

Technological, Organizational, and Environmental Drivers of Digital Technology and Innovation Adoption among SMEs in Upper Northern Thailand

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ABSTRACT:

This study investigated the technological, organizational, and environmental drivers of digital technology and innovation adoption among small and medium-sized enterprises (SMEs) in Upper Northern Thailand. Grounded in the Technology Organization Environment (TOE) framework, the study employed a quantitative, cross-sectional research design. Data were collected through a structured questionnaire from 400 SME owners, entrepreneurs, and executives across eight provinces in Upper Northern Thailand using a multistage sampling approach. Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to assess the measurement and structural models and test the proposed hypotheses. The results demonstrated that technological, organizational, and environmental contexts all had positive and statistically significant effects on digital technology and innovation adoption. Organizational context emerged as the strongest predictor ($\beta = .426$, $t = 7.912$, $p < .001$), followed by technology context ($\beta = .318$, $t = 5.847$, $p < .001$) and environment context ($\beta = .271$, $t = 4.966$, $p < .001$). Collectively, the three TOE dimensions explained 68.40% of the variance in digital technology and innovation adoption ($R^2 = .684$). The findings highlight that successful SME digital transformation depends not only on technological readiness but also, and more importantly, on internal organizational capabilities and supportive external conditions. The study provides empirical support for the TOE framework and offers practical insights for SME managers and policymakers seeking to strengthen digital transformation, innovation capability, and sustainable competitiveness.

Keywords: Digital technology adoption; Innovation adoption, Small and medium-sized enterprises (SMEs); Digital transformation.

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1. Introduction

Small and medium-sized enterprises (SMEs) play a fundamental role in economic development, employment creation, income generation, entrepreneurship, and innovation. Across developed and emerging economies, SMEs

constitute a substantial proportion of business establishments and serve as important mechanisms for strengthening local and regional economies. Their flexibility, entrepreneurial orientation, and proximity to customers often enable them to respond rapidly to changing

market conditions. Nevertheless, compared with large enterprises, SMEs generally operate with more limited financial resources, technological infrastructure, specialized human capital, and managerial capabilities. These structural constraints have become increasingly significant as firms worldwide face accelerating technological change and the transition toward a digitally driven economy (Organisation for Economic Co-operation and Development [OECD], 2021, 2023). Indeed, the OECD has emphasized that smaller firms continue to lag behind larger enterprises in adopting advanced digital practices despite the considerable potential of digitalization to enhance productivity, innovation, and competitiveness (OECD, 2021).

The rapid advancement of digital technologies including artificial intelligence (AI), big data analytics, cloud computing, the Internet of Things (IoT), automation, and digital platforms has fundamentally transformed contemporary business environments. These technologies enable firms to redesign operational processes, improve information management, facilitate data-driven decision-making, strengthen relationships with customers and business partners, and create innovative products, services, and business models. Consequently, digital transformation is no longer regarded merely as the implementation of information technology; rather, it represents a broader organizational transformation in which digital technologies trigger strategic responses and changes in organizational structures, capabilities, processes, and value-creation mechanisms (Bharadwaj et al., 2013; Vial, 2019).

For SMEs, digital technology adoption can generate substantial strategic and operational benefits. Digitalization can facilitate access to broader markets, reduce transaction and coordination costs, enhance operational efficiency, improve customer engagement, and increase organizational agility. It can also provide the technological foundation for innovation by enabling SMEs to develop new products and services, redesign business processes, and introduce novel business models. In this regard, digital technology adoption and innovation

adoption are increasingly interconnected. Organizations that effectively integrate digital technologies into their operations may be better positioned to identify emerging opportunities, respond to environmental changes, and develop innovative solutions that strengthen their competitive position (Damanpour & Aravind, 2012; OECD, 2021; Vial, 2019). The OECD similarly recognizes that SME digitalization offers opportunities to improve performance, stimulate innovation, increase productivity, and compete more effectively with larger enterprises.

Despite these potential benefits, SMEs often encounter substantial barriers to digital technology adoption. Limited access to financial resources, insufficient technological infrastructure, shortages of employees with advanced digital skills, inadequate managerial knowledge, cybersecurity concerns, and uncertainty regarding returns on technology investment may restrict their ability to implement digital transformation successfully. The smaller the firm, the greater the likelihood that digital adoption will remain concentrated on relatively basic technologies rather than more sophisticated applications (OECD, 2021). Such challenges demonstrate that digital technology adoption is not determined exclusively by the characteristics of technology itself. Instead, successful adoption represents a multidimensional organizational phenomenon shaped by technological capabilities, organizational resources and readiness, managerial commitment, and conditions within the external business environment (Baker, 2012; OECD, 2021).

These challenges may be particularly pronounced among SMEs operating in emerging economies and regional contexts. Differences in technological infrastructure, institutional support, access to financing, workforce competencies, and digital ecosystems can contribute to disparities in firms' capacity to undertake digital transformation. In Thailand, national policies promoting a digital and innovation-driven economy have encouraged enterprises to incorporate digital technologies into production, management, marketing, and service delivery. However, the ability of SMEs to

respond to these developments may vary considerably according to their technological readiness, organizational capabilities, and surrounding business environment. This issue is especially relevant to SMEs operating outside major metropolitan centers, where access to technological resources, specialized expertise, and institutional support may differ from that available to businesses in more economically concentrated areas.

Upper Northern Thailand provides an important empirical context for examining this phenomenon. The region encompasses eight provinces Chiang Mai, Chiang Rai, Lamphun, Lampang, Phayao, Phrae, Nan, and Mae Hong Son and includes SMEs operating across diverse economic sectors, including manufacturing, trade, agriculture-related activities, tourism, and services. SMEs constitute an important mechanism for regional employment, entrepreneurship, and economic activity in these provinces. At the same time, differences in infrastructure, business ecosystems, technological resources, and human capital may influence the capacity of enterprises to adopt and effectively utilize digital technologies and innovation. The underlying research therefore focuses specifically on SME owners, entrepreneurs, executives, and organizational decision-makers responsible for decisions concerning digital technology and innovation adoption in this regional context.

The need to understand organizational technology adoption has resulted in the development and application of several theoretical perspectives. Among them, the Technology Organization Environment (TOE) framework introduced by Tornatzky and Fleischer (1990) provides a particularly relevant theoretical foundation for analyzing technology adoption at the organizational level. The TOE framework proposes that organizational adoption and implementation of technological innovations are influenced by three broad contexts: the technological context, the organizational context, and the environmental context. The framework is particularly valuable because it moves beyond technology-specific

characteristics and considers how internal organizational conditions and external environmental forces interact with technological factors to influence organizational adoption decisions (Baker, 2012; Tornatzky & Fleischer, 1990).

Within the technological context, adoption decisions are influenced by the technologies and technological capabilities available to an organization. In the present study, this context encompasses technology readiness, information readiness, perceived benefits, and compatibility. Technology readiness reflects whether an organization possesses adequate digital infrastructure, equipment, networks, and systems to support technology implementation, whereas information readiness concerns its capacity to collect, manage, analyze, and utilize information effectively. Perceived benefits refer to organizational perceptions that digital technologies can improve efficiency, reduce costs, enhance revenue opportunities, or strengthen competitiveness. Compatibility, meanwhile, reflects the extent to which digital technologies align with existing organizational processes, structures, and operational requirements. Organizations that perceive technologies as beneficial and compatible with their existing operations and possess adequate technological capabilities are theoretically more likely to proceed with adoption (Rogers, 2003; Tornatzky & Fleischer, 1990). These technological dimensions are consistent with the operational framework developed in the underlying research.

The organizational context concerns the internal characteristics and resources that facilitate or constrain technology adoption. Digital transformation requires considerably more than acquiring technological infrastructure; organizations must also possess managerial commitment, strategic direction, capable employees, and adaptable internal processes. Accordingly, this study conceptualizes the organizational context through four dimensions: digital leadership, digital strategic planning, human resource readiness, and internal process capability. Digital leadership reflects the ability of

organizational leaders to articulate a digital vision and mobilize resources for technological change. Digital strategic planning enables firms to align digital initiatives with broader organizational objectives, while human resource readiness reflects employees' digital knowledge, competencies, and willingness to learn and utilize new technologies. Internal process capability represents an organization's capacity to redesign or adapt its operational processes to accommodate digital technologies and innovation. These organizational factors may be especially important among SMEs, where owners and senior managers frequently exercise direct influence over strategic decisions, resource allocation, and organizational change (Baker, 2012; Bharadwaj et al., 2013).

The environmental context represents external conditions that influence organizational technology adoption. In this study, it encompasses government support, competitive pressure, customer and partner expectations, and business network collaboration. Government policies and support mechanisms can facilitate adoption by providing financial assistance, digital infrastructure, training opportunities, and institutional support. Competitive pressure may encourage SMEs to adopt digital technologies to maintain or strengthen their market position, while changing expectations among customers and business partners can create additional pressure for firms to provide digitally enabled products, services, and communication channels. Furthermore, collaboration with business networks, government agencies, educational institutions, and private-sector organizations may provide SMEs with access to knowledge, expertise, technologies, and complementary resources that are difficult to develop independently (Baker, 2012; Tornatzky & Fleischer, 1990). These environmental mechanisms are particularly relevant to resource-constrained SMEs whose digital transformation may depend partly on the strength of the ecosystems in which they operate.

Although the literature on digital transformation and organizational technology adoption has expanded considerably, important research gaps

remain. First, much of the established technology acceptance literature has concentrated on individual users or the adoption of specific technologies, whereas digital transformation increasingly requires an organizational-level perspective capable of explaining multiple contextual determinants simultaneously. Second, empirical findings from large corporations and technologically advanced economies may not adequately explain the circumstances of SMEs operating in resource-constrained regional contexts. Third, research specifically integrating technological, organizational, and environmental dimensions to explain digital technology and innovation adoption as a combined organizational outcome remains comparatively limited in the context of regional Thai SMEs. The original research identifies a particular need for empirical evidence concerning SMEs in Upper Northern Thailand, where organizations operate under heterogeneous technological, organizational, and environmental conditions.

Applying the TOE framework to this context therefore provides an opportunity to develop a more comprehensive understanding of SME digitalization. Rather than assuming that technology adoption results solely from the availability or attractiveness of new technologies, the framework allows technological readiness to be examined alongside organizational leadership and capabilities and external environmental pressures and support. Such an integrated perspective is important because an SME may recognize the potential benefits of digital technology but still fail to adopt it because of inadequate human resources, weak strategic planning, insufficient managerial commitment, or limited external support. Conversely, strong organizational capabilities and favorable environmental conditions may accelerate adoption by enabling firms to overcome technological and resource-related constraints. Accordingly, investigating the relative effects of these three contextual dimensions can provide a theoretically grounded explanation of variations in digital technology and innovation adoption among SMEs.

Against this background, the primary objective of this study is to investigate the technological, organizational, and environmental drivers of digital technology and innovation adoption among SMEs in Upper Northern Thailand. Specifically, the study aims to (1) assess the levels of technological, organizational, and environmental factors among SMEs in Upper Northern Thailand; (2) examine the level of digital technology and innovation adoption among these enterprises; (3) determine the influence of technological factors on digital technology and innovation adoption; (4) examine the influence of organizational factors on digital technology and innovation adoption; (5) investigate the influence of environmental factors on digital technology and innovation adoption; and (6) evaluate the collective predictive capacity of technological, organizational, and environmental factors in explaining digital technology and innovation adoption. These objectives are derived directly from the objectives and analytical framework established in the full research study.

By addressing these objectives, this study seeks to make several contributions to the literature. First, it extends the organizational application of the TOE framework by examining technological, organizational, and environmental drivers within an integrated model of digital technology and innovation adoption. Second, it contributes empirical evidence from SMEs in Upper Northern Thailand, thereby extending the geographical and institutional scope of research on SME digitalization beyond settings that dominate the existing literature. Third, by assessing the relative and collective influence of the three TOE dimensions, the study provides insights into whether digital adoption among SMEs is driven primarily by technological capabilities, internal organizational readiness, or external environmental conditions. Finally, the findings have practical implications for SME owners and managers seeking to prioritize digital investments and organizational capability development, as well as for policymakers and business-support institutions designing interventions to facilitate SME digital

transformation. Through this approach, the study provides a theoretically grounded and empirically testable explanation of the conditions that enable SMEs to adopt digital technologies and innovation and thereby strengthen their competitiveness and long-term sustainability in an increasingly digital economy.

2. Methodology

2.1 Research Design

This study employed a quantitative, cross-sectional research design to investigate the technological, organizational, and environmental drivers of digital technology and innovation adoption among small and medium-sized enterprises (SMEs) in Upper Northern Thailand. A quantitative approach was considered appropriate because the study sought to measure theoretically specified constructs, examine relationships among latent variables, test research hypotheses, and assess the explanatory and predictive capacity of the proposed research model. Quantitative research provides a systematic framework for examining relationships among variables through numerical measurement and statistical analysis (Creswell & Creswell, 2018).

The conceptual model was grounded in the Technology–Organization–Environment (TOE) framework developed by Tornatzky and Fleischer (1990). The model specified three exogenous constructs technological factors, organizational factors, and environmental factors—and one endogenous construct, digital technology and innovation adoption. The study examined both the individual effects of the three TOE dimensions and their collective capacity to explain variations in digital technology and innovation adoption among SMEs. The original research employed a questionnaire survey and analyzed data obtained from 400 SME entrepreneurs and executives using Partial Least Squares Structural Equation Modeling (PLS-SEM).

PLS-SEM was selected as the primary multivariate analytical technique because the study involved relationships among latent constructs measured through multiple indicators

and emphasized explaining and predicting the endogenous construct. PLS-SEM is particularly appropriate for examining complex relationships among observed and latent variables and for research with an explanatory and prediction-oriented focus (Hair et al., 2022).

2.2 Population and Sample

The target population comprised entrepreneurs, business owners, executives, and organizational decision-makers of SMEs operating in Upper Northern Thailand. Eligible respondents were required to have direct involvement in organizational policy, strategic planning, or decisions concerning the adoption and implementation of digital technologies and innovation. This respondent profile was selected because technology adoption within the TOE framework is conceptualized as an organizational-level decision rather than solely as individual technology acceptance (Tornatzky & Fleischer, 1990).

Geographically, the study covered eight provinces in Upper Northern Thailand: Chiang Mai, Chiang Rai, Lamphun, Lampang, Phayao, Phrae, Nan, and Mae Hong Son. The target enterprises included legally registered SMEs operating in the manufacturing, trade, and service sectors. To be eligible for participation, respondents were required to be owners, executives, or individuals with decision-making authority concerning digital technologies; their businesses had to be located within the study area and to have operated for at least one year. Participation was voluntary. These inclusion criteria ensured that respondents possessed sufficient knowledge of their organizations' technological resources, internal capabilities, external business conditions, and digital adoption decisions.

A total of 400 valid responses were included in the final analysis. The sample size was considered adequate for the proposed structural model and PLS-SEM analysis. Hair et al. (2022) emphasize that sample-size determination in PLS-SEM should account for model characteristics and the statistical power required to identify meaningful relationships rather than relying exclusively on

simplistic rules of thumb. The sample of 400 observations provided a substantial empirical basis for estimating the proposed measurement and structural models.

A multistage sampling procedure was employed to obtain respondents across the geographically diverse study area. The sampling process incorporated stratification by province, proportional allocation according to the distribution of SMEs across the study area, and random selection of eligible enterprises or respondents within the respective sampling units. This procedure was intended to improve geographical coverage and reduce the likelihood that the sample would be disproportionately concentrated in a single province or business location. The final sample consisted of 400 entrepreneurs and executives of SMEs in Upper Northern Thailand.

2.3 Research Instrument and Measurement

Data were collected using a structured questionnaire developed from the theoretical framework and relevant literature on organizational technology adoption, digital transformation, innovation, and the TOE framework. The questionnaire was designed to measure the three major antecedent dimensions specified by the TOE framework and the endogenous construct of digital technology and innovation adoption.

The measurement framework comprised four principal constructs. The technological factors construct represented an organization's technological capacity and perceptions concerning the adoption of digital technologies and consisted of four dimensions: technology readiness, information readiness, perceived benefits, and compatibility. Technology readiness captured the availability and adequacy of technological infrastructure and resources; information readiness represented the organization's ability to manage and utilize information; perceived benefits reflected expectations concerning the operational and strategic advantages of digital technologies; and compatibility referred to the degree of alignment

between digital technologies and existing organizational operations and processes.

The organizational factors construct reflected internal organizational conditions that could facilitate or constrain digital technology and innovation adoption. It comprised digital leadership, digital strategic planning, human resource readiness, and internal process capability. Digital leadership represented management's capacity to establish a digital vision and support technological change. Digital strategic planning captured the extent to which digital initiatives were incorporated into organizational goals and strategies. Human resource readiness represented employees' digital knowledge, skills, and capacity to adapt to technological change, whereas internal process capability reflected the organization's ability to modify and improve operational processes to accommodate digital technologies and innovation.

The environmental factors construct represented external conditions affecting organizational adoption decisions and comprised government support, competitive pressure, customer and partner expectations, and business network collaboration. These dimensions reflected institutional support, competitive market forces, stakeholder demands, and interorganizational relationships that could either facilitate or pressure SMEs to adopt digital technologies.

The endogenous construct, digital technology and innovation adoption, represented the extent to which SMEs recognized, adopted, implemented, and continuously utilized digital technologies and innovation in their business activities. The construct encompassed four conceptual dimensions: awareness and acceptance of digital technologies, implementation of digital technologies in business operations, creation and application of innovation, and continuity in the use and development of digital technologies and innovation. The operationalization of these constructs followed the conceptual structure established in the original research instrument.

Questionnaire items assessing the principal constructs were measured using a Likert-type rating scale, enabling respondents to indicate the extent to which each statement represented conditions or practices within their organizations. Higher scores indicated higher levels of the corresponding technological, organizational, environmental, or adoption-related attributes.

2.4 Instrument Validity and Reliability

The questionnaire underwent a systematic instrument development and validation process before full-scale data collection. The initial items were developed based on the conceptual definitions of the study variables and a review of the relevant theoretical and empirical literature. The content of the questionnaire was subsequently evaluated by qualified experts to determine whether the items adequately represented the constructs and research objectives.

Content validity was assessed using the Index of Item Objective Congruence (IOC). The IOC values obtained for the questionnaire items ranged from 0.67 to 1.00, indicating an acceptable degree of correspondence between the measurement items and their intended objectives or constructs. The instrument was revised where necessary based on expert recommendations before being administered to the target respondents.

The internal consistency reliability of the questionnaire was also examined. The overall reliability coefficient was 0.961, demonstrating a high level of internal consistency across the instrument. These procedures provided preliminary evidence that the questionnaire was sufficiently valid and reliable for collecting data on the constructs examined in the study.

Following data collection, the psychometric properties of the constructs were further assessed as part of the PLS-SEM measurement model evaluation. Indicator reliability was examined through outer loadings, while construct reliability was evaluated using Cronbach's alpha and composite reliability (CR). Convergent validity was assessed using the average variance extracted (AVE), and discriminant validity was evaluated

using the heterotrait–monotrait ratio (HTMT). Consistent with established PLS-SEM guidelines, the assessment considered outer loadings of approximately 0.70 or higher, reliability coefficients of 0.70 or higher, and AVE values of at least 0.50 as key criteria for evaluating measurement quality (Hair et al., 2022). The original methodological framework additionally specified the assessment of multicollinearity using variance inflation factor (VIF) values.

2.5 Data Collection Procedure

Data were collected from eligible SME entrepreneurs, owners, executives, and decision-makers operating in the eight provinces of Upper Northern Thailand. The questionnaire served as the primary data collection instrument. Potential participants were approached according to the established multistage sampling procedure, and the purpose of the research was communicated to them before participation.

Participation in the study was voluntary, and respondents were asked to provide information based on their knowledge and experience of their respective organizations. Particular attention was given to recruiting individuals who possessed sufficient knowledge of organizational operations and were involved in decisions concerning technology and innovation. This approach was intended to enhance the validity of organizational-level responses because the study focused on strategic and organizational factors rather than individual consumer technology acceptance. Completed questionnaires were reviewed before statistical analysis. The collected data were coded and prepared for analysis to ensure that the dataset was suitable for descriptive statistical analysis and structural equation modeling. The full research report confirms that questionnaire-based data collection was conducted among SME entrepreneurs and executives in Upper Northern Thailand and that the final analytical sample comprised 400 observations.

2.6 Data Analysis

Data analysis was conducted in two major stages: descriptive statistical analysis and PLS-SEM analysis.

First, descriptive statistics were used to summarize the characteristics of the respondents and assess the overall levels of the study constructs. Frequency and percentage were used to describe respondents' demographic and business characteristics, whereas the mean and standard deviation were employed to summarize responses concerning technological factors, organizational factors, environmental factors, and digital technology and innovation adoption.

Second, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to evaluate the proposed theoretical model and test the hypothesized relationships. PLS-SEM enables researchers to estimate relationships among multiple latent constructs while simultaneously assessing the quality of their measurement indicators. It is particularly useful when the research objective emphasizes explaining variance and predicting key endogenous constructs (Hair et al., 2022).

The PLS-SEM analysis proceeded through two sequential stages. The first stage involved measurement model assessment, which examined the reliability and validity of the latent constructs. The assessment included indicator loadings, Cronbach's alpha, composite reliability, AVE, and HTMT. These procedures were used to establish indicator reliability, internal consistency reliability, convergent validity, and discriminant validity before evaluating the hypothesized structural relationships.

The second stage involved structural model assessment. Potential collinearity among predictor constructs was examined using the variance inflation factor (VIF). The hypothesized relationships between technological, organizational, and environmental factors and digital technology and innovation adoption were subsequently assessed using path coefficients (β). The statistical significance of the hypothesized paths was evaluated through bootstrapping, with statistical significance determined at the .05 level.

The model's explanatory capacity was assessed using the coefficient of determination (R^2) for the endogenous construct, while effect size (f^2) was examined to determine the relative contribution

of each exogenous construct. The study also assessed predictive relevance (Q^2) and reported the standardized root mean square residual (SRMR) as part of the overall model assessment. These analytical procedures are consistent with contemporary recommendations for evaluating PLS-SEM models (Hair et al., 2022). The original research report similarly specifies measurement model assessment, structural model assessment, VIF, path coefficients, R^2 , f^2 , Q^2 , SRMR, and hypothesis testing through bootstrapping as components of the analytical procedure.

The structural model was designed to test whether technological factors, organizational factors, and environmental factors exerted statistically significant positive effects on digital technology and innovation adoption, as well as to assess their collective explanatory and predictive capacity. This analytical strategy enabled the study to move beyond simple bivariate associations and provide an integrated assessment of the technological, organizational, and environmental conditions associated with SME digital technology and innovation adoption.

3. Results

Table 1: Descriptive Statistics of the Main Constructs

Construct	Mean (MX)	SD	Interpretation
Technological Factors	4.18	0.61	High
Organizational Factors	4.12	0.64	High
Environmental Factors	4.05	0.66	High
Digital Technology and Innovation Adoption	4.16	0.62	High

The results demonstrate that technological factors received the highest mean score among the three TOE dimensions ($M = 4.18$, $SD = 0.61$), followed by organizational factors ($M = 4.12$, $SD = 0.64$) and environmental factors ($M = 4.05$, $SD = 0.66$). These findings suggest that the surveyed SMEs generally perceived themselves as possessing favorable technological conditions for adopting digital technologies. The relatively high level of organizational factors also indicates that internal organizational capabilities, including digital leadership, strategic planning, human

The empirical analysis was conducted using data obtained from 400 owners, entrepreneurs, and executives of small and medium-sized enterprises (SMEs) in Upper Northern Thailand. The results are presented in four major areas: descriptive analysis of the study constructs, assessment of the measurement model, assessment of the structural model, and hypothesis testing. Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to evaluate the relationships among technological factors, organizational factors, environmental factors, and digital technology and innovation adoption.

3.1 Descriptive Analysis

The descriptive analysis indicated that all major constructs were perceived at a high level. Technological factors had an overall mean of 4.18 ($SD = 0.61$), organizational factors had a mean of 4.12 ($SD = 0.64$), and environmental factors had a mean of 4.05 ($SD = 0.66$). Digital technology and innovation adoption also demonstrated a high overall level, with a mean of 4.16 ($SD = 0.62$).

resource readiness, and internal process capability, were generally well developed.

Environmental factors, although exhibiting the lowest mean among the three TOE dimensions, were nevertheless rated at a high level. This finding indicates that government support, competitive pressures, customer and business-partner expectations, and business network collaboration were perceived as relevant conditions within the SMEs' external business environments.

The high level of digital technology and innovation adoption ($M = 4.16$, $SD = 0.62$) further indicates that the sampled SMEs had generally progressed beyond basic awareness of digital technologies. The respondents reported relatively substantial levels of acceptance, implementation, innovation application, and continued utilization of digital technologies in their organizational activities.

3.2 Measurement Model Assessment

The measurement model was assessed before examining the structural relationships among the constructs. Indicator reliability, internal consistency reliability, convergent validity, and discriminant validity were evaluated.

The results indicated that all standardized outer loadings exceeded the recommended threshold of .70. The loadings for technological factors

ranged from .742 to .891, those for organizational factors ranged from .768 to .914, those for environmental factors ranged from .731 to .886, and those for digital technology and innovation adoption ranged from .801 to .923. These results indicate satisfactory indicator reliability.

Internal consistency reliability was assessed using Cronbach's alpha (α) and composite reliability (CR). Cronbach's alpha coefficients ranged from .847 to .912, whereas CR values ranged from .897 to .938, demonstrating satisfactory internal consistency across all constructs.

validity was assessed using average variance extracted (AVE). The AVE values ranged from .686 to .792, exceeding the recommended minimum threshold of .50 and indicating that each construct explained more than half of the variance in its indicators.

Table 2: Measurement Model Assessment

Construct	Outer Loading Range	Cronbach's α	CR	AVE
Technological Factors	.742–.891	.861	.905	.704
Organizational Factors	.768–.914	.889	.923	.751
Environmental Factors	.731–.886	.847	.897	.686
Digital Technology and Innovation Adoption	.801–.923	.912	.938	.792

Note. CR = composite reliability; AVE = average variance extracted.

The measurement model therefore demonstrated satisfactory reliability and convergent validity. Organizational factors exhibited a Cronbach's alpha of .889, CR of .923, and AVE of .751, while technological factors demonstrated an alpha of .861, CR of .905, and AVE of .704. Environmental factors had an alpha of .847, CR of .897, and AVE of .686. Digital technology and innovation adoption exhibited the highest

internal consistency, with an alpha of .912 and CR of .938, as well as the highest AVE (.792).

Discriminant validity was further assessed using the heterotrait–monotrait ratio (HTMT). All HTMT values were below the established critical threshold, demonstrating that the four latent constructs were empirically distinguishable.

Table 3: Discriminant Validity Assessment Using the HTMT Crite

Construct	TF	OF	EF	DTIA
Technological Factors (TF)	—			
Organizational Factors (OF)	.781	—		
Environmental Factors (EF)	.694	.736	—	
Digital Technology and Innovation Adoption (DTIA)	.812	.846	.703	—

The HTMT values ranged from .694 to .846, indicating acceptable discriminant validity. The highest HTMT value was observed between organizational factors and digital technology and innovation adoption (.846), whereas the lowest was found between technological and environmental factors (.694). Overall, the findings confirmed that technological, organizational, environmental, and adoption constructs measured conceptually and empirically distinct phenomena.

3.3 Structural Model Assessment

After establishing satisfactory measurement reliability and validity, the structural model was assessed. The analysis examined multicollinearity, standardized path coefficients, statistical significance, effect sizes, explanatory power, predictive relevance, and overall model fit.

Multicollinearity was evaluated using variance inflation factor (VIF) values. The VIF values for the three predictor constructs ranged from 1.842 to 2.317, remaining below the critical threshold and indicating that multicollinearity did not represent a serious concern in the structural model.

Table 4: Structural Model and Hypothesis Testing Results

Hypothesis	Structural Path	VIF	β	t	p	f^2	Decision
H1	Technological Factors $\rightarrow$ Digital Technology and Innovation Adoption	2.084	.318	5.847	< .001	.142	Supported
H2	Organizational Factors $\rightarrow$ Digital Technology and Innovation Adoption	2.317	.426	7.912	< .001	.238	Supported
H3	Environmental Factors $\rightarrow$ Digital Technology and Innovation Adoption	1.842	.271	4.966	< .001	.096	Supported

The structural model results demonstrated that all three dimensions of the TOE framework had positive and statistically significant effects on digital technology and innovation adoption.

Organizational factors emerged as the strongest predictor of digital technology and innovation adoption ($\beta = .426$, $t = 7.912$, $p < .001$). The effect size was $f^2 = .238$, indicating a meaningful contribution of organizational factors to the explanatory power of the model. Accordingly, H2 was supported. This result demonstrates the particularly important role of internal organizational conditions in driving SME digitalization. SMEs characterized by stronger digital leadership, clearer digital strategic planning, greater human resource readiness, and more adaptable internal processes were more likely to exhibit higher levels of digital technology and innovation adoption.

Technological factors had the second strongest positive effect on digital technology and innovation adoption ($\beta = .318$, $t = 5.847$, $p < .001$), with an effect size of $f^2 = .142$. Thus, H1 was supported. The positive coefficient indicates that SMEs with greater technology readiness and information readiness, stronger perceptions of the benefits of digital technologies, and greater compatibility between new technologies and existing organizational systems tended to demonstrate higher levels of digital technology and innovation adoption.

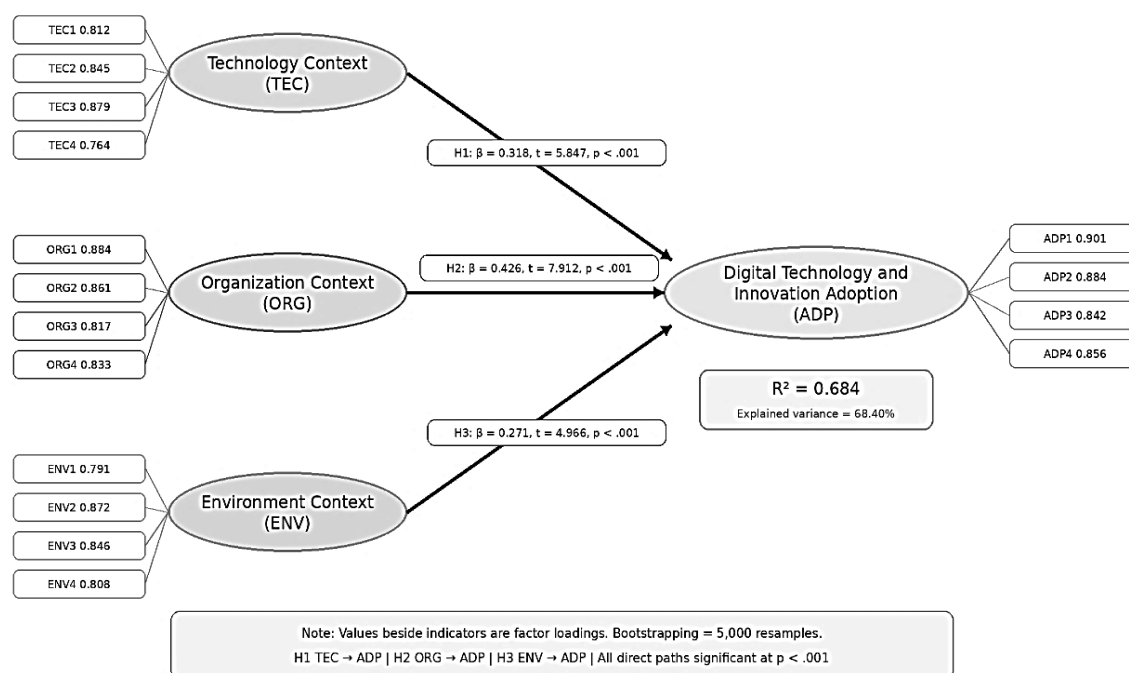
Environmental factors also had a positive and statistically significant effect on digital technology and innovation adoption ($\beta = .271$, $t = 4.966$, $p < .001$). The corresponding effect size was $f^2 = .096$, and H3 was therefore supported. Although environmental factors had the smallest direct effect among the three TOE dimensions, the findings demonstrate that government support,

competitive pressure, customer and partner expectations, and business network collaboration remained important external conditions influencing SME digitalization.

The relative magnitude of the standardized path coefficients was therefore: Organizational Factors ($\beta = .426$) > Technological Factors ($\beta = .318$) > Environmental Factors ($\beta = .271$).

Following the assessment of the measurement model, the structural model was evaluated to examine the hypothesized relationships between

the three TOE dimensions and digital technology and innovation adoption. As illustrated in Figure 1, all three exogenous constructs had positive and statistically significant effects on digital technology and innovation adoption. Organizational context exhibited the strongest effect ($\beta = .426$, $t = 7.912$, $p < .001$), followed by technology context ($\beta = .318$, $t = 5.847$, $p < .001$) and environment context ($\beta = .271$, $t = 4.966$, $p < .001$). The model explained 68.40% of the variance in digital technology and innovation adoption ($R^2 = .684$).



Note. TEC = technology context; ORG = organization context; ENV = environment context; ADP = digital technology and innovation adoption. Values adjacent to the indicators represent standardized factor loadings. Standardized path coefficients (β), t -values, and p -values were obtained using bootstrapping with 5,000 resamples. All direct effects were statistically significant at $p < .001$.

3.4 Explanatory Power, Predictive Relevance, and Model Fit

The coefficient of determination (R^2) was used to evaluate the proportion of variance in digital technology and innovation adoption explained by the three TOE dimensions. The structural model

yielded an R^2 value of .724, indicating that technological, organizational, and environmental factors collectively explained 72.40% of the variance in digital technology and innovation adoption.

Predictive relevance was assessed using Stone–Geisser's Q^2 . The Q^2 value was .512, exceeding zero and indicating satisfactory out-of-sample predictive relevance for the endogenous construct. Model fit was additionally evaluated using the standardized root mean square residual (SRMR), which yielded a value of .061, indicating an acceptable fit between the empirical data and the proposed model.

Table 5: Explanatory Power, Predictive Relevance, and Model Fit

Endogenous Construct	R ²	Adjusted R ²	Q ²	SRMR	Explained Variance
Digital Technology and Innovation Adoption	.724	.722	.512	.061	72.40%

The R² value of .724 demonstrates that the integrated TOE model possessed substantial explanatory power. Specifically, approximately 72.40% of the variation in digital technology and innovation adoption was accounted for by technological, organizational, and environmental factors, leaving 27.60% attributable to other factors outside the proposed model and residual variation.

The Q² value of .512 further demonstrates that the model had predictive relevance for digital

technology and innovation adoption. In combination with an SRMR value of .061, the findings indicate that the proposed structural model provided an acceptable representation of the empirical relationships among the study constructs.

3.5 Hypothesis Testing

Bootstrapping with 5,000 resamples was employed to assess the statistical significance of the hypothesized structural relationships. All three hypotheses were supported at $p < .001$.

Table 6: Summary of Hypothesis Testing

Hypothesis	Proposed Relationship	β	t -value	p -value	Result
H1	Technological Factors → Digital Technology and Innovation Adoption	.318	5.847	< .001	Supported
H2	Organizational Factors → Digital Technology and Innovation Adoption	.426	7.912	< .001	Supported
H3	Environmental Factors → Digital Technology and Innovation Adoption	.271	4.966	< .001	Supported

The results provided empirical support for H1, confirming that technological factors positively influenced digital technology and innovation adoption ($\beta = .318$, $t = 5.847$, $p < .001$). H2 was also supported, with organizational factors demonstrating the largest standardized path coefficient ($\beta = .426$, $t = 7.912$, $p < .001$). Finally, H3 was supported, as environmental factors had a significant positive effect on adoption ($\beta = .271$, $t = 4.966$, $p < .001$).

Overall, the hypothesis-testing results consistently support the central proposition of the TOE framework: organizational technology adoption is determined by the combined influence of technological conditions,

organizational capabilities, and environmental forces.

3.6 Overall Empirical Findings

The empirical findings demonstrate that digital technology and innovation adoption among SMEs in Upper Northern Thailand is shaped by the combined influence of technological, organizational, and environmental conditions. All three TOE dimensions had statistically significant positive effects on adoption, collectively explaining 72.40% of its variance ($R^2 = .724$).

The most important empirical finding was the dominant role of organizational factors ($\beta = .426$). This result indicates that the ability of

SMEs to successfully adopt digital technologies and innovation depends substantially on their internal organizational capacity. In particular, digital leadership, digital strategic planning, human resource readiness, and internal process capability constitute critical organizational foundations for digital transformation. The result implies that the acquisition of technology alone is unlikely to ensure successful digitalization unless an organization possesses the leadership, strategic direction, workforce capabilities, and operational flexibility required to effectively integrate technological change.

Technological factors ($\beta = .318$) represented the second strongest predictor. This finding demonstrates that technological and information readiness, perceived benefits, and compatibility remain important conditions for SME digital adoption. Firms are more likely to embrace digital technologies when they possess adequate technological infrastructure and information capabilities and perceive new technologies as beneficial and compatible with existing business processes.

Although environmental factors ($\beta = .271$) demonstrated the smallest direct effect among the three dimensions, their influence remained positive and statistically significant. This result confirms that SME digital transformation does not occur independently of the external business ecosystem. Government support, competitive pressures, changing expectations among customers and business partners, and access to collaborative networks all contribute to organizational decisions regarding digital technology and innovation adoption.

Taken together, the findings establish the following empirical hierarchy of drivers:

Organizational Factors ($\beta = .426$) >
 Technological Factors ($\beta = .318$) >
 Environmental Factors ($\beta = .271$) → Digital
 Technology and Innovation Adoption ($R^2 = .724$)

The results therefore demonstrate that digital technology and innovation adoption is not merely a technology-driven process. Rather, it represents a broader organizational

transformation shaped by the interaction of technological capabilities, internal organizational readiness, and external environmental conditions. Among these dimensions, strengthening organizational capacity appears to offer the greatest potential for accelerating digital transformation among SMEs. At the same time, technological preparedness and a supportive external ecosystem remain essential complementary conditions for enabling SMEs to effectively adopt, implement, and sustain digital technologies and innovation.

4. Discussion

The present study examined the effects of technological, organizational, and environmental contexts on digital technology and innovation adoption among small and medium-sized enterprises (SMEs) in Upper Northern Thailand. Drawing on the Technology–Organization–Environment (TOE) framework, the findings demonstrate that all three contextual dimensions exerted positive and statistically significant effects on digital technology and innovation adoption. Specifically, the organizational context emerged as the strongest predictor ($\beta = .426$, $t = 7.912$, $p < .001$), followed by the technology context ($\beta = .318$, $t = 5.847$, $p < .001$) and the environment context ($\beta = .271$, $t = 4.966$, $p < .001$). Collectively, the three TOE dimensions explained 68.40% of the variance in digital technology and innovation adoption ($R^2 = .684$). These findings provide empirical support for the applicability of the TOE framework in explaining organizational-level digital adoption among SMEs and demonstrate that successful digitalization is shaped not by technological considerations alone but by the combined influence of internal organizational capabilities and external environmental conditions.

4.1 The Influence of Technology Context on Digital Technology and Innovation Adoption

The results support H1, demonstrating that the technology context has a positive and statistically significant effect on digital technology and innovation adoption ($\beta = .318$, $t = 5.847$, $p < .001$). This finding indicates that SMEs with greater technological readiness, information

readiness, perceived benefits, and compatibility are more likely to adopt and integrate digital technologies and innovation into their business operations.

This result is theoretically consistent with the TOE framework, which proposes that an organization's technological context represents a fundamental determinant of its capacity and willingness to adopt technological innovations (Tornatzky & Fleischer, 1990). From an organizational perspective, the availability of appropriate technological infrastructure provides the foundation upon which digital initiatives can be developed. SMEs lacking reliable hardware, software, connectivity, information systems, and data-management capabilities may experience substantial barriers when attempting to implement more advanced digital technologies.

The importance of technology readiness observed in this study is particularly relevant to SMEs because smaller enterprises generally possess fewer financial and technological resources than large organizations. Consequently, their ability to undertake digital transformation may depend heavily on whether existing technological resources are sufficiently developed to accommodate new digital applications. However, technological infrastructure alone does not necessarily lead to adoption. The organization's capacity to collect, process, analyze, and utilize information also represents an important component of digital readiness because contemporary digital technologies increasingly rely on organizational data and information-processing capabilities.

The significant technological effect can also be interpreted through the perceived benefits and compatibility of digital technologies. SMEs are more likely to invest in technologies when decision-makers perceive tangible benefits, such as improved operational efficiency, reduced costs, increased productivity, enhanced customer service, broader market access, and improved competitiveness. This interpretation is consistent with the diffusion of innovations perspective, which emphasizes relative advantage and compatibility as important attributes influencing

innovation adoption (Rogers, 2003). When digital technologies are perceived as compatible with existing organizational processes, technological infrastructure, and business requirements, the uncertainty and disruption associated with implementation may be reduced.

The finding is also consistent with the broader conceptualization of digital transformation proposed by Vial (2019), who argues that digital technologies generate organizational disruptions that trigger strategic responses and changes in value-creation pathways. From this perspective, technological resources represent critical enablers, but their organizational value depends on how effectively firms incorporate them into broader processes of organizational transformation.

The present findings therefore suggest that technology context serves as an important enabling foundation for SME digitalization. Nevertheless, the standardized coefficient for technology context ($\beta = .318$) was smaller than that for organization context ($\beta = .426$). This difference is theoretically meaningful because it indicates that possessing or accessing technology may be necessary but insufficient for successful adoption. SMEs may have access to digital infrastructure and recognize the potential benefits of technology but remain unable to translate these resources into actual adoption if they lack organizational leadership, strategic direction, skilled employees, or adaptable internal processes.

4.2 The Influence of Organization Context on Digital Technology and Innovation Adoption

The most notable finding of the study concerns the organization context, which emerged as the strongest predictor of digital technology and innovation adoption ($\beta = .426$, $t = 7.912$, $p < .001$). The result provides strong support for H2 and indicates that digital leadership, digital strategic planning, human resource readiness, and internal process capability are particularly important determinants of digital adoption among SMEs in Upper Northern Thailand.

This finding reinforces the argument that digital transformation is fundamentally an

organizational transformation rather than merely a technological implementation process. Although organizations require appropriate technologies, the benefits of those technologies cannot be fully realized without corresponding changes in organizational strategy, structures, competencies, and processes. Vial (2019) similarly conceptualizes digital transformation as involving strategic organizational responses to technology-driven disruption and emphasizes the structural changes and organizational barriers that shape transformation outcomes.

The particularly strong effect of organization context may be explained by the characteristics of SMEs. In smaller enterprises, strategic decision-making is frequently concentrated among business owners and senior executives. Consequently, leaders can directly influence technology investment decisions, resource allocation, employee participation, organizational priorities, and the willingness of the firm to undertake change. Strong digital leadership may therefore accelerate adoption by creating a clear digital vision, communicating the strategic importance of technology, allocating necessary resources, and encouraging employees to participate in transformation initiatives.

Digital strategic planning represents another important component of this relationship. Technology investments made without alignment with organizational objectives may produce fragmented systems or underutilized technologies. By contrast, when digital initiatives are incorporated into strategic planning, SMEs can more effectively prioritize investments and align technological resources with business objectives. This argument corresponds with the concept of digital business strategy, in which digital resources increasingly become integrated with business strategy rather than remaining isolated within traditional information technology functions (Bharadwaj et al., 2013).

Human resource readiness also provides a plausible explanation for the dominant organizational effect. Employees ultimately interact with, implement, and utilize digital systems. An SME may invest substantially in

technology but fail to generate meaningful outcomes when employees lack the necessary digital competencies or willingness to adapt their work practices. The importance of human and organizational dimensions is also reflected in research synthesizing the factors that facilitate or constrain digital transformation, which identifies both technological and human components as central to firms' transformation processes (Feliciano-Cestero et al., 2023).

Similarly, internal process capability is essential because digital transformation often requires organizations to redesign workflows rather than simply digitize existing inefficient practices. Digital adoption can therefore necessitate changes in operating procedures, communication mechanisms, decision-making processes, customer interactions, and coordination across organizational functions. Recent digital-transformation research likewise emphasizes that digitalization can reshape organizational strategy, processes, and other organizational dimensions rather than functioning as a stand-alone technological intervention.

The dominant effect of organization context also has an important implication for understanding SME digitalization in regional economies. SMEs in Upper Northern Thailand may face constraints regarding access to sophisticated technologies or specialized external resources. Under such conditions, their internal capacity to mobilize available resources becomes particularly important. Effective leaders may compensate for resource limitations by prioritizing strategic digital investments, developing employee capabilities, creating partnerships, and gradually transforming internal processes.

The result is also broadly consistent with recent TOE-based research showing that digital transformation among SMEs depends on configurations of technological, organizational, and environmental conditions rather than a single isolated determinant. N'Dri and Su (2024), for example, examined TOE conditions in the digital transformation of exporting manufacturing SMEs and highlighted the relevance of multiple

configurations of TOE factors for transformation success.

Nevertheless, the present study adds an important contextual insight: among SMEs in Upper Northern Thailand, the organization context exerted the greatest direct effect. This suggests that internal organizational capacity may function as the primary mechanism through which technological opportunities and environmental pressures are converted into actual digital technology and innovation adoption.

4.3 The Influence of Environment Context on Digital Technology and Innovation Adoption

The results further support **H3**, demonstrating that the environment context positively and significantly influences digital technology and innovation adoption ($\beta = .271$, $t = 4.966$, $p < .001$). Although this effect was smaller than those of the organization and technology contexts, its statistical significance confirms that SMEs' digital adoption decisions are influenced by conditions beyond organizational boundaries.

This finding is consistent with the TOE framework, which recognizes that organizations operate within broader institutional, competitive, and interorganizational environments (Tornatzky & Fleischer, 1990). In the context of the present study, government support, competitive pressure, customer and partner expectations, and business network collaboration collectively represent external mechanisms that can facilitate or stimulate digital adoption.

Government support may be especially important for SMEs because resource limitations can restrict their capacity to independently finance technology investments, acquire specialist expertise, or provide advanced digital training. Government policies, financial support, infrastructure development, advisory services, and capacity-building programs can therefore reduce barriers to digitalization. Such support may be particularly relevant in regional contexts where digital resources and specialized expertise are less concentrated than in major urban centers.

Competitive pressure provides another mechanism through which the environment may accelerate digital adoption. As competitors increasingly utilize digital technologies to improve efficiency, enhance customer experiences, and develop innovative products and services, SMEs may face pressure to undertake comparable digital initiatives. Failure to respond may weaken their competitive position, particularly in markets where customers increasingly expect digital communication, transactions, and service delivery.

Customer and business-partner expectations similarly create external pressures for adoption. Digitalization increasingly affects how organizations communicate with stakeholders, coordinate supply chains, process transactions, and deliver services. SMEs may therefore adopt digital technologies not solely because of internally generated strategies but also because key customers, suppliers, and partners expect digitally enabled interactions.

The significant environmental effect is consistent with prior research conducted in Thailand. Mahakittikun et al. (2021), in examining mobile payment from the perspective of Thai retail and service firms, found that several TOE-related factors, including competitive pressure and external support, were relevant to firm outcomes. Although their technological context and dependent variable differ from those of the present study, the findings similarly demonstrate the importance of external pressures and support mechanisms in technology-related organizational behavior within Thailand.

At the same time, the comparatively smaller coefficient for the environment context ($\beta = .271$) suggests that external support and pressure alone may not be sufficient to generate adoption. Government programs can provide resources, competitors can exert pressure, and customers can demand digital services, but SMEs must still possess the technological and organizational capacity required to respond. Thus, the environmental context may function primarily as a catalyst or enabling condition, while the organization's internal capabilities determine its

capacity to translate external opportunities and pressures into actual adoption.

4.4 Integrated Interpretation of the TOE Framework

When considered collectively, the findings provide strong empirical support for the fundamental logic of the TOE framework. Technology, organization, and environment contexts jointly explained 68.40% of the variance in digital technology and innovation adoption ($R^2 = .684$). This level of explanatory power indicates that the TOE framework provides a useful multidimensional perspective for understanding digital adoption among SMEs in the study context.

The relative effects can be expressed as: Organization Context ($\beta = .426$) > Technology Context ($\beta = .318$) > Environment Context ($\beta = .271$) $\rightarrow$ Digital Technology and Innovation Adoption ($R^2 = .684$)

This ordering offers an important interpretation of the digital transformation process. Technology creates the capability and opportunity for digitalization; organizational conditions determine the capacity to mobilize and implement digital change; and the environment provides the external support, incentives, and pressures that encourage adoption.

The findings therefore challenge an overly technology-centric understanding of SME digitalization. Simply increasing access to digital tools may not be sufficient to generate meaningful adoption. Digital transformation requires firms to develop complementary organizational capabilities that allow technologies to be incorporated into strategy and business processes. This interpretation aligns with the broader digital transformation literature, which conceptualizes digital transformation as involving profound changes in organizational value creation, strategy, structures, and processes (Vial, 2019).

The findings also reinforce the value of examining digital transformation through an integrated rather than isolated perspective. Recent research has increasingly recognized that

successful digital transformation may emerge from combinations or configurations of technological, organizational, and environmental conditions. Evidence from exporting manufacturing SMEs, for example, suggests that different configurations of TOE factors can contribute to successful digital transformation, highlighting the interconnected nature of these conditions (N'Dri & Su, 2024).

For SMEs in Upper Northern Thailand, the findings imply a sequential but interconnected process. Firms first require sufficient technological readiness to participate in digital transformation. However, organizational capabilities particularly leadership, strategic planning, human resources, and adaptable processes appear to determine whether those technological resources are effectively converted into adoption. The external environment subsequently reinforces this process by creating competitive incentives and providing institutional and network resources.

4.5 Theoretical Implications

This study contributes theoretically to the literature in several ways. First, it provides empirical support for the applicability of the TOE framework to the study of digital technology and innovation adoption among SMEs. Rather than focusing on a single technology, the study conceptualizes adoption more broadly as an organizational phenomenon involving digital technologies and innovation. This approach reflects the evolving nature of digital transformation, in which multiple technologies and organizational changes increasingly converge.

Second, the findings demonstrate that the three TOE dimensions do not exert equivalent effects. The organization context emerged as the strongest predictor, suggesting that the explanatory relevance of the TOE framework may depend not only on the inclusion of its three contexts but also on their relative importance within specific organizational and institutional settings.

Third, the study extends empirical knowledge concerning digital adoption in a regional

emerging-economy context. Much of the digital transformation literature has developed across technologically advanced markets or major urban and industrial settings. Evidence from SMEs in Upper Northern Thailand demonstrates that the TOE framework remains relevant in a geographically dispersed regional context in which SMEs may face distinctive technological, human-resource, infrastructure, and institutional constraints.

Fourth, the results contribute to an organizational interpretation of digital transformation. The stronger effect of organization context suggests that digital adoption is not primarily a question of whether technology is available but whether organizations possess the capabilities required to exploit it. This finding supports the broader argument that digital transformation represents a strategic and organizational process rather than merely the deployment of information technologies (Vial, 2019).

4.6 Practical and Policy Implications

The findings provide several implications for SME owners, managers, policymakers, and business-support organizations. For SME owners and managers, the strongest organizational effect indicates that investments in technology should be accompanied by investments in organizational capabilities. Managers should establish a clear digital vision, integrate digitalization into strategic planning, develop employees' digital competencies, and redesign internal processes where necessary.

The significant technological effect indicates that SMEs should simultaneously strengthen their technological foundations. This includes not only hardware and software but also information management, data capabilities, system compatibility, and careful evaluation of the business benefits associated with technological investments. Technology selection should therefore be guided by strategic fit rather than technological novelty alone.

For policymakers, the findings suggest that policies designed to accelerate SME digitalization should extend beyond subsidies for purchasing

technology. Effective interventions should incorporate digital-skills development, leadership training, strategic advisory services, infrastructure support, and mechanisms for knowledge sharing. Because environmental conditions exert a significant effect, governments and regional development agencies can also facilitate adoption by strengthening digital ecosystems and connecting SMEs with technology providers, educational institutions, industry associations, and other business networks.

Overall, the findings suggest that successful SME digital transformation requires a coordinated ecosystem approach. Technological investment, organizational capability development, and environmental support should be developed simultaneously. Policies emphasizing technology provision without addressing organizational readiness may produce limited outcomes, while firms with strong organizational capabilities but inadequate technological infrastructure or external support may similarly struggle to sustain digital transformation.

4.7 Overall Discussion

Overall, this study demonstrates that digital technology and innovation adoption among SMEs in Upper Northern Thailand is best understood as a multidimensional organizational phenomenon. The significant effects of all three TOE contexts confirm that SMEs' adoption decisions are simultaneously embedded in technological capabilities, internal organizational conditions, and external environmental forces.

The strongest effect of organization context represents the central finding of the study. It suggests that while technological readiness enables digital transformation and environmental conditions encourage it, organizational capability ultimately plays the most influential role in translating digital opportunities into actual adoption. The results therefore shift attention from the question of whether SMEs have access to technology toward the broader question of whether they possess the leadership, strategy, human capabilities, and organizational processes required to use technology effectively.

With 68.40% of the variance in digital technology and innovation adoption explained by the TOE model, the findings provide substantial empirical support for an integrated approach to understanding SME digitalization. At the same time, the unexplained variance of 31.60% indicates that additional determinants may warrant examination in future research, including financial readiness, organizational culture, entrepreneurial orientation, digital capabilities, cybersecurity concerns, owner-manager characteristics, and institutional conditions.

Taken together, the findings demonstrate that SME digital transformation should not be approached as a one-dimensional technology investment decision. Instead, sustainable digital technology and innovation adoption requires the alignment of technological readiness, organizational capability, and environmental support, with internal organizational readiness serving as the most influential driver in the empirical context of Upper Northern Thailand.

5. Conclusion

This study demonstrates that technological, organizational, and environmental contexts significantly influence digital technology and innovation adoption among SMEs in Upper Northern Thailand. The findings provide empirical support for the Technology–Organization–Environment (TOE) framework, with the proposed model explaining 68.40% of the variance in digital technology and innovation adoption ($R^2 = .684$). Among the three dimensions, organizational context exerted the strongest influence ($\beta = .426$), followed by technology context ($\beta = .318$) and environment context ($\beta = .271$), with all relationships statistically significant at $p < .001$. These findings highlight that successful digital transformation depends not only on technological readiness but, more importantly, on organizational capabilities, including digital leadership, strategic planning, human resource readiness, and adaptable internal processes, supported by favorable external conditions. Therefore, SMEs seeking sustainable digital transformation should adopt an integrated approach that simultaneously strengthens

technological infrastructure, develops internal organizational capabilities, and leverages government support, competitive dynamics, stakeholder expectations, and business networks to enhance innovation, competitiveness, and long-term organizational sustainability.

Recommendations

Based on the findings, SMEs should prioritize strengthening organizational capabilities by developing digital leadership, integrating digital initiatives into strategic planning, enhancing employees' digital competencies, and redesigning internal processes to support technological change. Investments in digital infrastructure and information capabilities should be aligned with business needs to maximize perceived benefits and compatibility. Government agencies and policymakers should provide targeted financial assistance, digital-skills training, technological infrastructure, and advisory services, particularly for SMEs in regional areas. Furthermore, collaboration among SMEs, government agencies, educational institutions, technology providers, and business networks should be strengthened to facilitate knowledge exchange and access to digital resources. Future research should examine additional factors, such as financial readiness, organizational culture, digital capabilities, cybersecurity, and entrepreneurial orientation, and employ longitudinal or comparative designs to better understand the evolution of SME digital transformation across different industries and regions.

Future Research Directions

Future research should examine additional determinants of digital technology and innovation adoption, including financial readiness, organizational culture, digital capabilities, cybersecurity concerns, and entrepreneurial orientation. Longitudinal studies are recommended to capture changes in digital transformation over time and provide stronger insights into causal relationships. Comparative studies across industries, regions, and countries could further enhance the generalizability of the findings. Future studies may also integrate complementary theoretical perspectives and

investigate mediating or moderating mechanisms to provide a more comprehensive understanding of SME digital transformation and innovation adoption.

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Author Declaration

The authors declare that this manuscript is an original work, has not been previously published, and is not currently under consideration for publication elsewhere. All sources, theories, data, and scholarly contributions used in this study have been appropriately acknowledged and cited in accordance with established academic and ethical standards.

The authors declare that they have no conflicts of interest related to the research, authorship, or publication of this manuscript. All authors have reviewed and approved the final version of the manuscript and accept responsibility for the accuracy, integrity, and academic content of the work. The authors further confirm that the research was conducted in accordance with applicable institutional research and ethical standards and that the data and findings presented in this manuscript accurately represent the results of the study.