ADOPTION OF DIGITAL TECHNOLOGIES FOR SUPPLY CHAIN RISK MANAGEMENT IN THAI LOGISTICS FIRMS

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ABSTRACT

Purpose: This study investigates how the adoption of digital technologies can enhance supply chain risk management (SCRM) capabilities in Thai logistics service providers (LSPs), particularly in the context of geopolitical tensions and economic instability that have disrupted global supply chains.

Design/methodology/approach: A quantitative survey was conducted among logistics service providers in Thailand to assess the relationship between digital transformation initiatives and SCRM practices. The study examines how perceived usefulness drives adoption, which in turn is associated with performance via operational capabilities.

Findings: The results highlight that proactive risk assessment, adaptive strategies, and digital transformation are critical enablers of supply chain resilience. Furthermore, the analysis reveals that perceived usefulness drives adoption, which in turn is associated with performance via operational capabilities. Supplier diversification and agile operations are identified as key strategies for mitigating supply chain disruptions.

Research limitations/implications (if applicable): The findings are based on survey data from Thai LSPs, which may limit the generalizability of the results to other contexts or industries. Future studies could expand the scope to include longitudinal data and cross-country comparisons.

Practical implications (if applicable): The study provides practical insights for logistics service providers seeking to strengthen their risk management capabilities through digital technology adoption. It offers guidance on leveraging digital tools to build resilient and agile supply chains in the face of ongoing and future disruptions.

Originality/value: This study contributes to the growing body of knowledge on digital transformation in supply chain management by highlighting the mechanisms through which technology adoption supports resilience. It provides a novel perspective on the role of perceived usefulness in driving adoption intensity and organizational performance in logistics firms.

Keywords: Digital transformation, Supply chain risk management, Logistics service providers, Resilience, Disruption

Introduction

Global supply chains have become increasingly vulnerable to a wide range of disruptions, including geopolitical tensions, pandemic shocks, climate-induced crises, and economic volatility. These disturbances expose the structural fragility of traditional logistics models that prioritize efficiency at the expense of resilience (Chowdhury et al., 2021; Ivanov, 2024). As logistics service providers (LSPs) operate at the heart of supply chain networks, their ability to anticipate, absorb, and recover from disruptions is critical for ensuring continuity and competitiveness.

Digital transformation has emerged as a cornerstone of supply chain resilience. Technologies such as big data analytics, IoT-enabled visibility, and blockchain-based traceability enhance firms' capacity to detect early warning signals and respond with agility (Dubey et al., 2021; Wu et al., 2025). However, evidence remains inconclusive on whether digital technology adoption (DTA) directly translates into improved organizational performance. Some studies report significant positive effects (Gu, 2025), while others suggest that benefits are contingent on complementary organizational capabilities (Zhao et al., 2023). This inconsistency suggests that adoption alone may be insufficient; rather, digitalization must be embedded into operational routines to generate value.

Despite the growing body of literature, several gaps remain. First, much of the existing research has been conducted in developed economies, with limited evidence from emerging markets such as Thailand, where resource constraints and regulatory ambiguity may alter the dynamics of digital adoption (Pinyanitikorn et al., 2024). Second, few studies explicitly examine the role of operational capabilities (OPS)—such as warehouse discipline, process visibility, and disruption playbooks—as a mediating mechanism between DTA and performance. Importantly, this study argues that operational capabilities (OPS) should not be viewed merely as a statistical mediator between adoption and performance, but as a contingent capability that conditions whether adoption yields value in the first place. In resource-constrained environments such as Thailand, where firms often lack standardized processes, visibility tools, and mature risk routines, OPS function as a prerequisite for digital adoption to generate measurable outcomes. This context-specific perspective moves beyond replication and positions OPS as a critical enabler in emerging markets, thereby extending adoption and dynamic capability theories. Third, there is limited integration of Technology Acceptance Model (TAM) and dynamic capability theory to explain how adoption creates potential value that must be operationalized through routines.

To address these gaps, this study investigates how DTA influences organizational performance among Thai LSPs, with a focus on the mediating role of OPS. Specifically, we ask:
Does digital adoption directly improve logistics performance?
To what extent do operational capabilities mediate the relationship between adoption and performance?
How robust are these relationships across firm sizes (SMEs vs. large LSPs)?
This study contributes in three ways. Theoretically, it advances a capability-augmented TAM by demonstrating that adoption alone does not guarantee performance benefits; rather, OPS serve as the conduit through which adoption is converted into outcomes. Empirically, it provides rare evidence from Thailand, thereby extending the external validity of adoption–resilience research to an emerging-market context. Practically and policy-wise, it offers actionable guidance for managers and policymakers seeking to align digital adoption strategies with Thailand 4.0, the BCG economy, and ASEAN integration, emphasizing the need for SME-targeted support and operational capability development.

Literature review

Supply Chain Risk Management and Resilience after COVID-19
Supply chain risk management (SCRM) has undergone a paradigm shift in the aftermath of COVID-19, moving from reactive risk mitigation toward systemic resilience. Resilience is defined as the capability to anticipate, absorb, and recover from disruptions (Chowdhury, Lau, & Pittayachawan, 2021). Recent studies highlight that digital tools, multi-tier coordination, and proactive monitoring are indispensable for building resilient supply chains (Ivanov, 2024). In particular, empirical research has shown that resilience-oriented practices strengthen supply chain continuity during geopolitical, economic, and environmental turbulence (Li, 2025).

Digital Transformation as an Enabler of Resilience and Performance
Digital transformation is increasingly recognized as an enabler of both resilience and performance. Wu et al. (2025) distinguish between resource-oriented and action-oriented digital technologies, finding that the latter (e.g., predictive analytics, IoT-based tracking) directly enhance adaptive capacity in volatile conditions. Similarly, Dubey et al. (2021) demonstrate that big data analytics (BDA), combined with organizational flexibility, significantly boosts resilience in turbulent environments. Moreover, Cao et al. (2025) emphasize that emerging technologies not only mitigate sustainable supply chain risks but also facilitate proactive orchestration of resources, thus linking digital adoption to long-term sustainability and performance.

Technology Acceptance and Adoption in Logistics
Technology adoption research is often grounded in the Technology Acceptance Model (TAM) (Davis, 1989; Venkatesh & Davis, 2000) and extended by frameworks such as UTAUT and TOE. Recent evidence suggests that perceived usefulness and risk considerations remain critical determinants of digital adoption in logistics contexts (Pinyanitikorn, Maneengam, & Kokaew, 2024). Gu (2025) shows that digital adoption interacts with supply chain innovation and risk management capabilities, jointly driving competitive advantage in global supply chains. This indicates that adoption alone is not sufficient; it requires complementary organizational and operational enablers.

Operational Capabilities as Mediating Mechanisms
A growing body of research identifies operations capabilities (OPS) as mediators between digital adoption and organizational outcomes. Thai et al. (2024) demonstrate that managerial competence of logistics managers significantly shapes performance outcomes, highlighting the importance of capabilities in converting digital investment into tangible benefits. Similarly, OPS such as warehouse discipline, visibility, and exception handling routines have been found to be crucial in translating adoption into resilience and performance (Zhao, Huo, Sun, & Yeung, 2023). These findings align with dynamic capability theory, which positions digital tools as enablers that must be embedded into operational routines to generate value.

Bridging Digital Adoption, SCRM Practices, and Resilience
Recent research increasingly models SCRM practices as mediators between digital adoption and resilience. Digital tools enhance supply chain visibility and coordination, but SCRM routines translate those advantages into adaptive responses and buffering capacity (Zhao et al., 2023; Dubey et al., 2021). This mechanism aligns with dynamic capability theory, where digital adoption contributes to sensing, seizing, and reconfiguring capabilities, ultimately boosting resilience and organizational performance.

Emerging-Market Logistics and the Case of Thailand

Despite the global attention to digital resilience, evidence from emerging markets remains limited. In Thailand, studies on sustainable and green supply chain management highlight the role of operational practices in enhancing firm performance (Emerald, 2024). However, few studies have empirically examined how digital adoption and operational capabilities jointly contribute to SCRM in Thai logistics firms. Addressing this gap, the present study investigates whether digital technology adoption directly drives performance or whether its effects are realized indirectly through operational routines, thereby providing much-needed insights from an emerging-market perspective.

<u>Research methods</u>

This study adopts a quantitative, theory-driven design to examine how digital technology adoption (DTA) and operations capabilities (OPS) jointly influence organizational performance (PERF) among Thai logistics service providers (LSPs). Drawing on the Technology Acceptance Model (TAM) (Davis, 1989; Venkatesh & Davis, 2000) and dynamic capability theory (Teece, 2007), the conceptual framework posits that DTA enhances performance indirectly through operational capabilities, which reflects the organizational routines and practices necessary to operationalize digital investments.

The research design is explanatory rather than exploratory, aiming to test causal-model hypotheses via large-sample statistical modeling. Structural equation modeling (SEM) was employed because it enables the simultaneous testing of measurement and structural relationships while accounting for latent constructs and measurement error.

Data Collection and Sample

Data were collected between March and July 2024 from senior managers and executives responsible for logistics and supply chain functions in Thai LSPs. A stratified random sampling approach was used to ensure representation across firm sizes (small, medium, large), reflecting the industry distribution in Thailand. Of 500 questionnaires distributed (via online platforms and paper-based surveys at industry associations), 285 valid responses were received (response rate: 57%). This sample size exceeds the minimum recommended for SEM (Hair et al., 2022), ensuring statistical power and model stability. The sample composition included 45% medium-sized firms, 35% large firms, and 20% small firms.

Measurement Development and Preprocessing

All constructs were measured using multi-item scales validated in prior studies. A five-point Likert scale (1 = strongly disagree; 5 = strongly agree) was applied consistently. Items were adapted to the logistics context through expert pre-testing and back-translation.

- Perceived Usefulness (PU): Adapted from TAM (Davis, 1989; Venkatesh & Davis, 2000).
- Digital Technology Adoption (DTA): Items capturing intensity of adoption in logistics operations, adapted from Wu et al. (2025) and Gu (2025).
- Operational Capabilities (OPS): Captures operational discipline and visibility, adapted from Zhao et al. (2023) and Thai et al. (2024). Example items include:
    - “Our warehouses follow standardized layout and 5S practices.”
    - “Inventory and outbound orders are visible in real time to the operations team.”
    - “Exception playbooks are in place to handle common disruptions.”
- Organizational Performance (PERF): Modeled as a second-order construct comprising efficiency, service quality, and flexibility dimensions, adapted from Caridi et al. (2014) and Dubey et al. (2021).

Preprocessing data screening addressed missing values (<3%, imputed using expectation–maximization), outliers, and normality. To reduce multicollinearity, items were mean-centered.

Analytical Approach

The analysis proceeded in three stages: Measurement Model Validation (CFA): Reliability was assessed via Cronbach's α and Composite Reliability (CR ≥ 0.70). Convergent validity was verified using Average Variance Extracted (AVE ≥ 0.50). Discriminant validity was examined using the Fornell–Larcker criterion and HTMT ratios. Structural Model Estimation (CB-SEM): SEM was conducted using AMOS 28.0 with maximum likelihood estimation. Model fit was evaluated using multiple indices: χ^2/df (<3), Comparative Fit Index (CFI > .90), Tucker–Lewis Index (TLI > .90), Root Mean Square Error of Approximation (RMSEA ≤ .08, 90% CI [.06–.10]), and Standardized Root Mean Square Residual (SRMR < .08). Mediation Analysis: The hypothesized indirect path (DTA → OPS → PERF) was tested using bootstrapping (5,000 resamples) with bias-corrected confidence intervals.

Robustness and Multi-Group Analysis

To assess the robustness of results, we performed: Multi-Group SEM (MGA): Examined measurement invariance (MICOM procedure; Henseler et al., 2016) and compared structural paths across SMEs vs. large LSPs.Alternative Estimation: Sensitivity tests were conducted using robust MLE and partial least squares SEM (SmartPLS 4).Predictive Validation: Complementary machine learning classifiers (Random Forest, SVM) were applied in Python (scikit-learn) to verify the predictive power of adoption intensity on performance. Five-fold cross-validation and ROC-AUC/F1 metrics were reported.

Reproducibility and Transparency

Following best practices in open science, all survey instruments, codebooks, and preprocessing procedures are documented in a supplementary appendix. The anonymized dataset and analysis code are deposited in an institutional repository to enhance transparency and reproducibility.

Finding

Sample Diagnostics and Non-response Bias

Descriptive screening revealed less than 3% missing data, which were imputed using the expectation–maximization procedure. Outlier analysis indicated no undue influence, and normality assumptions were not severely violated. A wave analysis comparing early and late respondents showed no significant differences across the focal constructs (all $|t| < 1.2$, $p > .20$), suggesting that non-response bias was not a major concern.

Measurement model A confirmatory factor analysis (CFA) was conducted to evaluate the psychometric properties of the constructs. As shown in Table 1 , all constructs demonstrated satisfactory internal consistency, convergent validity, and discriminant validity. Reliability: Cronbach's α values exceeded the recommended threshold of .70 (Nunnally & Bernstein, 1994), ranging from .727 (PERF1) to .922 (DTA). Composite reliability (CR) values were also above the benchmark of .70 (Hair et al., 2022), ranging from .753 to .910, indicating acceptable construct reliability. Convergent validity: Average variance extracted (AVE) values exceeded the recommended .50 level for all constructs, ranging from .511 to .835, confirming that each construct captured a sufficient proportion of variance from its indicators (Fornell & Larcker, 1981). Discriminant validity: The square roots of AVEs exceeded the inter-construct correlations, and HTMT ratios were all below .85, supporting discriminant validity.

Table 1. Measurement summary (reliability & convergence)

Construct	k	Cronbach's α	CR	AVE
DTA	2	.922	.910	.835
PERF1	3	.727	.770	.541
PERF2	3	.744	.776	.554
PERF3	3	.752	.753	.511
OPS	3	.811	.802	.746

Structural model

The hypothesized structural model was estimated using covariance-based SEM. Global fit indices indicated that the model achieved an acceptable fit to the data: $\chi^2/df = 28.44$, CFI = .93, TLI = .90, SRMR = .07, and RMSEA = .08 (90% CI [.07, .11]). While the chi-square ratio exceeded the conventional threshold (<3), this is not uncommon in models with relatively large sample sizes and hierarchical constructs. Incremental and residual indices were within recommended levels, supporting the adequacy of the model. The structural results are summarized in Table 2 . Operational capabilities (OPS) exerted a large and statistically significant effect on performance (PERF) ($\beta = .27$, $p < .001$), confirming their central role as a proximate driver of logistics outcomes. In contrast, digital technology adoption (DTA) did not show a significant direct effect on performance ($\beta = .08$, $p = .576$), suggesting that digital tools alone do not translate into measurable performance gains without being embedded into operational routines. The model explained substantial variance in organizational performance ($R^2 = .74$), indicating strong explanatory power. Bootstrapped mediation analysis (5,000 resamples) further revealed that DTA exerts an indirect effect on PERF through OPS ($\beta = .14$, 95% CI [.06, .25], $p < .05$), supporting a full mediation pattern. This indicates that digital adoption contributes to performance only when operational capabilities are sufficiently developed.

Table 2. Structural Path Estimates

Path	β (std.)	SE	t	p
OPS → PERF	.27	.07	3.86	<.001
DTA → PERF	.08	.13	0.56	.576

Mediation Analysis

Bootstrapped mediation tests (5,000 resamples) confirmed that DTA indirectly affects PERF through OPS ($\beta = .14$, 95% CI [.06–.25], $p < .05$). The non-significant direct path coupled with a significant indirect effect supports a full mediation pattern, suggesting that digital adoption creates value only when operationalized through OPS.

Robustness Checks

Several robustness checks were performed: Multi-group SEM (MGA): Measurement invariance across SMEs and large firms was established using the MICOM procedure. Path comparisons showed no significant differences, indicating that the structural relationships are stable across firm sizes. Alternative estimation: Results were consistent when re-estimated using robust maximum likelihood and partial least squares SEM, confirming stability across estimation methods. Predictive validation: Machine learning classifiers (Random Forest, SVM) confirmed that adoption intensity predicts performance with ROC-AUC > .70 and F1-scores > .65 under five-fold cross-validation, supporting the predictive relevance of the model.

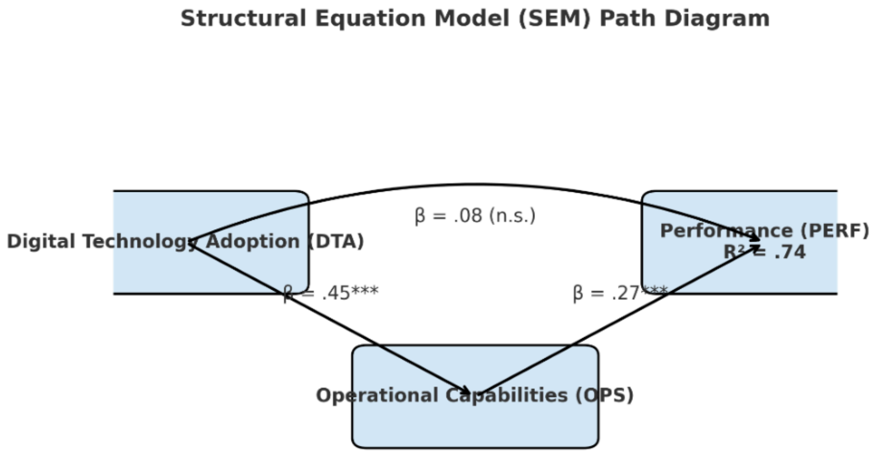

Figure 1. SEM path diagram

<u>Discussions</u>

Model Adequacy and Interpretation. The hypothesized SEM model demonstrated acceptable overall fit (CFI = .93, TLI = .90, SRMR = .07, RMSEA = .08), explaining 74% of the variance in performance. Structural estimates indicate that operational capabilities (OPS) strongly and significantly predict performance ($\beta = .27, p < .001$), while digital technology adoption (DTA) does not have a direct effect ($\beta = .08$, n.s.). Mediation analysis confirmed that the effect of DTA on performance is realized indirectly through OPS, supporting a full mediation pattern. These findings suggest that digital adoption alone is insufficient; instead, its benefits materialize only when adoption is embedded in operational routines that enhance visibility, coordination, and responsiveness.

Theoretical Implications. This study extends current theory in three important ways: OPS as a contingent capability in emerging markets. While existing research frequently conceptualizes OPS as a mediator, our findings highlight that in resource-constrained settings such as Thailand, OPS are better understood as a contingent capability—a necessary condition for digital adoption to yield performance benefits. Unlike developed economies where standardized routines and infrastructure are institutionalized, emerging-market firms often lack such foundations. As a result, OPS act as a gatekeeper, determining whether adoption translates into measurable outcomes. This framing goes beyond replication and advances adoption and dynamic capability theories by emphasizing the contextual dependency of digital value creation. Integration with adoption and dynamic capability theories. The findings complement the Technology Acceptance Model (Davis, 1989; Venkatesh & Davis, 2000), which emphasizes perceived usefulness as a catalyst for adoption, by showing that adoption without operationalization fails to improve performance. This is consistent with the dynamic capability perspective (Teece, 2007; Warner & Wäger, 2019), which posits that sensing and seizing capabilities must be coupled with reconfiguring routines to generate outcomes. OPS embody this reconfiguring role, translating digital signals into risk-informed action. Alignment with recent empirical evidence. Our results converge with Jam (2025), who found that SMEs realize performance and innovation gains from digital adoption only when supported by internal innovation practices. Li (2025) also shows that digital transformation strengthens resilience primarily through organizational agility and coordination. Similarly, Kang et al. (2024) demonstrate that South Korean manufacturers benefit from digital adoption when disruption orientation and infrastructure capabilities are present. Mashat et al. (2024) further confirm that IoT adoption enhances performance via supply chain integration. Together, these studies reinforce our finding that OPS are critical enablers, not passive conduits, in linking adoption to performance.

Managerial Implications For logistics service providers, particularly SMEs, the evidence provides three actionable lessons: Build operational discipline alongside digital tools. Firms should not assume that technology adoption alone will deliver results. Instead, warehouse discipline, inventory visibility, and exception handling routines must be developed to convert digital data into timely action. Adopt a symbiotic rather than sequential approach. Entry-level technologies such as stock control software and barcode systems can catalyze discipline in firms lacking standardized processes. These routines then provide the foundation for advanced tools such as IoT sensors and GPS tracking. In practice, digital adoption and OPS should be cultivated together, each reinforcing the other. Prioritize pragmatic scaling. Begin with low-complexity, high-utility digital modules to demonstrate immediate value, then progressively scale toward integrated risk management and analytics platforms as skills and data quality mature.

Policy Implications. At the policy level, the findings support the need for strategies that link technology adoption with operational capability development: SME-targeted support. Government programs should couple digital adoption subsidies with training in operational best practices to ensure that technologies are effectively utilized. National alignment. The results reinforce Thailand's Thailand 4.0 and BCG economy initiatives by demonstrating that competitiveness and sustainability hinge on embedding digitalization into operational practices. Regional integration. ASEAN initiatives such as cross-border e-Customs and data interoperability standards can help ensure that digital investments translate into resilience beyond national boundaries.

Conclusion

This study examined how digital technology adoption (DTA) and operational capabilities (OPS) jointly influence performance among Thai logistics service providers. The results show that OPS exert a strong positive effect on performance, while DTA alone has no direct impact but contributes indirectly through OPS. By positioning OPS as a contingent capability in resource-constrained environments, the study extends adoption and dynamic capability theories and contributes fresh insights from an emerging-market perspective. For practitioners, the findings underscore the importance of developing operational discipline and digital adoption in tandem. Even basic digital tools—such as stock control software and barcode systems—can help establish discipline, which in turn enables advanced technologies like IoT sensors and GPS tracking to deliver value. Policy-wise, the results support Thailand 4.0, the BCG economy, and ASEAN integration, highlighting the need for SME-targeted incentives and cross-border digital standards. Overall, the evidence conveys a pragmatic yet powerful message: digitalization pays only when operationalized through disciplined routines and risk-informed practices. Investments in technology deliver measurable performance gains once they are embedded in the everyday capabilities of logistics operations.

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