria decision-making models are predominantly found in large enterprises or in other national contexts, limiting their applicability to SMEs operating under Vietnam's distinct financial, technological, and institutional constraints.

To address this underexplored gap, this study employs an integrated SWOT-AHP-TOWS framework to develop DT strategies for SCM in Vietnamese SMEs. Specifically, the research

(1) identifies the key strengths, weaknesses, opportunities, and threats associated with SCM digitalization in the Vietnamese SME context,

(2) quantifies their relative importance using the AHP to reduce subjectivity inherent in conventional SWOT analyses, and

(3) derives and prioritizes strategic alternatives through the TOWS matrix.

By embedding AHP-based weighting within the SWOT-TOWS logic, the study advances the methodological rigor of strategic analysis and generates context-specific strategic priorities rather than generic recommendations. Accordingly, this research contributes novel empirical evidence by demonstrating how an integrated SWOT-AHP-TOWS framework can be operationalized for SMEs in an emerging economy, while also providing a structured and actionable roadmap for Vietnamese SMEs pursuing sustainable DT in SCM.

THEORETICAL BACKGROUND

Related Concepts

DT

DT can be understood as an ongoing shift in how businesses use digital tools to manage their operations and deliver value (Romero & Mammadov, 2025; Vial, 2019). Rather than applying information technology in a few separate functions, DT involves rethinking how an organization works as a whole–from its internal structure to the way managers lead and employees collaborate (Martínez-Peláez et al., 2024). In practice, this transformation often shows clearly in SCM, where technologies such as big data, AI, IoT, and blockchain make forecasting more accurate and coordination faster (Costa Melo et al., 2023). For many SMEs, DT brings both opportunity and strain: it can open new markets but also requires investment, new digital capabilities, and a mindset ready for change. At the same time, companies adopting DT tend to move closer to sustainability goals by using resources more efficiently and reducing unnecessary waste (Sang, 2023).

SCM

SCM can be described as how firms coordinate the flow of goods, information, and finances to create value and remain competitive (T. D. Nguyen & Ngo, 2022). Over the past few years, technologies such as cloud computing, blockchain, and the Internet of things (IoT) have gradually reshaped how supply chains function. These tools make operations more transparent and responsive, yet their adoption is not always straightforward (Ta & Lin, 2023). For SMEs, the move toward digital SCM often promises lower costs and broader market access. Still, many firms struggle with limited technical capacity, tight budgets, and resistance to change within their own organizations.

SD

The idea of SD first appeared in our common future report by the WCED in 1987. Over time, it has been expanded through the "triple-bottom-line" concept, which links economic growth, social welfare, and environmental protection (Elkington, 2018). In business practice, SD is often expressed through ESG actions such as reducing emissions, managing resources more efficiently, and developing circular economic approaches. Supply chains play a crucial role in turning these ideas into reality by connecting production, logistics, and consumption in a more responsible way. For SMEs, limited capital and expertise often make this transition difficult. Still, growing pressure from stakeholders and global sustainability trends are motivating many SMEs to use digital tools that enhance transparency and help measure their progress toward sustainability (Wang et al., 2024).

SMEs

SMEs are often defined by how many employees they have and the amount of revenue they generate. In Vietnam, these firms make up nearly 98% of all registered businesses and play an essential part in job creation and innovation (Sang, 2023). Many small and medium-sized firms in Vietnam often run into familiar troubles–they do not have much capital, their tools or

technology are not always up to date, and their managers lack experience (Walsh et al., 2023). Because of these issues, it becomes quite hard for them to move ahead with digital or green projects. Still, being small sometimes helps; they can try new things and make changes faster than big firms.

DT in SMEs

Recent research has shown that DT is gradually reshaping how SMEs compete by expanding online trade, applying digital tools, and deepening customer engagement (Thanh, 2024). However, many of these firms continue to struggle with constraints in funding, workforce skills, and technological readiness (Anh et al., 2024). Effective leadership, policy backing, and cooperation with outside partners are widely regarded as crucial drivers of progress in this area (Mick et al., 2024). Within the Vietnamese context, DT contributes not only to smoother supply chain operations but also strengthens the role of SMEs in pursuing SD objectives. Despite this, existing studies have mostly examined DT and SCM in isolation, leaving the combined impact of both on sustainability relatively underexplored.

Related Theoretical Foundations

SWOT and TOWS models in strategic management

The SWOT framework has long been used to understand what a business can do internally and what it faces externally (King et al., 2023). For SMEs, it offers a simple way to see both their strengths and the gaps in resources, while also pointing out possible risks from policy shifts or sustainability demands. One major drawback, however, is that the results often depend too much on personal judgment (Shiwakoti & Regmi, 2022). To address this limitation, Weihrich (1982) proposed the TOWS framework as a way to move from simple evaluation to more concrete planning. It outlines four main strategy types–SO, WO, ST, and WT–that help firms connect their strengths and weaknesses with external factors. For SMEs, this approach can be quite practical. They might, for instance, build online platforms to expand e-commerce (SO) or improve their digital skills to approach new customer segments (WO) (Abidin et al., 2024). When combined with quantitative methods such as AHP, the TOWS framework helps make strategic planning more grounded in practice by allowing firms to set clearer and more feasible priorities (Mihajlović et al., 2024).

AHP in decision-making

The AHP, first introduced by T. L. Saaty (1980), offers a structured way to deal with complex decisions by breaking them into layers and comparing elements in pairs to identify their relative importance (T. L. Saaty, 2008). Within the SME context, AHP has been effectively used in areas such as choosing technologies, managing limited resources, and assessing innovation options (Limaei et al., 2024). Bošnjaković and Santa (2025) further note that AHP supports decision-making across different levels–from long-term strategy down to daily operations. When combined with SWOT and TOWS, this method forms a well-rounded framework that connects qualitative understanding with quantitative analysis, making it a practical fit for SMEs pursuing DT.

Technology acceptance theories

Although the SWOT-AHP-TOWS framework supports strategic planning for SMEs, the success of DT in SCM depends largely on organizational and employee acceptance of digital technologies. Technology acceptance theories offer useful conceptual insights into this process. The technology acceptance model (TAM) highlights perceived usefulness and perceived ease of use as core determinants of technology adoption, while the unified theory of acceptance and use of technology (UTAUT) extends this view by incorporating performance expectancy, effort expectancy, social influence, and facilitating conditions. In addition, the theory of reasoned action (TRA) and the theory of planned behavior (TPB) emphasize the influence of attitudes, social norms, and perceived behavioral control on behavioral intentions.

In this study, these theories are employed solely as a conceptual lens to support the interpretation of human and organizational factors within the SWOT analysis, particularly internal weaknesses and threats such as skill gaps, resistance to change, and inadequate facilitating conditions. They are not operationalized in the AHP weighting process, thereby ensuring theoretical grounding while maintaining methodological coherence and analytical rigor.

Sustainable supply chain management

From a wider perspective, sustainable supply chain management (SSCM), as described by Seuring and Müller (2008), brings together economic, social, and environmental considerations in managing supply chains. For SMEs, which often face limitations in funding and staff, digital tools like ERP, IoT, Blockchain, or AI can help ease these constraints. Such technologies simplify daily operations, increase transparency, and make it easier for SMEs to meet ESG standards (Ngo et al., 2023). In addition to boosting efficiency, SSCM supports SMEs in aligning with global sustainability expectations (Le et al., 2024).

Synthesis

The current literature suggests that no single theory fully captures the process of DT in SME supply chains. To provide a more complete understanding, this study proposes a combination of three theoretical layers:

- **Strategic layer:** SWOT-AHP-TOWS gives SMEs a practical way to assess internal capabilities and plan digital initiatives.
- **Behavioral-technological layer:** TAM, UTAUT, TRA, and TPB explain why and how people adopt digital technologies, taking into account perceived usefulness, performance expectations, social influence, and behavioral control.
- **Sustainability layer:** SSCM highlights the long-term goal of digitalization, aiming for efficiency while meeting social and environmental responsibilities.

By connecting these layers, the framework offers a clear and integrated approach: strategic decisions follow SWOT-AHP-TOWS, technology adoption is interpreted through TAM-UTAUT-TRA-TPB, and long-term sustainability is guided by SSCM. Together, they provide a solid and practical foundation for investigating DT in SMEs.

Research Gaps

Most previous studies looked at strategic decisions, production, and supply chain using SWOT-TOWS or AHP. However, they rarely use AI for predicting or improving operations (Khatri & Metri, 2016; Mihajlović et al., 2024). In sustainable supply chains, research is mostly theoretical and seldom applies blockchain for data transparency or traceability (Feng, 2025). Similarly, studies on logistics usually describe processes with SWOT or AHP, without using IoT or big data to make operations more efficient (González-Cancelas et al., 2020; Quan et al., 2023).

Second, some studies show that digital technologies can help with strategy, production, and logistics (Jatmiko et al., 2021; Li et al., 2024). But many SMEs still face problems. They often have limited funds, not enough skilled staff, and struggle to use complex technologies. These issues make adopting digital solutions hard (Tuan & Canh, 2024). Overall, research does not fully reflect the real situation of DT in Vietnamese SMEs.

Third, in terms of methodology, most studies only combine SWOT-AHP or SWOT-TOWS in descriptive or semi-qualitative approaches (Quan et al., 2023; Tuan & Canh, 2022). The integrated application of SWOT-AHP-TOWS within a qualitative-quantitative analytical framework to develop feasible DT strategies has not yet been thoroughly explored. This gap limits the ability to propose specific, actionable, and highly practical strategic recommendations for SMEs (Mihajlović et al., 2024).

Fourth, with regard to application domains, many studies have concentrated on agriculture, mining, or general manufacturing (Spanidis et al., 2023; Tuan & Canh, 2022), without adequately reflecting the distinct characteristics of SCM, which is a cornerstone of SMEs' competitiveness and market adaptability. Although some works have addressed logistics, most remain at the level of general assessments without concrete strategic action plans. Furthermore, sustainability (ESG) considerations are often treated as secondary and have not been systematically integrated with DT objectives.

Fifth, existing research does not sufficiently capture the specific characteristics of SMEs in Vietnam-namely, their small scale, low level of digitalization, and lack of long-term development strategies. Although some domestic studies have examined local enterprises, they mostly focus on provincial-level planning and do not delve into digital capabilities or concrete transformation models in supply chains (Dinh, 2024; Tuan & Canh, 2024). Specifically, how digital capabilities, supply chain strategies, and sustainability goals interact in the post-COVID-19 period is still not well studied. Moreover, the contribution of experts in assigning and calculating strategic priorities through AHP–a key element for ensuring practical use–has often been neglected.

Overall, these gaps show that in Vietnam, no research has fully used the SWOT-AHP-TOWS approach to create DT strategies for SMEs' SCM with a clear focus on sustainability. Addressing this gap by combining analytical tools with real-world data, mixing quantitative analysis with expert judgment, and taking into account local conditions and technological contexts can offer both practical solutions and theoretical insights.

SWOT-AHP-TOWS Analytical Model

The SWOT-AHP-TOWS model is structured in four levels, covering twenty sub-elements. At the top level, the model sets the main goal: developing strategies to guide SMEs in implementing DT within SCM while supporting SD in Vietnam's digital era. The second level groups factors into the four SWOT categories: strengths (S), weaknesses (W), opportunities (O), and threats (T). The third level breaks these groups down into detailed criteria, selected from the factor-identification process in each SWOT category. At the fourth level, the TOWS matrix generates strategies classified as SO (leveraging strengths to pursue opportunities), WO (addressing weaknesses to capture opportunities), ST (using strengths to counter threats), and WT (reducing weaknesses to avoid risks). **Figure 1** illustrates the overall framework.

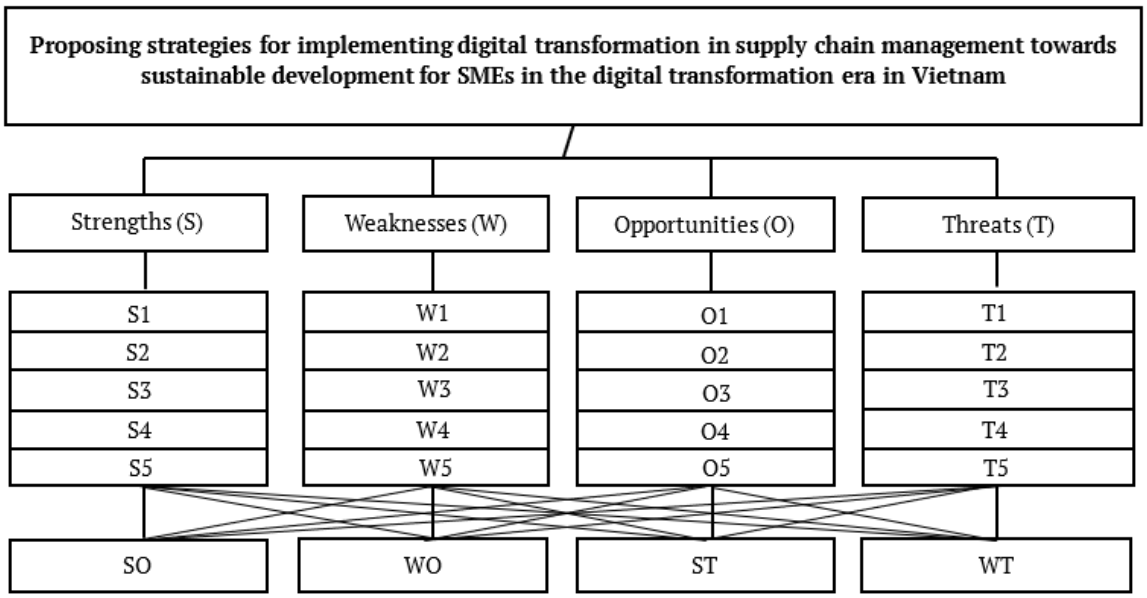

Figure 1. SWOT-AHP-TOWS model (Source: Authors' own elaboration)

RESEARCH METHODOLOGY

Data Collection Method

This study uses a mixed-methods design, combining qualitative and quantitative approaches to balance theoretical understanding with practical relevance. This allows the research to organize existing knowledge while testing which factors are most important in real-world business settings (Kalani et al., 2017).

In the qualitative stage, the team reviewed academic literature carefully, focusing on recent studies published in reputable international and domestic journals that reflect trends in DT and SD. Data were drawn from scholarly articles and industry reports indexed in trusted databases such as Scopus and Web of Science. From this review, the researchers identified 31 key factors distributed across the SWOT categories: 7 strengths, 8 weaknesses, 8 opportunities, and 8 threats. According to Wang et al. (2024), the number of experts involved in an AHP analysis typically ranges from 10 to 30. To ensure the reliability and representativeness of the study, 20 experts were selected to participate in the survey. The expert selection criteria included holding positions related to DT or SCM, possessing practical knowledge of DT implementation within enterprises, having experience in applying technologies such as ERP, CRM, and IoT, and being capable of providing objective evaluations of the investigated factors.

The quantitative stage sought to confirm these factors and determine their relative importance. A survey was created based on the 31 identified factors, using a rating scale to measure significance. Twenty experts–including business managers, professionals, and staff with experience in DT and SCM–participated in the survey. Responses were summarized by counting selections for each factor and calculating the corresponding percentages. This combination of qualitative and quantitative work ensures that the study is both methodologically sound and practically relevant for understanding DT in Vietnamese SMEs.

To control potential bias in expert judgments, this study applied multiple bias-mitigation mechanisms within the AHP evaluation process. Expert bias was first reduced by selecting experts from diverse professional backgrounds, thereby limiting individual and sector-specific perspectives. Interpretation and anchoring bias were further controlled through the use of a standardized questionnaire and unified evaluation guidelines. In addition, the pairwise comparison approach of AHP constrains subjective bias by requiring relative judgments rather than absolute scoring. Logical bias was monitored through consistency ratio (CR) verification, and only comparison matrices satisfying the threshold of CR < 0.1 were retained. Finally, aggregating individual expert judgments helped minimize the influence of extreme or outlier evaluations, enhancing the robustness and objectivity of the final results.

Data Processing Method

This study applies to the integrated SWOT-AHP-TOWS model to develop and prioritize DT strategies oriented toward SD for SMEs. This method combines the systematic nature of SWOT, the quantitative weighting capability of AHP, and the action-oriented guidance of TOWS, thereby addressing the subjective limitations of each tool when used independently (Bošnjaković & Santa, 2025; Khatri & Metri, 2016). The implementation process follows five steps (**Figure 2**).

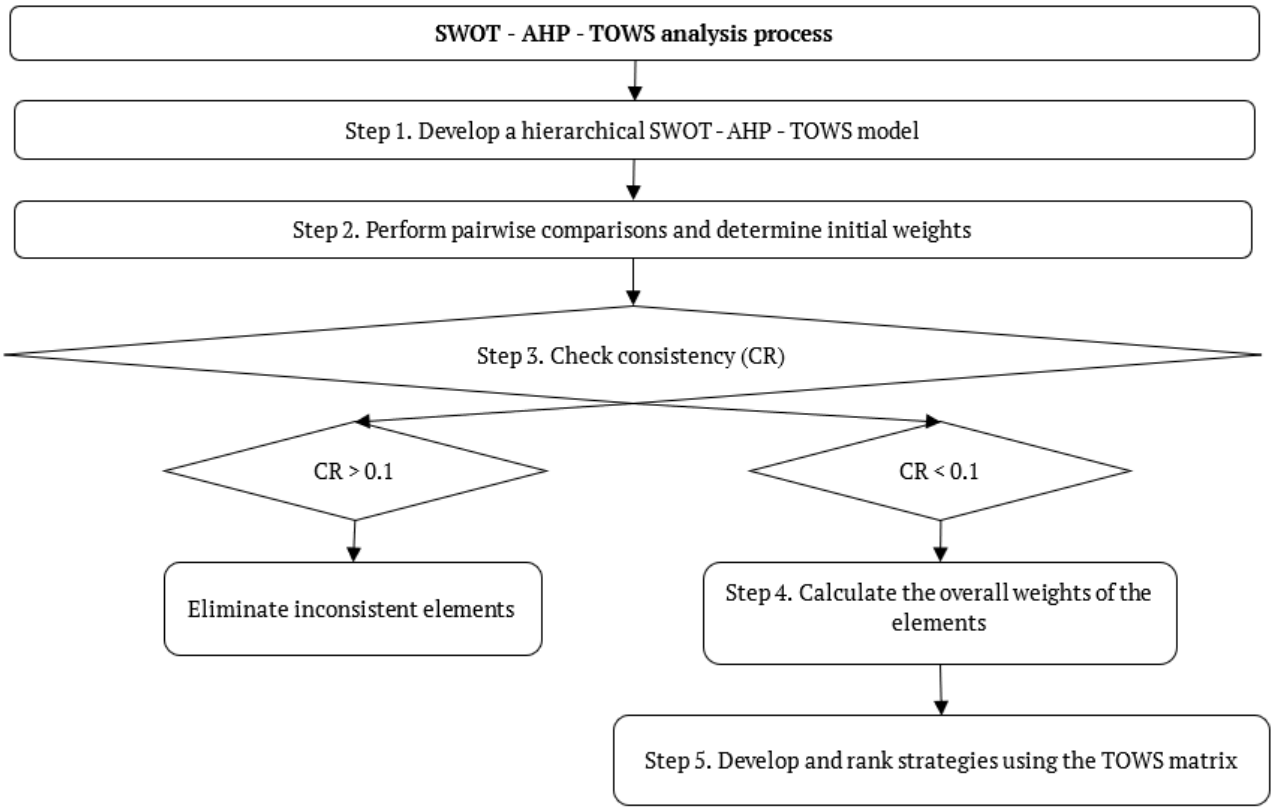

Figure 2. SWOT-AHP-TOWS analysis process (Source: Authors' own elaboration)

Table 1. Saaty's rating scale (Kalani et al., 2017; R. W. Saaty, 1987)

Scale rating	Definition	Explanation
1	Equally important	Two factors contribute equally to the overall goal.
3	Slightly more important	Experience or judgment slightly favors one factor over the others.
5	More important	Experience & judgment show one factor is clearly more significant than other.
7	Very important	Practice shows this factor has a noticeably stronger influence.
9	Extremely important	Evidence confirms the factor's highest level of superiority over others.
2, 4, 6, 8	Intermediate value between two adjacent levels	Used when the evaluation falls between two adjacent levels.

Table 2. RI values (Kalani et al., 2017)

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Step 1. Developing the hierarchical SWOT-AHP-TOWS model

First, the study identified both internal factors (strengths and weaknesses) and external factors (opportunities and threats) that affect SMEs during DT. These were gathered through expert surveys and a review of secondary data. The factors were then organized into a three-level hierarchy:

(1) the main objective, which is a sustainable DT strategy,

(2) the four SWOT categories, and

(3) the detailed sub-factors within each category (Li et al., 2024).

Step 2. Pairwise comparison and initial weight determination

Experts conducted pairwise comparisons among the factors using Saaty's 1-9 scale (**Table 1**). The results were synthesized into a comparison matrix, from which eigenvectors and initial weights for each factor were calculated.

Step 3. CR verification

To ensure reliability, the CR is calculated following the procedure proposed by T. L. Saaty (1980).

1. *Consistency index (CI)*

$$CI = \frac{\lambda_{max} - n}{n-1}. \quad (1)$$

- If $CI = 0$, the matrix is perfectly consistent.
- The smaller the CI value, the higher the degree of consistency.

2. *CR*

$$CR = \frac{CI}{RI}. \quad (2)$$

RI denotes the random index, which was calculated by Saaty based on Monte Carlo simulations of randomly generated matrices. Standard RI values are shown in **Table 2**.

3. *Evaluation of results*

- If CR < 0.1: the matrix satisfies the consistency requirement, and the comparison results are accepted.
- If CR > 0.1: the matrix is considered inconsistent, requiring adjustments to expert judgments and recalculation.

CR values were calculated for all pairwise comparison matrices to ensure the reliability of expert judgments, with all CR values remaining below the recommended threshold of 0.10. While sensitivity analysis was not conducted in this study, future research is encouraged to further examine the robustness of the proposed strategy rankings under alternative weighting scenarios.

Step 4. Calculation of composite weights

Once all sub-matrices achieve CR < 0.1, the weights are aggregated according to the hierarchical structure. For each sub-factor i within group g:

$$W_i^{global} = W_g^{group} \times W_{ilg}^{local}, \quad (3)$$

where W_g^{group} epresents the weight of the SWOT group (S, W, O, T) at the upper level, and W_{ilg}^{local} is the local weight of sub-factor i within that group. Normalization is then applied so that: $\sum w^{global} = 1$.

Step 5. Strategy formulation and ranking using the TOWS matrix

Finally, the SWOT factors are systematically combined in the TOWS matrix to generate four groups of strategies: SO, WO, ST, and WT. The previously calculated weights are applied to rank the priority level of each strategy. This outcome enables SMEs to identify optimal solutions that balance the exploitation of internal strengths with responses to external pressures in the DT process. The integration of the SWOT-AHP-TOWS methodology ensures comprehensiveness by simultaneously analyzing both internal and external factors, while enhancing objectivity through the quantification of weights and consistency verification. At the same time, it provides concrete strategic directions via the TOWS matrix (**Table 3**). This approach is particularly suitable for SMEs, which often face resource constraints but require sustainable and feasible DT strategies.

Table 3. TOWS matrix analysis

External factors	Internal factors	
	Strengths (S): S1 … Sn	Weaknesses (W): W1 … Wn
Opportunities (O): O1 … On	SO strategies: Leverage core strengths to fully exploit opportunities in the external environment.	WO strategies: Address or mitigate internal weaknesses by capitalizing on opportunities in the external environment.
Threats (T): T1 … Tn	ST strategies: Utilize existing resource advantages to minimize external risks.	WT strategies: Develop strategies to reduce vulnerabilities and mitigate external risks.

Table 4. Summary table of SWOT components

Components	Sub-components
Strengths	S1-Financial efficiency S2-Capacity for experience accumulation S3-Innovation-oriented culture S4-Serving as an industry benchmark S5-Reduction in operational and maintenance costs S6-Enhanced innovation capacity of enterprises S7-More flexible organizational structure
Weaknesses	W1-High initial technology investment costs W2-Operational disruptions due to change W3-Lack of system integration W4-Insufficient infrastructure W5-Absence of legal binding frameworks W6-Lack of strategic planning W7-High administrative requirements for SMEs W8-Shortage of highly skilled workforce
Opportunities	O1-Emerging business sectors in developing markets O2-Access to new and advanced technologies O3-Job creation potential O4-Attraction and repatriation of talents from abroad O5-Support from international financial institutions O6-Government incentives and support for technology investment O7 – Increasing market demand O8 – International cooperation and exchange
Threats	T1-Data security risks T2-Underdeveloped innovation support systems T3-External dependence on technology development T4-Shortage of technological equipment for specific process stages T5-Uncertain economic conditions T6-Competitive pressures T7-Increasing supply chain risks T8-Integration barriers

RESEARCH FINDINGS

SWOT Analysis

The research team collected data from 16 studies related to DT, SCM, and SME management. The synthesized data are presented in **Table 4**. In the first round of interviews, the authors consulted experts regarding the SWOT factors identified through the synthesis and analysis of prior literature. The experts' feedback and insights were recorded, refined, and categorized to establish the preliminary SWOT factors presented in **Table 4**.

In the second round, the experts were invited to evaluate the relative importance of the factors within each SWOT group using the pairwise comparison method, which served as the basis for subsequent data processing under the AHP model. The comparisons were conducted following (T. L. Saaty, 1980) scale of relative importance ranging from 1 to 9, allowing experts to express differentiated judgments across the factors. This qualitative analysis not only provided the initial structural foundation for the AHP model but also ensured both practical relevance and theoretical grounding for the strategic options proposed in the TOWS matrix, as shown in **Table 5**.

Results of the SWOT-AHP Analysis

This section presents the results of the SWOT-AHP analysis, through which the TOWS matrix was constructed to systematize the interrelationships among factors. Based on this framework, appropriate DT strategies are proposed to advance the goal of SD for SMEs.

Table 5. Screening of SWOT components

Components	Sub-components
Strengths	S1-Financial efficiency S2-Capacity for experience accumulation S3-Innovation-oriented culture S4-Enhancement of firms' innovation capability S5-More flexible organizational structure
Weaknesses	W1-High initial technology investment costs W2-Lack of system integration W3-Inadequate infrastructure W4-Absence of strategic planning W5-Shortage of highly skilled human resources for implementation
Opportunities	O1-Access to new and advanced technologies O2-Support from international financial institutions O3-Government incentives and support for technology investment O4-Attraction and repatriation of overseas talents O5-International cooperation and exchange
Threats	T1-Data security risks T2-Underdeveloped innovation support systems T3-External dependence on technology development T4-Competitive pressure T5-Integration barriers

Table 6. Results of SWOT-AHP weight analysis

Factor	Weight (W)	Component	L'W	G'W
Strengths (S)	0.1534	S1	0.5018	0.0770
		S2	0.1457	0.0223
		S3	0.0853	0.0131
		S4	0.0555	0.0085
		S5	0.2117	0.0325
Weaknesses (W)	0.5242	W1	0.4950	0.2595
		W2	0.1484	0.0778
		W3	0.0552	0.0290
		W4	0.2205	0.1156
		W5	0.0808	0.0424
Opportunities (O)	0.0701	O1	0.1560	0.0109
		O2	0.2409	0.0169
		O3	0.4702	0.0330
		O4	0.0533	0.0037
		O5	0.0796	0.0056
Threats (T)	0.2523	T1	0.4935	0.1245
		T2	0.2366	0.0597
		T3	0.0548	0.0138
		T4	0.1380	0.0348
		T5	0.0771	0.0194

The analysis results indicate that the three factors with the highest weights across the entire matrix are W1 (0.2595), T1 (0.1245), and W4 (0.1156), whereas O4 (0.0037) has the lowest weight (**Table 6**). Within the strengths group, S1 (0.0770) is rated the highest, reflecting financial efficiency, while S4 (0.0085) is the lowest, highlighting differences in expert perspectives. In the weaknesses group, W1-high initial technology investment costs-and W4-lack of strategic planning-stand out as key barriers. In the opportunities group, O3 (0.0330) underscores the importance of national policies, whereas O4 receives minimal prioritization. For the threats group, T1 (0.1245) and T2 (0.0597) are the most concerning,

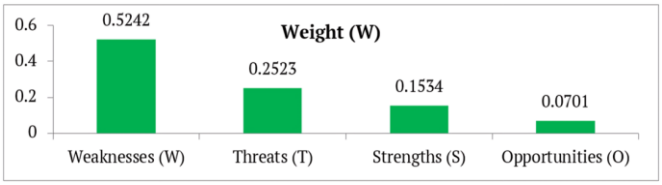

Figure 3. Relative importance of SWOT factors (Source: Authors' own elaboration)

reflecting cybersecurity and infrastructure risks, while other factors exhibit lower levels of impact.

Figure 3 illustrates that the highest weighted factor is weaknesses (W = 0.5242), followed by threats (W = 0.2523), then strengths (W = 0.1535), and finally opportunities (W = 0.0701). **Table 7** shows the L' weights of each factor within the SWOT groups.

TOWS Analysis Results

Based on the integrated SWOT-AHP-TOWS approach, the authors propose four groups of strategies: SO, WO, ST, and WT (**Table 8**). These strategies aim to assist enterprises in the technology and innovation sectors in implementing more effective actions within the context of international integration, guided by priority weights and corresponding strategic recommendations (**Table 9**).

Although the TOWS strategies are formulated based on economic and operational considerations, their underlying orientation is closely aligned with SD principles. In this study, sustainability is interpreted through the ESG framework, encompassing environmental responsibility (E), social inclusion and workforce development (S), and governance and resilience in digital SCM (G). Accordingly, each proposed strategy contributes not only to short-term efficiency and competitiveness but also to long-term sustainable value creation for SMEs.

Table 7. L' weights of each factor within the SWOT groups

Component	L' weight
S1	0.1534
S2	0.0445
S3	0.0261
S4	0.0170
S5	0.0647
W1	0.5242
W2	0.1571
W3	0.0585
W4	0.2336
W5	0.0856
O"1	0.0233
O2	0.0359
O3	0.0701
O4	0.0079
O5	0.0119
T1	0.2523
T2	0.1210
T3	0.0280
T4	0.0706
T5	0.0394

From **Table 6**, twelve specific strategies can be derived from the TOWS matrix:

1. Enterprises leverage financial efficiency and accumulated experience to capitalize on support from international financial institutions.
2. Combine an innovative culture and innovative capabilities to expand international cooperation and strengthen competitive advantages.
3. Utilize flexible organizational structures to promptly adapt to technology investment incentive policies.
4. Take advantage of government and international organizational support policies to offset limitations in investment costs and infrastructure.

Table 8. TOWS analysis

Components	Sub-components
SO	SO1. Enterprises leverage financial efficiency and experience accumulation to capitalize on opportunities provided by international financial institutions, thereby increasing their capacity to invest in modern technologies (S1, S2, O1, O2, O3). SO2. By combining an innovative culture and innovation capabilities, enterprises can attract international talent and expand international cooperation, contributing to enhanced competitiveness (S3, S4, O4, O5). SO3. Flexible organizational structures are utilized to promptly adapt to technology investment incentive policies and quickly access new technologies (S5, O1, O3).
WO	WO1. Enterprises take advantage of technology investment support policies and funding from international financial institutions to overcome limitations related to high initial technology costs and insufficient infrastructure (W1, W3, O2, O3). WO2. Strengthen international links and attract high-quality foreign experts and human resources to address the shortage of skilled personnel and limited strategic planning capabilities (W4, W5, O4, O5). WO3. Exploit opportunities to access new technologies to improve system integration, creating a more synchronized and efficient platform (W2, O1).
ST	ST1. Leverage innovation capabilities and an innovative culture to address challenges arising from underdeveloped domestic innovation support systems and integration barriers (S3, S4, T2, T5). ST2. Utilize flexible organizational structures and financial efficiency to adapt to competitive pressures and external dependencies (S1, S5, T3, T4). ST3. Exploit experience accumulation to develop solutions that mitigate data security risks and ensure system safety (S2, T1).
WT	WT1. Promote training and development of high-quality human resources while leveraging government support policies to cope with competitive pressures and integration barriers (W5, T4, T5). WT2. Mobilize domestic and international resources to gradually reduce infrastructure burdens, thereby minimizing data security risks (W3, W5, T1, T3). WT3. Review management and strategic planning systems to proactively respond to external dependencies and enhance system integration capabilities (W2, W4, T3).

Table 9. Results of the priority weight analysis of TOWS strategies

Strategy	Combined elements for each strategy	TW	Ranking
SO1	S1, S2, O1, O2, O3	0.00603642	3
SO2	S3, S4, O4, O5	0.00020123	12
SO3	S5, O1, O3	0.00142515	10
WO1	W1, W3, O2, O3	0.01437914	1
WO2	W4, W5, O4, O5	0.00147175	9
WO3	W2, O1	0.00085055	11
ST1	S3, S4, T2, T5	0.00170946	8
ST2	S1, S5, T3, T4	0.00532292	4
ST3	S2, T1	0.00278201	5
WT1	W5, T4, T5	0.00229931	7
WT2	W3, W5, T1, T3	0.00986493	2
WT3	W2, W4, T3	0.00267215	6

5. Strengthen international linkages to attract high-quality experts and skilled human resources.
6. Exploit opportunities from new technologies to enhance system integration and operational efficiency.
7. Leverage innovation capabilities and an innovative culture to address technological risks and challenges.
8. Enhance flexible organizational structures and financial efficiency to adapt to competitive pressures and external dependencies.
9. Utilize accumulated experience to develop security solutions that mitigate data risks.
10. Promote training and development of high-quality human resources to reduce dependence on international personnel.
11. Mobilize domestic and international resources to gradually upgrade infrastructure and limit data security risks.
12. Review and improve strategic management systems to minimize integration risks and enhance system integration capabilities.

From **Table 4**, it is evident that these strategies are systematically constructed based on the TOWS matrix.

Based on the survey results and subsequent analysis, the authors employed a combination of the SWOT-TOWS framework and the AHP method to quantify the relative importance of each factor within the system. Internal factors (S, W) and external factors (O, T) were identified and grouped into strategic categories through the TOWS matrix, while the AHP method facilitated the determination of relative weights via pairwise comparisons. CR tests indicated that all comparison matrices had CR < 0.1, reflecting the validity and reliability of the data. This confirms that the survey data are highly stable, ensuring accuracy in determining the prioritization of strategic factors.

DISCUSSION

The research results indicate that integrating the SWOT-AHP-TOWS framework provides significant added value, as it not only quantifies the relative importance of various factors but also offers concrete guidance for DT strategies for SMEs in Vietnam. This finding aligns with Khatri and Metri (2016); however, the present study extends the scope from production and operations to digital SCM, reflecting the specific needs of SMEs in the digital era. Barriers related to investment costs and high-quality human resources continue to be identified as critical constraints. This result is consistent with Pesce et al. (2018), yet the current study differs by employing AHP to rank the priorities, thereby providing clearer quantitative evidence. Simultaneously, the issue of insufficient system integration is also noted, as in (González-Cancelas et al., 2020), indicating that this is a universal challenge; however, in the Vietnamese context, financial and infrastructure factors are particularly prominent.

Furthermore, comparisons with studies conducted in Indonesia (Jatmiko et al., 2021) and Turkey (Ernur & Yüksel, 2022) reveal both similarities and notable contextual differences. Similar to Vietnam, these studies emphasize the importance of managerial capacity and stakeholder coordination in implementing strategic initiatives. However, the underlying reasons for these factors differ across countries due to variations in financial capacity and infrastructure development. In Indonesia, limitations mainly stem from uneven regional fiscal capacity and disparities in digital infrastructure between urban and rural areas, which constrain the effective deployment of strategic programs. In contrast, Turkey benefits from relatively more developed financial mechanisms and technological infrastructure but faces challenges related to regulatory complexity and coordination among public institutions. Within the Vietnamese context, financial constraints are more pronounced due to limited local budgets and strong dependence on public investment, while data infrastructure and cybersecurity systems remain fragmented and underdeveloped. Therefore, this study uniquely prioritizes strategies such as WO1 (leveraging supportive policies and international funding to overcome financial constraints) and WT2 (mobilizing resources to strengthen data security), reflecting their greater urgency and relevance compared to the contexts of Indonesia and Turkey. Notably, domestic studies (Thuyen, 2023; Tuan & Canh, 2022) also confirm the effectiveness of the SWOT-AHP approach; however, the present research advances further by integrating the TOWS matrix to propose twelve actionable strategies. As a result, the study not only assesses the impact of factors but also provides practical guidance for SMEs during DT. In summary, the study builds on both international and domestic theoretical foundations while providing empirical evidence suited to the context of Vietnamese SMEs. Its significant contribution lies in demonstrating the effectiveness of the

SWOT-AHP-TOWS model and suggesting prioritized strategies, thereby offering valuable additions to both theory and practice in SCM during the DT era.

New insights from the study indicate that government encouragement and support for technology investment occupy a dominant position among all factors, underscoring the strong influence of macro-level policies in creating external opportunities and representing a key consideration for enterprises throughout the digitalization process. Concurrently, the study highlights that internal weaknesses-particularly high initial technology investment costs and inadequate technical infrastructure-play a decisive role in shaping the success potential of SMEs in DT, often outweighing potential advantages. Notably, although SMEs possess certain strengths in financial efficiency, these advantages are insufficient to offset the imbalance caused by substantial cost limitations and strategic planning gaps, making it challenging for enterprises to achieve optimal outcomes in their digitalization journey.

CONCLUSIONS AND MANAGERIAL IMPLICATIONS

Conclusions

This study analyzed the current state of DT implementation in SCM among Vietnamese SMEs using the SWOT-AHP-TOWS framework, thereby clarifying the internal and external factors influencing this process. Specifically, the study identified five strengths (S1-S5), five weaknesses (W1-W5), five opportunities (O1-O5), and five threats (T1-T5), reflecting both enabling foundations and critical barriers to DT. Based on these insights, twelve strategic alternatives were formulated. Among them, WO1 (W1, W3, O2, O3) emerged as the top priority (TW = 0.014379), emphasizing the need to leverage supportive policies and international funding mechanisms to alleviate capital shortages and infrastructure constraints. This was followed by WT2 (W3, W5, T1, T3), which highlights the urgency of mobilizing resources to strengthen data security and mitigate digital risks, while SO1 (S1, S2, O1, O2, O3) focuses on utilizing existing financial capacity and managerial experience to accelerate technology investment. Strategies ST2 and ST3 further demonstrate the importance of aligning internal strengths with proactive responses to external competitive and security threats, whereas lower-weighted strategies reflect practical limitations in implementation.

From a managerial perspective, these findings suggest that Vietnamese SMEs should prioritize investments in core digital infrastructure and human resource capabilities, particularly in areas related to data management, cybersecurity, and SCM analytics. Managers are encouraged to adopt a phased DT roadmap, beginning with scalable and low-cost technologies (e.g., cloud-based SCM platforms) while gradually enhancing organizational digital skills and governance mechanisms.

From a policy perspective, the results indicate a strong need for targeted financial instruments and institutional support tailored to SMEs, such as concessional credit schemes, blended finance programs, and international cooperation initiatives aimed at digital infrastructure development. Policymakers should also strengthen regulatory frameworks related to data protection and cybersecurity, while promoting public-private partnerships and capacity-building programs to reduce implementation risks.

Managerial Implications

Based on the SWOT-AHP-TOWS analysis, the study proposes twelve managerial implications to support Vietnamese SMEs in implementing DT, effectively utilizing internal resources and external opportunities while mitigating risks arising from existing limitations. These implications are designed to be both practical and aligned with long-term SD strategies.

In the SWOT-AHP-TOWS analysis, strategy WO1 has the highest weight (TW = 0.014379), highlighting the urgency of addressing barriers related to initial investment costs and infrastructure in the DT process of Vietnamese SMEs. Investment costs not only directly affect technology accessibility but also have cascading effects on human resource capacity, organizational infrastructure, and competitive ability. Therefore, SMEs should approach DT as a phased strategic investment, prioritizing low-cost but high-impact technological solutions such as CRM, cloud accounting software, and integrated e-commerce platforms. Concurrently, enterprises should actively leverage national support programs such as SMEDF, SMEdx, and international funding from organizations like IFC or JICA to alleviate initial financial pressure, create opportunities for reinvestment, enhance access to modern technology, and ensure sustainability in the DT process.

Strategy WT2, with a weight of TW = 0.009865, belongs to the group of relatively high-priority strategies. Despite challenges in capital, technology, and human resources, reducing infrastructure pressure and enhancing data security remain critical issues directly affecting safe and sustainable operations during DT. To implement this strategy, SMEs should actively utilize external resources such as business development funds, international cooperation programs, and government or NGO-supported DT projects to upgrade technological infrastructure, secure information, and improve data storage systems. At the same time, SMEs need to develop internal capacities through staff training in data management and cybersecurity, harmonizing external and internal resources to reduce dependency and enhance autonomy. Implementing comprehensive risk management mechanisms, including infrastructure safety assessments, data backups, and adherence to international security standards, will help maintain continuous operations, minimize losses, increase trust from supply chain partners, and facilitate international collaboration and SD.

Strategy SO1, with a priority weight of TW = 0.006036, is an important strategy for the DT of Vietnamese SMEs. It emphasizes the combination of internal financial capacity and managerial experience with external support resources to drive technological investment. The study shows that relying solely on internal resources makes it difficult for SMEs to overcome technology cost barriers, but effective utilization of international funding and managerial experience enhances the ability to access and apply modern technologies.

Enterprises should treat DT as a phased strategic investment, testing solutions step-by-step to reduce financial risks before full-scale implementation. Additionally, SMEs should deploy cost-effective digital technologies with immediate impact in revenue-generating areas such as sales, marketing, and customer management, then use accumulated cash flow to reinvest in more advanced technologies, reducing reliance on external capital. Moreover, leveraging international financial support programs also provides opportunities for knowledge transfer, technical consulting, enhanced managerial capacity, digital skill development, and increased credibility and access to future partners and funding sources.

Strategy ST2, with a weight of TW = 0.005323, belongs to the medium-to-high priority group, emphasizing the foundational role of organizational structure improvement and financial efficiency in enhancing adaptability and stability for SMEs. Developing a flexible organizational structure allows enterprises to respond rapidly to external changes-from customer demands to supply chain fluctuations and competitive pressures-while promoting internal collaboration and effective DT project implementation. Concurrently, optimizing financial efficiency through cash flow management, cost control, and prudent capital use facilitates investment in innovative initiatives while minimizing risks during volatile periods. The combination of organizational flexibility and financial efficiency enables SMEs to better cope with external dependencies such as raw material price fluctuations, regulatory changes, global economic events, maintaining competitive advantage, and sustainable growth in an increasingly complex digital environment.

Strategy ST3, with a weight of TW = 0.005323, is a medium-priority strategy, indicating that while not the most urgent, accumulated experience and data security risk management play important roles in the operational efficiency of digital systems and the reliability of SME supply chains. SMEs should establish mechanisms to systematize internal experience through standardized procedures, guidance documents, and knowledge sharing among departments, while leveraging training programs, workshops, and collaborations with technology partners to enhance security and system management capabilities. Additionally, implementing continuous evaluation, testing, and improvement mechanisms-including periodic audits, penetration testing, and risk scenario simulations-will help detect vulnerabilities promptly, minimize cyberattack risks, and ensure the integrity of digital systems.

Beyond high-priority strategies, SMEs should also focus on medium-priority strategies that are essential for enhancing adaptability and SD during DT. Specifically, strategy WT3 (TW = 0.002672) reflects the need to improve internal governance to reduce external dependency and increase system integration. Strategy WT1 (TW = 0.002299) emphasizes the role of human resources in operating new technologies, enhancing productivity and innovation capacity. Strategy ST1 (TW = 0.001709) is significant for the long term, helping address the shortage of highly skilled personnel and strategic planning limitations. Strategy WO2 (TW = 0.001472) allows SMEs to leverage government support policies and rapidly access new technologies, reducing initial investment pressures. Meanwhile, some lower-priority strategies, such as SO3 (TW = 0.001425) or WO3 (TW = 0.000851), remain foundational for building an innovation culture and system synchronization. However, strategy SO2 (TW = 0.000201) is currently limited due to financial and managerial constraints. Overall, even less urgent strategies contribute to long-term competitive capacity and improve the effectiveness of DT in Vietnamese SMEs.

Limitations and Future Research Directions

Although this study provides a comprehensive analytical framework by integrating SWOT, AHP, and TOWS for strategic planning, several limitations remain. Relying on subjective expert assessments during the AHP stage may introduce bias and reduce reproducibility, while the static nature of SWOT analysis does not capture rapid changes in the business environment, potentially making TOWS-derived strategies less relevant over time. Additionally, the survey sample was small (20 SMEs) and conducted over a short period, reflecting only a snapshot rather than tracking ongoing changes. Furthermore, the study primarily reflects the perspective of internal managers and does not incorporate viewpoints from stakeholders such as suppliers, customers, or policymakers, limiting comprehensiveness. Future studies could adopt more advanced methodological approaches to extend this research. Longitudinal case studies of Vietnamese SMEs could be conducted to examine the evolution of DT strategies in SCM over time. In addition, expanding the sample and incorporating multiple stakeholder perspectives, such as policymakers, technology providers, and supply chain partners, would improve the representativeness and reliability of the findings. Methodological enhancements, including fuzzy AHP, Delphi techniques, or mixed-method designs, may further reduce subjectivity and strengthen the robustness of results

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