The Impact of Digital Transformation on Supply Chain Efficiency Among Small and Medium Enterprises (SMEs) in Selangor, Malaysia

Muhammad Dzulhakiem Alias[1*], Teh Zaharah Yaacob[2*], Nur Zawin Najiha Dhary[3*], Mohd Zulfabli Hasan[4], Muhammad Harith Zainal Abidin[5] and Hanini Ilyana Che Hashim[6]

[1,2.3,4,5] Department of Management and Technology, Faculty of Management, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

[6] Department of Accounting and Finance, Faculty of Management, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

***Corresponding Author**

DOI: https://doi.org/10.47772/IJRISS.2026.101000848

Received: 02 November 2026; Accepted: 07 November 2026; Published: 20 November 2026

ABSTRACT

Digital transformation has emerged as a strategic enabler of supply chain efficiency; however, many Small and Medium-Sized Enterprises (SMEs) in developing economies continue to face challenges in translating digital capabilities into improved operational performance. Despite growing research on digital transformation, empirical evidence examining the relative contributions of technological and organisational factors to supply chain efficiency among Malaysian SMEs remains limited. Guided by the Technology–Organisation–Environment (TOE) framework, this study investigates the relationships between Digital Technology Adoption, Process Digitalisation, Organisational Readiness, Data-Driven Decision-Making, and Supply Chain Efficiency among SMEs in Selangor, Malaysia. A quantitative cross-sectional design was used, with 271 SME representatives completing a structured questionnaire. Data were analysed using descriptive statistics, reliability analysis, Pearson correlation, and multiple linear regression through the Statistical Package for the Social Sciences (SPSS). The findings demonstrated satisfactory internal consistency across all five constructs (Cronbach's $\alpha = 0.816–0.921$), while all four digital transformation factors exhibited significant positive correlations with Supply Chain Efficiency ($r = 0.777–0.833$, $p < 0.001$). Multiple regression analysis revealed that Digital Technology Adoption was the strongest independent predictor ($\beta = 0.375$, $p < 0.001$), followed by Data-Driven Decision-Making ($\beta = 0.221$, $p < 0.001$), Organisational Readiness ($\beta = 0.213$, $p < 0.001$), and Process Digitalisation ($\beta = 0.151$, $p = 0.004$). The study contributes to the digital transformation literature by providing empirical evidence on the relative importance of technological and organisational capabilities in explaining supply chain efficiency within the Malaysian SME context. The findings highlight the need for SMEs to complement digital technology investments with organisational preparedness, process integration, and data-driven capabilities. From a policy perspective, the results offer practical insights for strengthening SME digitalisation initiatives aligned with Malaysia's Industry4WRD policy and Sustainable Development Goal 9. Nevertheless, the cross-sectional and self-reported nature of the data limits causal interpretation and generalisability.

Keywords: Digital transformation, Supply chain efficiency, SMEs, Organizational readiness, Data-driven decision making

INTRODUCTION

Small and medium enterprises (SMEs) are widely recognised as engines of economic growth because they create employment, stimulate competition and generate innovation (Crupi et al., 2020; Talib et al., 2023). In Malaysia, SMEs account for the overwhelming majority of business establishments and contributed 37.4%

of national gross domestic product (GDP) in 2021 (SME Corporation Malaysia, 2022). Selangor hosts the largest share of these firms, with 264,917 SME establishments out of 1,069,831 nationwide (Department of Statistics Malaysia [DOSM], 2023). This sector's competitiveness therefore has direct consequences for the national economy. Supply chains, rather than individual firms, increasingly compete, and the ability to deliver the right product to the right place at the right time with minimal resources has become a source of advantage (Negi, 2021; Singh et al., 2019).

Digital transformation, the integration of digital technologies into business operations and processes, has emerged as a key route to such efficiency (Mefid & Ridhaningsih, 2024). Technologies associated with the Fourth Industrial Revolution (IR4.0), including the Internet of Things (IoT), cloud computing, enterprise resource planning (ERP) systems, and big data analytics, improve visibility, real-time coordination, and decision-making across the supply chain (Büyüközkan & Göçer, 2018; Liu et al., 2022). Empirical work shows that digital transformation reduces information asymmetry, lowers costs, and increases inventory turnover, and that these benefits can be larger for SMEs than for large firms (Jing & Fan, 2024; Liu & Chi, 2024; Yu et al., 2024). Despite these benefits, Malaysian SMEs have adopted digital technologies slowly. Many operate at only a basic level of digitalisation and face persistent barriers such as limited financial resources, a shortage of digitally skilled staff, inadequate infrastructure and limited awareness of how technology can optimise supply chain operations (Crupi et al., 2020; Razak et al., 2023). As a result, SMEs cannot fully translate digital investment into supply chain performance. Prior studies on digital transformation and supply chain efficiency have largely relied on secondary data from listed firms in China (He et al., 2024; Teng et al., 2024; Zhang et al., 2025), leaving limited survey-based evidence on which specific digital transformation factors matter most for SMEs in developing economies such as Malaysia.

This study addresses this gap by examining how four key digital transformation factors Digital Technology Adoption, Process Digitalization, Organizational Readiness, and Data-Driven Decision-Making influence Supply Chain Efficiency among Small and Medium-Sized Enterprises (SMEs) in Selangor, Malaysia. Specifically, the study aims to (i) assess current levels of digital transformation and supply chain efficiency among SMEs, (ii) identify the most influential digital transformation factor for supply chain efficiency, and (iii) examine the individual relationships between each digital transformation factor and supply chain efficiency. By integrating technological and organizational perspectives, the study seeks to provide empirical evidence on the digital capabilities associated with improved supply chain performance, offering practical insights to help SMEs prioritize digital investments and strengthen operational competitiveness. Furthermore, the study contributes to the objectives of Sustainable Development Goal (SDG) 9, which emphasizes resilient infrastructure, inclusive and sustainable industrialization, and innovation, while supporting Malaysia’s National Policy on Industry 4.0 (Industry4WRD) in accelerating digital transformation and enhancing SME competitiveness.

LITERATURE REVIEW

Supply Chain Efficiency in SMEs

Supply chain management (SCM) coordinates the flow of materials, information, and services from suppliers to end customers, strengthening upstream and downstream linkages and fostering collaboration among partners (Talib et al., 2023). Supply chain efficiency is a primary indicator of supply chain performance. It refers to delivering products at the lowest resource cost while eliminating waste and non-value-adding activities (Negi, 2021), and it involves managing operations so that resources flow smoothly toward strategic aims such as cost reduction, speed, reliability, and flexibility (Gunasekaran et al., 2004).

Efficient supply chains contribute to customer satisfaction and the firm's financial success (Ellinger et al., 2012). For SMEs, digitalisation offers a way to overcome resource constraints. It streamlines operations, improves integration across supply chain processes, and enhances responsiveness to demand uncertainty (Liu & Chi, 2024; Yu et al., 2024). Digital transformation also improves supply chain efficiency by reducing transaction costs and strengthening governance (He et al., 2024), and its positive effect on supply chain performance is stronger for smaller firms (Jing & Fan, 2024; Ning & Yao, 2023).

Digital Transformation and Industry 4.0

Digital transformation involves incorporating innovative digital technologies to improve business operations and processes (Mefid & Ridhaningsih, 2024). Within supply chains, it represents a shift from traditional, linear chains to digitally integrated networks that can adapt quickly to changing customer needs (Büyüközkan & Göçer, 2018; Ivanov & Dolgui, 2021). IR4.0 technologies such as IoT, cloud computing, big data analytics, artificial intelligence, robotics and cyber-physical systems make this shift possible (Oztemel & Gursev, 2020; Queiroz et al., 2021).

Automation and robotics reduce labour costs, predictive maintenance and optimised inventory management reduce downtime (Hrouga & Sbihi, 2023), and digital platforms enable closer collaboration among suppliers, manufacturers, logistics providers and customers (Al-Shboul, 2023). Successful transformation, however, requires investment in both technological and organisational capabilities (Bag et al., 2018).

Theoretical Foundation on The TOE Framework

This study draws on the Technology–Organisation–Environment (TOE) framework of Tornatzky and Fleischer (1990), which distinguishes technological, organisational and environmental conditions affecting innovation. Digital Technology Adoption (DTA) and Process Digitalisation (PD) represent technology-related capabilities, while Organisational Readiness (OR) represents internal organisational resources and preparedness. Data-Driven Decision-Making (DDM) is treated as an information-use capability spanning technological and organisational practices; it is not a direct measure of the TOE environmental dimension. External influences, including competitive pressure, customer and supplier requirements, and government support, provide a relevant contextual lens but were not operationalised or tested in the present survey. Accordingly, the empirical model examines selected technological and organisational capabilities rather than the complete TOE framework (Tornatzky & Fleischer, 1990; Senna et al., 2023; Badghish & Soomro, 2024).

Digital Technology Adoption and Supply Chain Efficiency

Digital Technology Adoption plays a crucial role in enhancing Supply Chain Efficiency by improving operational visibility, information integration, coordination, and responsiveness across supply chain activities. Previous studies have demonstrated that adopting digital technologies in Supply Chain Management (SCM) processes contributes positively to SME performance by strengthening operational capabilities and facilitating more efficient resource utilisation (Zimmermann et al., 2024). In particular, the Internet of Things (IoT), supported by sensors and Radio Frequency Identification (RFID) technologies, enables real-time monitoring of inventory, product movements, and shipment conditions, thereby improving supply chain visibility, traceability, and operational accuracy (Ben-Daya et al., 2019; Yu et al., 2016).

Similarly, cloud computing enables efficient data storage, information sharing, and collaboration among supply chain partners, allowing SMEs to access critical operational information regardless of location (Cámara et al., 2015). Furthermore, cloud-based Enterprise Resource Planning (ERP) systems integrate essential business functions, including procurement, inventory management, logistics, and order processing, into a unified platform, supporting better coordination and reducing operational inefficiencies (Costa et al., 2016; Mefid & Ridhaningsih, 2024). Big data analytics further strengthens supply chain capabilities by supporting demand forecasting, inventory optimisation, logistics planning, and purchasing decisions (Arunachalam et al., 2018). Collectively, these technologies enable SMEs to streamline supply chain processes, minimise operational delays, improve resource allocation, and respond more effectively to changing market demands.

Process Digitalization and Supply Chain Efficiency

Process Digitalisation (PD) refers to embedding digital tools into routine supply chain workflows, such as electronic procurement, digital order processing, inventory recording, shipment tracking, and electronic payment. Unlike Digital Technology Adoption, which concerns the availability and use of technologies, PD concerns the extent to which operational activities are actually conducted through integrated digital

procedures. Digital workflows can reduce manual handovers, duplicated data entry, delays and communication gaps, thereby supporting faster fulfillment and more consistent coordination among suppliers and customers (Bienhaus & Haddud, 2018; Croom, 2000; Croom & Johnston, 2003). Nevertheless, implementation may be fragmented when firms lack staff capabilities or when partners continue to rely on manual processes. PD is therefore examined as a distinct potential correlate of Supply Chain Efficiency, alongside technology adoption and organisational capabilities.

Organizational Readiness and Supply Chain Efficiency

Organizational Readiness is a critical determinant of successful digital transformation, reflecting an organization's capacity to adopt, integrate, and effectively utilize digital technologies to enhance Supply Chain Efficiency. Assessing digital readiness is an essential initial step in supply chain digitalisation, as it enables firms to identify existing capabilities, resource limitations, and areas requiring improvement (Aamer et al., 2023; Ardito et al., 2019; Parihar & Sinha, 2021). Organisational readiness encompasses technological infrastructure, workforce digital competencies, innovation capabilities, and strategic alignment with Industry 4.0 initiatives (Dalenogare et al., 2018; Geissbauer et al., 2016). Continuous employee training and digital skills development are essential to facilitate technology adoption and improve operational adaptability (Bag et al., 2018; Queiroz et al., 2021).

Furthermore, top management commitment plays a significant role in establishing a supportive organisational culture, allocating resources, and aligning digital transformation initiatives with supply chain objectives (Bienhaus & Haddud, 2018; Ghadge et al., 2020). A clearly defined digitalisation strategy further supports the effective integration of technological investments into supply chain operations (Aamer et al., 2023; Chen et al., 2025). However, SMEs often encounter financial constraints, limited technological expertise, and resistance to organisational change, which may restrict their ability to realise the full benefits of digital transformation. These challenges highlight that technological investment alone is insufficient without adequate organisational preparedness and strategic commitment

Data-Driven Decision Making and Supply Chain Efficiency

Data-Driven Decision-Making plays an increasingly important role in enhancing Supply Chain Efficiency by enabling organisations to make timely, accurate, and evidence-based operational decisions. Organisations that establish a data-driven culture are better positioned to transform information into strategic value, improving operational performance and responsiveness to changing market conditions (LaValle et al., 2010). By treating information as a strategic asset, firms can leverage near-real-time data to improve supply chain visibility, minimise information gaps, and strengthen coordination across operational activities (Mason-Jones & Towill, 1997). Furthermore, advanced data analytics supports inventory optimisation, reduces operational disruptions, and enables more efficient resource allocation (Kache & Seuring, 2017).

Predictive analytics utilises historical data and statistical models to forecast demand, anticipate potential disruptions, and support proactive operational planning (Deloux et al., 2009; Shmueli & Koppius, 2011). The integration of data platforms and multi-tier supply chain visibility further enhances information accessibility, collaboration, and organisational agility, contributing to more efficient supply chain operations (Kache & Seuring, 2017).

However, the effectiveness of data-driven decision-making depends on data quality, analytical capabilities, and the ability to translate insights into operational actions. SMEs may face challenges such as fragmented information systems, limited analytical expertise, and inadequate technological infrastructure, which can limit the benefits of data-driven practices. Consequently, strengthening data-driven decision-making capabilities is essential for SMEs in Selangor to improve supply chain responsiveness, operational efficiency, and competitiveness in an increasingly digital business environment. Figure 1 shows the conceptual framework linking the four digital transformation factors to supply chain efficiency.

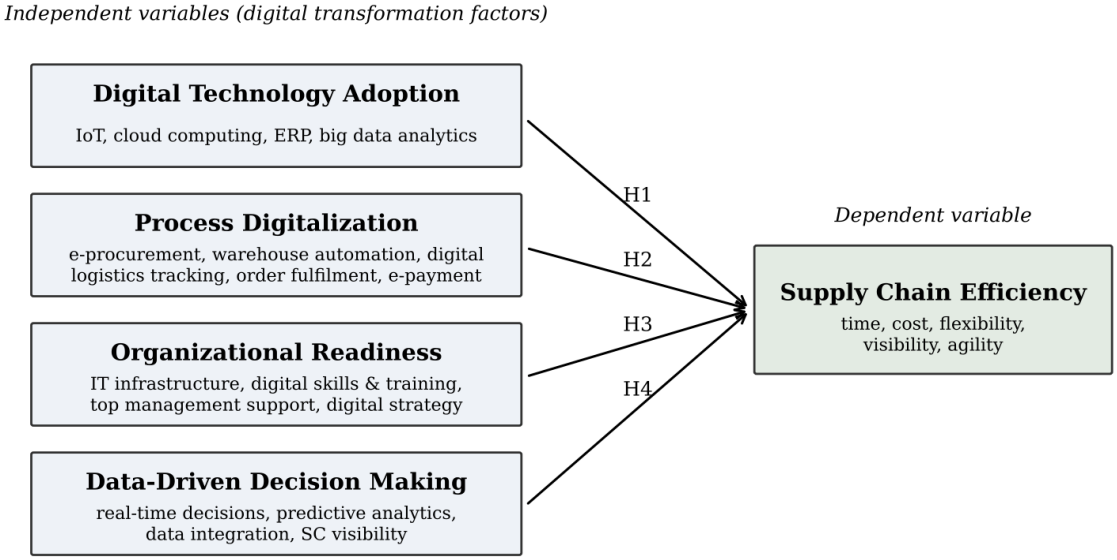


Figure 1. Conceptual Framework

METHODOLOGY

Research Design, Population and Sample

This study used a quantitative, cross-sectional online survey of SME owners and managers in Selangor, Malaysia, with the SME as the intended unit of analysis and one managerial respondent providing information about each participating firm. The target population was 264,917 SME establishments (DOSM, 2023). A conventional sample-size benchmark of 384 was identified using a 95% confidence level and 5% margin of error (Krejcie & Morgan, 1970); 271 usable questionnaires were obtained (70.6% of the target, a shortfall of 113). The original manuscript describes probability sampling but does not state whether simple random or stratified selection was used, nor does it document a complete establishment-level sampling frame or a random-selection procedure. Consequently, the available records do not allow verification of probability sampling or representativeness. Before submission, the authors should specify the actual recruitment channel, the source and coverage of the SME contact list (if any), eligibility checks, selection procedure, and whether multiple responses from the same SME were prevented. Unless a verifiable probability selection procedure is documented, the recruitment should be described as non-probability online sampling, with corresponding limitations on generalisation. The achieved sample supports estimation of a four-predictor regression but does not, by itself, meet the originally stated 384-case benchmark or establish population representativeness.

Research Instrument

This study adopted a quantitative research approach using a structured, self-administered online questionnaire to examine the relationship between digital transformation factors and Supply Chain Efficiency among Small and Medium-Sized Enterprises (SMEs) in Selangor, Malaysia. A total of 271 completed responses were obtained from SME owners and managers, against an initial target sample size of 384. The questionnaire included 22 measurement items across five constructs: Digital Technology Adoption (4 items), Process Digitalization (5 items), Organizational Readiness (4 items), Data-Driven Decision-Making (4 items), and Supply Chain Efficiency (5 items). All items were measured using a five-point Likert scale. Data analysis involved several statistical procedures. First, the internal consistency of the measurement constructs was evaluated using Cronbach's alpha, with values of 0.70 or above indicating acceptable reliability (Hair et al., 2010). Second, multicollinearity among the independent variables was examined using tolerance values and the Variance Inflation Factor (VIF), applying conventional thresholds of tolerance greater than 0.10 and VIF below 10 (Hair et al., 2010). Subsequently, multiple linear regression analysis was performed to assess the relationships between the four digital transformation factors and

Supply Chain Efficiency. Regression coefficients and corresponding p-values determined the statistical significance and direction of these relationships, while standardized beta coefficients were compared to identify the strongest predictor. These analyses provided empirical evidence of the relative contributions of Digital Technology Adoption, Process Digitalization, Organizational Readiness, and Data-Driven Decision-Making to Supply Chain Efficiency among SMEs in Selangor.

Table 1. Measurement of Constructs

Construct	**Items**	**Sample item**	**Source**
Digital Technology Adoption (DTA)	4	We would like to adopt IoT devices to help track inventory in real time, enhancing supply chain visibility.	Sahoo et al. (2023); Zimmermann et al. (2024)
Process Digitalization (PD)	5	We would like to use digital tracking systems to monitor shipments and deliveries and reduce delays.	Saberi et al. (2019)
Organizational Readiness (OR)	4	We would like top management to actively support digital transformation by allocating resources and providing leadership.	Geissbauer et al. (2016)
Data-Driven Decision Making (DDM)	4	We use predictive analytics to forecast demand and potential supply chain disruptions.	Kache & Seuring (2017)
Supply Chain Efficiency (SCE)	5	We have reduced operational costs by digitising our supply chain activities.	Gunasekaran et al. (2004)

The survey was administered online during July–October 2026 and yielded 271 usable SME responses against a target of 384 (70.6% target attainment; shortfall = 113). Target attainment is not a survey response rate: a valid response rate requires the number of eligible SMEs invited or contacted as its denominator. The source manuscript did not report that denominator; therefore, an invitation-based response rate cannot be calculated reliably. The authors should retrieve the number of invitations, undeliverable contacts, ineligible firms, incomplete questionnaires, and duplicate submissions, and report the resulting participation/usable-response rate if these records exist. The questionnaire contained 22 five-point Likert items: DTA (4), PD (5), OR (4), DDM (4) and SCE (5). The 271 cases are sufficient to estimate a parsimonious four-predictor regression in a descriptive sense, but statistical power, precision, and generalisability require separate assessment; the reduced sample and possible online self-selection should be acknowledged.

Data Collection and Analysis

Data from 271 usable questionnaires were analysed in SPSS using descriptive statistics, Cronbach's alpha, Pearson correlations and multiple linear regression. The primary model regressed SCE on DTA, PD, OR and DDM; standardised coefficients, t-tests, p-values, tolerance and VIF were examined. Firm size, industry and annual sales were reported descriptively but were not included as regression controls in the available analysis. Their omission may leave residual confounding, because organisational scale and sector can affect both digital capability and supply chain outcomes. If respondent-level data remain available, a hierarchical robustness model should enter firm size, industry and sales (subject to appropriate coding and category frequencies) before the four focal predictors; report changes in R^2 and coefficients. If re-estimation is not possible, retain the original model and explicitly acknowledge that the coefficients are unadjusted for these

firm characteristics. The full SPSS Model Summary and ANOVA outputs should be used to report R^2, adjusted R^2, $F(4, 266)$ and the model p-value; these statistics cannot be reconstructed reliably from the published coefficients alone.

RESULTS

Respondent Profile

A total of 271 respondents participated in the study, representing SMEs operating across various industries in Selangor, Malaysia. Most were chief executive officers, directors, or business owners (52.4%, n = 142), followed by general managers (42.1%, n = 114) and respondents in other positions (5.5%, n = 15). In terms of industry distribution, food and beverages accounted for the largest proportion (31.4%), followed by textiles and apparel (24.7%), healthcare and personal care (14.4%), construction, automotive and handyman services (12.5%), electrical, telecommunications and air conditioning (9.2%), and other industries (7.8%). Regarding firm size, 42.8% of SMEs employed fewer than 10 workers, while 42.4% employed between 10 and 50 workers, indicating that the sample was predominantly small enterprises. Furthermore, 46.9% of the participating firms reported annual sales below RM200,000. Overall, the respondent profile reflects substantial representation of business owners and senior managers from SMEs operating across diverse industries, providing relevant managerial perspectives on digital transformation and supply chain efficiency.

Reliability and Descriptive Statistics

The reliability analysis demonstrated satisfactory internal consistency across all five constructs, with Cronbach's alpha coefficients ranging from 0.816 to 0.921, exceeding the recommended threshold of 0.70. These results suggest that the measurement items within each construct consistently measure their respective underlying concepts. Furthermore, the overall Cronbach's alpha coefficient of 0.971 for the 22 measurement items indicates excellent internal consistency across the instrument. However, a high reliability coefficient does not necessarily establish construct validity. Table 2 presents the detailed reliability results for each construct.

Table 2. Reliability and Descriptive Statistics of Each Construct

Constructs	**Cronbach's α**
Digital Technology Adoption (DTA)	0.912
Process Digitalization (PD)	0.816
Organizational Readiness (OR)	0.919
Data-Driven Decision Making (DDM)	0.921
Supply Chain Efficiency (SCE)	0.921

The descriptive statistics for the five Supply Chain Efficiency items revealed mean scores ranging from 3.84 to 4.03 and standard deviations between 0.922 and 0.977, indicating generally favourable perceptions of supply chain performance, with some variation in respondents' assessments. Business Competitiveness recorded the highest mean score (M = 4.03, SD = 0.977), followed by Overall Supply Chain Performance (M = 4.01, SD = 0.974), suggesting that respondents perceived relatively stronger performance in these areas. Supply Chain Responsiveness (M = 3.93, SD = 0.922) and Delivery Efficiency (M = 3.86, SD = 0.944) also received favourable assessments. In contrast, Operational Cost Reduction recorded the lowest mean

score (M = 3.84, SD = 0.970), suggesting that cost-related efficiency was perceived less favorably than the other dimensions assessed, as shown in Table 3.

Table 3: Descriptive Statistics of Supply Chain Efficiency

Constructs	Mean	Standard Deviation
Delivery Efficiency	3.86	0.944
Operational Cost Reduction	3.84	0.970
Supply Chain Responsiveness	3.93	0.922
Overall Supply Chain Performance	4.01	0.974
Business Competitiveness	4.03	0.977

Note: Descriptive statistics are based on the five Supply Chain Efficiency items (n = 271). Higher mean scores indicate more favourable respondent perceptions

Overall, these results indicate that respondents rated competitiveness and overall supply chain performance more positively than operational cost reduction. This pattern suggests that cost efficiency may warrant greater managerial attention alongside other aspects of supply chain performance. Nevertheless, the differences between item means are descriptive and should not be interpreted as statistically significant without further testing. As construct-level means and standard deviations were unavailable, the descriptive interpretation was restricted to the five reported Supply Chain Efficiency items.

Multicollinearity and Multiple Regression

Multiple regression indicated positive associations between each digital transformation factor and SCE after mutual adjustment for the other three factors: DTA (standardised $\beta = 0.375$, $t = 7.111$, $p < 0.001$), DDM ($\beta = 0.221$, $t = 3.896$, $p < 0.001$), OR ($\beta = 0.213$, $t = 3.645$, $p < 0.001$) and PD ($\beta = 0.151$, $t = 2.879$, $p = 0.004$). VIF values ranged from 3.351 to 4.156, indicating nontrivial overlap among predictors, although the original threshold did not classify them as severe multicollinearity. The model has four predictors and n = 271, so the conventional overall-model F-test would have degrees of freedom (4, 266) if all 271 cases were included. **STATISTICS TO INSERT FROM ORIGINAL SPSS OUTPUT: R^2 = [not supplied]; adjusted R^2 = [not supplied]; F(4, 266) = [not supplied]; model p = [not supplied].** These figures must be obtained from the actual Model Summary and ANOVA tables rather than inferred or fabricated. No firm-level control variables were included in the reported regression; thus, the estimates are adjusted for the other digital factors but not for firm size, industry, or turnover. The results support associations, not causal effects, as shown in Table 4.

Table 4: Multicollinearity and Multiple Regression

Hyp.	Path	β	t	p	VIF	Decision
H1	DTA → SCE	0.375	7.111	<0.001	3.386	Supported
H2	PD → SCE	0.151	2.879	0.004	3.351	Supported
H3	OR → SCE	0.213	3.645	<0.001	4.156	Supported
H4	DDM → SCE	0.221	3.896	<0.001	3.921	Supported

Note: β = standardised coefficient; model R^2, adjusted R^2 and F were not available in the thesis table; dependent variable: Supply Chain Efficiency.

DISCUSSION

All four digital transformation factors were positively associated with perceived SCE, consistent with the technological and organisational aspects of TOE. DTA had the largest standardised coefficient (β = 0.375): holding the other three digital factors constant, a one-standard-deviation higher DTA score was associated with a 0.375-standard-deviation higher SCE score. DDM (β = 0.221), OR (β = 0.213) and PD (β = 0.151) showed smaller but positive adjusted associations. These are standardised coefficients, not raw-unit slopes: the manuscript does not report unstandardised B values, so the change in SCE associated with a one-point increase on the five-point DTA scale cannot be quantified from the supplied results. The coefficients should not be interpreted as percentage improvements or causal impacts. DTA may reflect improved operational visibility and coordination through IoT, cloud systems, and ERP (Ben-Daya et al., 2019; Zimmermann et al., 2024). DDM may help convert supply chain information into planning decisions (Kache & Seuring, 2017), while OR may enable adoption through management support and staff capabilities (Ghadge et al., 2020). PD's smaller unique association may partly reflect conceptual overlap with DTA and DDM, given VIF values above 3.3, rather than an unimportant role for workflow integration. From a practical standpoint, SMEs could prioritise fit-for-purpose technologies while investing in staff training, usable data and end-to-end digital workflows. The TOE environmental dimension was not measured. Nevertheless, market competition, supply chain partner expectations and government digitalisation support could plausibly shape firms' incentives and resources (Badghish & Soomro, 2024); these are contextual interpretations, not findings tested by this dataset. Future research should directly measure these external pressures and examine their incremental contribution. Because the study is cross-sectional, self-reported, and lacks firm-level controls, causal conclusions and broad population generalisations are not warranted.

Digital Technology Adoption emerged as the strongest predictor of Supply Chain Efficiency (β = 0.375, $p < 0.001$), supporting H1. This finding aligns with previous studies highlighting the contribution of the Internet of Things (IoT), cloud computing, Enterprise Resource Planning (ERP) systems, and data analytics to supply chain visibility, coordination, and operational responsiveness (Ben-Daya et al., 2019; Zimmermann et al., 2024). The result suggests that adopting appropriate digital technologies is particularly relevant to improving operational efficiency among SMEs, although the cross-sectional research design does not establish causality. Process Digitalisation demonstrated a significant positive relationship with Supply Chain Efficiency (β = 0.151, p = 0.004), supporting H2. Although it recorded the smallest standardised coefficient, this finding reinforces the importance of digitalising procurement, inventory tracking, and order-processing activities to improve workflow consistency and information exchange (Croom, 2000; Gannamneni et al., 2022). Its smaller coefficient may reflect overlap with other digital capabilities rather than a lack of operational importance.

Organisational Readiness was also positively associated with Supply Chain Efficiency (β = 0.213, $p < 0.001$), supporting H3. This finding highlights the importance of management commitment, workforce digital competencies, technological infrastructure, and strategic alignment in supporting effective digital transformation (Ghadge et al., 2020; Queiroz et al., 2021). It suggests that technology adoption should be accompanied by organisational capabilities that enable SMEs to integrate digital solutions into existing supply chain operations. Similarly, Data-Driven Decision-Making showed a significant positive relationship with Supply Chain Efficiency (β = 0.221, $p < 0.001$), supporting H4 and emerging as the second-strongest predictor. This result is consistent with previous research emphasising the importance of information accessibility and analytical capabilities in improving supply chain planning, responsiveness, and operational decision-making (Kache & Seuring, 2017). This finding suggests that SMEs can strengthen supply chain efficiency by building the capacity to turn operational data into actionable insights. Overall, the findings indicate that digital transformation should be approached as an integrated organisational initiative rather than a technology investment alone. For SMEs in Selangor, prioritising suitable digital technologies while strengthening data analytics capabilities, organisational readiness, and process integration may support more efficient and responsive supply chain operations.

CONCLUSION

This study investigated the relationships between Digital Technology Adoption (DTA), Process Digitalisation (PD), Organisational Readiness (OR), Data-Driven Decision-Making (DDM), and perceived Supply Chain Efficiency (SCE) among 271 SME respondents in Selangor, Malaysia. The findings revealed that all four digital transformation factors were positively and significantly associated with SCE. Digital Technology Adoption emerged as the strongest predictor ($\beta = 0.375$), followed by Data-Driven Decision-Making ($\beta = 0.221$), Organisational Readiness ($\beta = 0.213$), and Process Digitalisation ($\beta = 0.151$). These findings highlight the importance of technological capabilities in explaining variation in perceived supply chain efficiency, while demonstrating the complementary contributions of organizational preparedness, digitalized processes, and data-driven decision-making.

From a theoretical perspective, the study contributes empirical evidence to the Technology–Organisation–Environment (TOE) framework by demonstrating the relevance of its technological and organisational dimensions within the Malaysian SME context. The relatively stronger association of Digital Technology Adoption suggests that access to and utilisation of digital technologies are particularly important for supply chain operations. Nevertheless, the significant contributions of Organisational Readiness and Data-Driven Decision-Making indicate that technological investments should be supported by managerial commitment, workforce digital competencies, and effective information utilisation. Although environmental influences, including competitive pressures, government support, and supply chain partner requirements, may shape SMEs' digital transformation, these factors were not examined directly and remain important considerations for future research.

From a practical perspective, the findings suggest that SME owners and managers should adopt an integrated approach to digital transformation by prioritising appropriate digital technologies while strengthening complementary organisational capabilities. Investments in cloud-based enterprise systems, digital inventory management, and supply chain tracking solutions may improve operational visibility and coordination when supported by employee training, leadership commitment, and data-driven planning. Policymakers and industry development agencies may also consider providing targeted financial assistance, digital skills development programmes, and technological infrastructure support to facilitate SME digitalisation. These recommendations align with Malaysia's Industry4WRD agenda and Sustainable Development Goal 9, particularly in promoting innovation, resilient infrastructure, and sustainable industrial development.

Despite these contributions, several methodological limitations should be acknowledged. The final sample of 271 SMEs represented approximately 70.6% of the initially targeted 384 respondents, potentially limiting the precision and generalisability of the findings. Furthermore, the sampling procedure requires clarification, and the absence of complete recruitment records prevents an accurate response rate from being established. The original regression model did not include firm-level control variables, and its overall explanatory power and significance require further verification through the R^2, adjusted R^2, and F-statistic reported in the SPSS output. Additionally, the cross-sectional design and reliance on self-reported data restrict causal interpretation.

Future research should employ clearly documented probability-based sampling procedures, larger and more geographically diverse samples, and longitudinal research designs. Incorporating firm characteristics and environmental factors, such as competitive pressure, government support, and supply chain partner expectations, would also provide a more comprehensive assessment of digital transformation and supply chain efficiency. Overall, the study provides useful empirical insights into the technological and organisational capabilities associated with supply chain efficiency among Malaysian SMEs and offers a foundation for further research and evidence-informed digitalisation strategies.

Acknowledgement

The author acknowledges Universiti Teknologi Malaysia, the Nexus UTM Postgraduate Grant VOT: Q.J130000.5329.00L94, for financial support and research publication.

REFERENCES

1. Aamer, A., Sahara, C. R., & Al-Awlaqi, M. A. (2023). Digitalization of the supply chain: Transformation factors. Journal of Science and Technology Policy Management, 14(4), 713–733. https://doi.org/10.1108/JSTPM-01-2021-0001
2. Ahmed, I. (2020). Technology organization environment framework in cloud computing. TELKOMNIKA (Telecommunication Computing Electronics and Control), 18(2), 716–725. https://doi.org/10.12928/telkomnika.v18i2.13871
3. Al-Shboul, M. A. (2023). Better understanding of triadic supply chain relationships through power dynamics in manufacturing firms context. Journal of Manufacturing Technology Management, 34(8), 1482–1505. https://doi.org/10.1108/JMTM-01-2023-0019
4. Ardito, L., Petruzzelli, A. M., Panniello, U., & Garavelli, A. C. (2019). Towards Industry 4.0. Business Process Management Journal, 25(2), 323–346. https://doi.org/10.1108/BPMJ-04-2017-0088
5. Arunachalam, D., Kumar, N., & Kawalek, J. P. (2018). Understanding big data analytics capabilities in supply chain management: Unravelling the issues, challenges and implications for practice. Transportation Research Part E: Logistics and Transportation Review, 114, 416–436. https://doi.org/10.1016/j.tre.2017.04.001
6. Badghish, S., & Soomro, Y. A. (2024). Artificial intelligence adoption by SMEs to achieve sustainable business performance: Application of technology–organization–environment framework. Sustainability, 16(5), 1864. https://doi.org/10.3390/su16051864
7. Bag, S., Telukdarie, A., Pretorius, J., & Gupta, S. (2018). Industry 4.0 and supply chain sustainability: Framework and future research directions. Benchmarking: An International Journal. https://doi.org/10.1108/BIJ-03-2018-0056
8. Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: A literature review. International Journal of Production Research, 57(15–16), 4719–4742. https://doi.org/10.1080/00207543.2017.1402140
9. Bienhaus, F., & Haddud, A. (2018). Procurement 4.0: Factors influencing the digitisation of procurement and supply chains. Business Process Management Journal, 24(4), 965–984. https://doi.org/10.1108/BPMJ-06-2017-0139
10. Brandon-Jones, A., & Carey, S. (2011). The impact of user-perceived e-procurement quality on system and contract compliance. International Journal of Operations & Production Management, 31(3), 274–296. https://doi.org/10.1108/01443571111111928
11. Büyüközkan, G., & Göçer, F. (2018). Digital supply chain: Literature review and a proposed framework for future research. Computers in Industry, 97, 157–177. https://doi.org/10.1016/j.compind.2018.02.010
12. Chen, M., Tan, X., Zhu, J., & Dong, R. K. (2025). Can supply chain digital innovation policy improve the sustainable development performance of manufacturing companies? Humanities and Social Sciences Communications, 12(1). https://doi.org/10.1057/s41599-025-04601-9
13. Chittipaka, V., Kumar, S., Sivarajah, U., Bowden, J. L., & Baral, M. M. (2023). Blockchain technology for supply chains operating in emerging markets: An empirical examination of technology-organization-environment (TOE) framework. Annals of Operations Research, 327(1), 465–492. https://doi.org/10.1007/s10479-022-04801-5
14. Costa, C. J., Ferreira, E., Bento, F., & Aparicio, M. (2016). Enterprise resource planning adoption and satisfaction determinants. Computers in Human Behavior, 63, 659–671. https://doi.org/10.1016/j.chb.2016.05.090

15. Croom, S. R. (2000). The impact of web-based procurement on the management of operating resources supply. Journal of Supply Chain Management, 36(4), 4–13. https://doi.org/10.1111/j.1745-493X.2000.tb00065.x
16. Croom, S., & Johnston, R. (2003). E-service: Enhancing internal customer service through e-procurement. International Journal of Service Industry Management, 14(5), 539–555. https://doi.org/10.1108/09564230310500219
17. Crupi, A., Del Sarto, N., Di Minin, A., Gregori, G. L., Lepore, D., Marinelli, L., & Spigarelli, F. (2020). The digital transformation of SMEs – a new knowledge broker called the digital innovation hub. Journal of Knowledge Management, 24(6), 1263–1288. https://doi.org/10.1108/JKM-11-2019-0623
18. Cámara, S. B., Fuentes, J. M., & Marín, J. M. M. (2015). Cloud computing, Web 2.0, and operational performance. The International Journal of Logistics Management, 26(3), 426–458. https://doi.org/10.1108/IJLM-07-2013-0085
19. Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019
20. Deloux, E., Castanier, B., & Bérenguer, C. (2009). Predictive maintenance policy for a gradually deteriorating system subject to stress. Reliability Engineering & System Safety, 94(2), 418–431. https://doi.org/10.1016/j.ress.2008.04.002
21. Department of Statistics Malaysia. (2023).
22. Di Vaio, A., & Varriale, L. (2020). Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry. International Journal of Information Management, 52, 102014. https://doi.org/10.1016/j.ijinfomgt.2019.09.010
23. Ellinger, A., Shin, H., Northington, W. M., Adams, F. G., Hofman, D., & O'Marah, K. (2012). The influence of supply chain management competency on customer satisfaction and shareholder value. Supply Chain Management: An International Journal, 17(3), 249–262. https://doi.org/10.1108/13598541211227090
24. Fan, X., Zhao, W., Zhang, T., & Yan, E. (2023). Mobile payment, third-party payment platform entry and information sharing in supply chains. Annals of Operations Research, 329(1–2), 353–372. https://doi.org/10.1007/s10479-020-03749-8
25. Gannamneni, N. K., Salunkhe, V., Chopra, P., Shrivastav, A., Goel, P., & Goel, O. (2022). Enhancing supply chain efficiency through SAP SD/OTC integration in S/4 HANA. Universal Research Reports, 9(4), 621–642. https://doi.org/10.36676/urr.v9.i4.1396
26. Geissbauer, R., Vedso, J., & Schrauf, S. (2016). Industry 4.0: Building the digital enterprise. PwC.
27. Ghadge, A., Kara, M. E., Moradlou, H., & Goswami, M. (2020). The impact of Industry 4.0 implementation on supply chains. Journal of Manufacturing Technology Management, 31(4), 669–686. https://doi.org/10.1108/JMTM-10-2019-0368
28. Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004). A framework for supply chain performance measurement. International Journal of Production Economics, 87(3), 333–347. https://doi.org/10.1016/j.ijpe.2003.08.003
29. Gupta, S., Ghardallou, W., Pandey, D. K., & Sahu, G. P. (2022). Artificial intelligence adoption in the insurance industry: Evidence using the technology–organization–environment framework. Research in International Business and Finance, 63, 101757. https://doi.org/10.1016/j.ribaf.2022.101757
30. Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). Multivariate data analysis (7th ed.). Pearson.
31. He, J., Fan, M., & Fan, Y. (2024). Digital transformation and supply chain efficiency improvement: An empirical study from A-share listed companies in China. PLoS ONE, 19(4), e0302133. https://doi.org/10.1371/journal.pone.0302133

32. Horne, D. R., Nickerson, D., & DeFanti, M. (2015). Improving supply chain efficiency through electronic payments: The case of micro-entrepreneurs in Kenya and Tanzania. Journal of Marketing Channels, 22(2), 83–92. https://doi.org/10.1080/1046669X.2015.1018074
33. Hrouga, M., & Sbihi, A. (2023). Logistics 4.0 for supply chain performance: Perspectives from a retailing case study. Business Process Management Journal, 29(6), 1892–1919. https://doi.org/10.1108/BPMJ-03-2023-0183
34. Ivanov, D., & Dolgui, A. (2021). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. Production Planning & Control, 32(9), 775–788. https://doi.org/10.1080/09537287.2020.1768450
35. Jing, H., & Fan, Y. (2024). Digital transformation, supply chain integration and supply chain performance: Evidence from Chinese manufacturing listed firms. SAGE Open, 14(3). https://doi.org/10.1177/21582440241281616
36. Kache, F., & Seuring, S. (2017). Challenges and opportunities of digital information at the intersection of big data analytics and supply chain management. International Journal of Operations & Production Management, 37(1), 10–36. https://doi.org/10.1108/IJOPM-02-2015-0078
37. Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. Educational and Psychological Measurement, 30(3), 607–610. https://doi.org/10.1177/001316447003000308
38. LaValle, S., Lesser, E., Shockley, R., Hopkins, M. S., & Kruschwitz, N. (2010, December 21). Big data, analytics and the path from insights to value. MIT Sloan Management Review. https://sloanreview.mit.edu/article/big-data-analytics-and-the-path-from-insights-to-value/
39. Liu, K. P., Chiu, W., Chu, J., & Zheng, L. J. (2022). The impact of digitalization on supply chain integration and performance. Journal of Global Information Management, 30(1), 1–20. https://doi.org/10.4018/JGIM.311450
40. Liu, Y., & Chi, G. (2024). Does digital transformation promote supply chain efficiency? Evidence from China. Managerial and Decision Economics, 45(8), 5562–5576. https://doi.org/10.1002/mde.4343
41. Mason-Jones, R., & Towill, D. R. (1997). Information enrichment: Designing the supply chain for competitive advantage. Supply Chain Management: An International Journal, 2(4), 137–148. https://doi.org/10.1108/13598549710191304
42. Mefid, K. N., & Ridhaningsih, F. (2024). The impact of digital transformation on supply chain management in small and medium enterprises: A systematic literature review. Jurnal Keilmuan dan Aplikasi Teknologi Industri, 24(1).
43. Negi, S. (2021). Supply chain efficiency framework to improve business performance in a competitive era. Management Research Review, 44(3), 477–508. https://doi.org/10.1108/MRR-05-2020-0272
44. Ning, L., & Yao, D. (2023). The impact of digital transformation on supply chain capabilities and supply chain competitive performance. Sustainability, 15(13), 10107. https://doi.org/10.3390/su151310107
45. Oztemel, E., & Gursev, S. (2020). Literature review of Industry 4.0 and related technologies. Journal of Intelligent Manufacturing, 31(1), 127–182. https://doi.org/10.1007/s10845-018-1433-8
46. Parihar, A. S., & Sinha, V. (2021). Cultural traits influencing the adoption of new ways of workings. International Journal of Innovation Science, 13(2), 145–160. https://doi.org/10.1108/IJIS-09-2020-0158
47. Queiroz, M. M., Pereira, S. C. F., Telles, R., & Machado, M. C. (2021). Industry 4.0 and digital supply chain capabilities. Benchmarking: An International Journal, 28(5), 1761–1782. https://doi.org/10.1108/BIJ-12-2018-0435
48. Razak, G. M., Hendry, L. C., & Stevenson, M. (2023). Supply chain traceability: A review of the benefits and its relationship with supply chain resilience. Production Planning & Control, 34(11), 1114–1134. https://doi.org/10.1080/09537287.2021.1983661

49. Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 57(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261
50. Senna, P. P., Barros, A. C., Roca, J. B., & Azevedo, A. (2023). Development of a digital maturity model for Industry 4.0 based on the technology-organization-environment framework. Computers & Industrial Engineering, 185, 109645. https://doi.org/10.1016/j.cie.2023.109645
51. Shmueli, G., & Koppius, O. R. (2011). Predictive analytics in information systems research. MIS Quarterly, 35(3), 553–572. https://doi.org/10.2307/23042796
52. Singh, C. S., Soni, G., & Badhotiya, G. K. (2019). Performance indicators for supply chain resilience: Review and conceptual framework. Journal of Industrial Engineering International, 15(S1), 105–117. https://doi.org/10.1007/s40092-019-00322-2
53. Talib, N. A. C., Razak, N. A., & Mahmud, N. (2023). Enhancing small and medium enterprise performance through supply chain integration: A case study of Malaysia. Information Management and Business Review, 15(3(I)), 405–417. https://doi.org/10.22610/imbr.v15i3(I).3551
54. Teng, Y., Du, A. M., & Lin, B. (2024). The mechanism of supply chain efficiency in enterprise digital transformation and total factor productivity. International Review of Financial Analysis, 103583. https://doi.org/10.1016/j.irfa.2024.103583
55. Tornatzky, L. G., & Fleischer, M. (1990). The processes of technological innovation. Lexington Books.
56. Wang, Q., Alyahya, S., Bennett, N., & Dhakal, H. (2015). An RFID-enabled automated warehousing system. International Journal of Materials, Mechanics and Manufacturing, 3(4), 287–293. https://doi.org/10.7763/IJMMM.2015.V3.212
57. Yu, X., Nguyen, B., & Chen, Y. (2016). Internet of things capability and alliance. Internet Research, 26(2), 402–434. https://doi.org/10.1108/IntR-10-2014-0265
58. Yu, Z., Cao, X., Tang, L., Yan, T., & Wang, Z. (2024). Does digitalization improve supply chain efficiency? Finance Research Letters, 67, 105822. https://doi.org/10.1016/j.frl.2024.105822
59. Zhang, X., Liang, R., & Chen, Y. (2025). The impact of digital transformation of chain-leading enterprises on supply chain efficiency. Supply Chain Management: An International Journal. https://doi.org/10.1108/SCM-11-2024-0772
60. Zimmermann, R., Soares, A., & Roca, J. B. (2024). The moderator effect of balance of power on the relationships between the adoption of digital technologies in supply chain management processes and innovation performance in SMEs. Industrial Marketing Management, 118, 44–55. https://doi.org/10.1016/j.indmarman.2024.02.004