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TRANSFORMATIONAL LEADERSHIP AND KNOWLEDGE INFRASTRUCTURE AS ENABLERS OF DIGITAL READINESS

Liderança transformacional e infraestrutura de conhecimento como facilitadoras da prontidão digital

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ABSTRACT

This study investigates how transformational leadership enhances digital readiness among Malaysian micro, small, and medium enterprises (MSMEs) by mediating knowledge infrastructure. It addresses the managerial question of how leaders' decisions translate into technological preparedness in resource-constrained contexts. Drawing on Transformational Leadership Theory, Dynamic Capabilities Theory, and the Knowledge-Based View, this study proposes and tests the Leadership–Knowledge Infrastructure Readiness Model (LKIRM). Data from 500 MSME owner-managers were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) to examine both direct and mediated effects. Transformational leadership significantly influences digital readiness, both directly and indirectly, through knowledge infrastructure. Knowledge infrastructure partially mediates this relationship, confirming that leadership and technology jointly build MSME digital capabilities. MSME leaders who articulate a digital vision, allocate resources effectively, and promote knowledge sharing accelerate organisational readiness. Policymakers should align leadership development initiatives with digital infrastructure programs to close the sectoral readiness gaps. This study integrates behavioural and structural perspectives by validating LKIRM within an emerging-economy context. It provides empirical evidence that leadership behaviours act as micro-foundations of dynamic capabilities, enabling digital transformation among MSMEs.

Keywords: Transformational leadership, Knowledge infrastructure, Digital readiness, MSMEs

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LIDERANÇA TRANSFORMACIONAL E INFRAESTRUTURA DO CONHECIMENTO COMO FACILITADORES DA PRONTIDÃO DIGITAL

Transformational Leadership and Knowledge Infrastructure as Enablers of Digital Readiness

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RESUMO

Este estudo investiga como a liderança transformacional melhora a prontidão digital entre micro, pequenas e médias empresas (MPMEs) da Malásia, por meio da mediação da infraestrutura de conhecimento. Aborda a questão gerencial de como as decisões dos líderes se traduzem em preparação tecnológica em contextos com recursos limitados. Com base na Teoria da Liderança Transformacional, na Teoria das Capacidades Dinâmicas e na Visão Baseada no Conhecimento, este estudo propõe e testa o Modelo de Prontidão Digital Liderança–Infraestrutura de Conhecimento (LKIRM). Dados de 500 proprietários-gerentes de MPMEs foram analisados utilizando Modelagem de Equações Estruturais por Mínimos Quadrados Parciais (PLS-SEM) para examinar os efeitos diretos e mediados. A liderança transformacional influencia significativamente a prontidão digital, tanto direta quanto indiretamente, por meio da infraestrutura de conhecimento. A infraestrutura de conhecimento medeia parcialmente essa relação, confirmando que liderança e tecnologia constroem conjuntamente as capacidades digitais das MPMEs. Líderes de MPMEs que articulam uma visão digital, alocam recursos de forma eficaz e promovem o compartilhamento de conhecimento aceleram a prontidão organizacional. Os formuladores de políticas públicas devem alinhar iniciativas de desenvolvimento de liderança com programas de infraestrutura digital para reduzir as lacunas de prontidão setorial. Este estudo integra perspectivas comportamentais e estruturais ao validar o LKIRM no contexto de uma economia emergente. Ele fornece evidências empíricas de que os comportamentos de liderança atuam como microfundamentos das capacidades dinâmicas, viabilizando a transformação digital nas MPMEs.

Palavras-chave: Liderança transformacional, Infraestrutura de conhecimento, Prontidão digital, MPMEs

INTRODUCTION

Micro, small, and medium companies are significant for the growth of the global economy. They create 60% to 70% of all new jobs and are engines of inclusive growth ("The Role of ICT in MSMEs' Performance", 2018). They use local resources and can quickly adjust to market changes, making them more resilient to financial shocks than larger enterprises. MSMEs not only provide jobs but also boost regional economies via entrepreneurship, involvement in supply chains, and localised production links (Ng & Kee, 2018; Vrchota et al., 2019). Their collaborations with research institutes promote innovation and technology dissemination (Castro & Zermeo, 2020), and their corporate social responsibility (CSR) efforts enhance social and environmental sustainability.

Despite these benefits, MSMEs have significant trouble going digital. Limited funds, insufficient technical know-how, and integration issues sometimes slow the adoption of Industry 4.0 technologies, such as automation, cloud computing, and the Internet of Things (IoT) (Iqbal et al., 2023; Vrchota & Pech, 2019). High capital costs, low levels of digital literacy, and severe regulatory regimes, such as data protection laws, hinder their capacity to compete and grow. Consequently, many MSMEs prioritise short-term survival over long-term technical upgrades, missing opportunities for digital innovation (Ingaldi & Ulewicz, 2019). To address these structural problems, companies, industry groups, and regulators must work together to make it easier for people to access money, information, infrastructure, and digital skills. Digitalisation policies that work may help MSMEs adopt Industry 4.0 technologies, boost productivity, and grow sustainably (Bajic et al., 2020; Cotrino et al., 2020).In this environment of change, leadership and digital (knowledge) infrastructure are two areas of decision-making that affect MSME competitiveness (Li, 2024; Saleem et al., 2020). Leadership provides people with a strategic vision and the drive to generate new ideas.

In contrast, digital infrastructure equips them with tools to share information, collaborate, and make real-time decisions (Nguyen et al., 2021). Transformational leaders communicate a compelling digital vision, manage limited resources effectively, and cultivate an organisational culture that promotes learning and experimentation. However, leaders' efforts typically do not yield real digital capabilities without the proper knowledge infrastructure, including IoT systems, cloud platforms, and high-speed connections (Iqbal & Zulhasni, 2025; Putra et al., 2023). During disruptive events such as the COVID-19 pandemic, when MSMEs need flexible digital systems and quick-thinking leaders to keep going and stay strong, the relationship between leadership and infrastructure becomes even more important. Leaders who invest in digital skills and encourage information sharing help their organisations learn more and stay competitive in the long run (Sinyuk et al., 2021). However, because they lack resources and experience, many MSMEs in developing countries struggle to use Industry 4.0 technologies effectively (Hossin, 2023).

Thus, leadership shapes the strategic orientation and knowledge culture of MSMEs, while digital infrastructure enables the acquisition, storage, and dissemination of the knowledge necessary for technological adaptation. In this dynamic, transformational leadership serves as a knowledge catalyst, while infrastructure operates as a knowledge enabler, together forming the behavioural-technological underpinning of digital readiness. Although many people agree that digitisation is important, there is little empirical research on how transformational leadership and knowledge infrastructure interact in emerging Asia-Pacific nations. MSMEs in these areas face specific challenges, including fragmented digital ecosystems, uneven ICT maturity, and institutional gaps that hinder knowledge dissemination (Lei et al., 2022; Putra et al., 2023). It is essential to investigate the interplay between leadership behaviour and infrastructure capacities in fostering digital readiness, as this represents a significant research gap with direct implications for policy and management. Prior research on Industry 4.0 has concentrated chiefly on large enterprises or overarching adoption frameworks, neglecting sectoral and contextual diversity (Iqbal et al., 2024; Rahim et al., 2021). These studies often neglect the co-evolution of leadership and infrastructure within the unique constraints of MSMEs, where limited financial resources, human capital, and digital competence require a more integrated, knowledge-driven approach. In the MSME environment, leadership and ownership often overlap, making the strategic vision and knowledge culture closely linked. In emerging economies such as Malaysia, leadership-driven digital initiatives often replace formal processes and institutional backing, underscoring the significance of the interplay between people and technology.

This study addresses three important gaps in the literature. First, it places the relationship between leadership and infrastructure in the context of the resource-limited conditions of Asia-Pacific MSMEs, using Malaysia as a model of a developing economy. Second, it combines three related but distinct theories—Transformational Leadership Theory, Dynamic Capabilities Theory, and the Knowledge-Based View (KBV)—into a single framework to explain phenomena. Transformational Leadership Theory elucidates the mechanisms by which visionary and empowering actions cultivate trust and facilitate learning within teams, thereby catalysing transformation. Dynamic Capabilities Theory explains how companies can recognise, grab, and change resources in fast-changing digital environments, turning a leader's vision into flexible operations. The Knowledge-Based View provides the fundamental justification for treating knowledge as a strategic asset, whereby leadership behaviours and digital infrastructure collaboratively enhance knowledge skills that sustain competitive advantage. This study synthesises many views to formulate the Leadership–Knowledge Infrastructure Preparedness Model (LKIRM), which asserts that knowledge infrastructure serves as a mediator in the interaction between transformational leadership and digital preparedness. Third, it provides sector-specific insights by comparing manufacturing and service MSMEs—two sectors that differ in terms of technology intensity, digital maturity, and process structure. Previous studies indicate that manufacturing enterprises are often more digitally ready; however, empirical evidence comparing MSME sub-sectors is limited and ambiguous. This study investigates whether leadership and knowledge infrastructure have analogous impacts across industries, thereby advancing understanding of sectoral diversity in digital transformation and shaping the discourse on MSME digitisation from a knowledge management and decision-making perspective, framing digital readiness because of integrated leadership and infrastructure competencies. The results add to the Knowledge-Based View by showing how leadership and infrastructure can work together and provide MSME leaders and policymakers in emerging countries with helpful guidance on improving digital readiness.

1 REVIEW OF THE LITERATURE

1.1 Theoretical foundation and hypothesis development

This study amalgamates three synergistic theoretical frameworks—Transformational Leadership Theory (TLT) (Bass & Avolio, 1993), Dynamic Capabilities Theory (DCT) (Teece et al., 1997), and Upper Echelons Theory (UET) (Hambrick & Mason, 1984) to elucidate the interplay between leadership behaviour and knowledge infrastructure in facilitating digital readiness within MSMEs. Together, these viewpoints provide comprehensive knowledge of the behavioural, cognitive, and structural factors that facilitate digital change.

Transformational leadership is essential for organisational transformation because visionary leaders define digital objectives, inspire followers, and foster faith in innovation. They foster a knowledge-oriented culture that improves technological adoption and learning outcomes by defining goals, stimulating minds, and giving people greater control. Dynamic Capabilities Theory adds to this by describing how businesses identify opportunities, secure resources, and adapt routines to sustain digital adoption. These capacities depend not only on physical technology but also on learning processes guided by leaders that shape and evolve the organisation's knowledge. Upper Echelons Theory posits that executives' cognitive frameworks and beliefs influence strategic choices, including technological investments and the establishment of knowledge infrastructure.

These theories work together to form transparent explanatory chains. UET explains why leadership traits and cognition are important building blocks of dynamic capabilities. TLT explains how these traits manifest through empowerment and motivation. DCT explains how these behaviours are translated into firm-level capabilities through knowledge creation, resource alignment, and digital experimentation. This integration encompasses both the behavioural and structural mechanisms by which leadership impacts learning, informs digital infrastructure investment, and drives preparedness.

Industry 4.0 leverages technologies such as IoT, AI, big data analytics, and automation to make MSMEs more competitive (Vrchota et al., 2019; Garzoni et al., 2020). Thus, readiness includes being ready with technology (such as the cloud and the Internet of Things), being organised (such as having strong leaders), and having the right people (such as those with digital skills) (Hossin, 2023). MSMEs often face financial constraints and labour shortages (Bortnar & Pucihar, 2021). Leaders who do not see the long-term benefits of digital transformation may

make it much harder for businesses to embrace it. In contrast, diagnostic tools such as Industry4WRD and TRI help businesses measure their preparedness and improve it (Iqbal & Zulhasni, 2025; Techanamurthy et al., 2025).

The adoption of Industry 4.0 increases productivity, innovation, and competitiveness, thereby driving long-term growth. However, these advantages rely on good leadership training and a strong knowledge base (Rahim et al., 2021). Leadership sets strategic direction, allocates resources, and involves employees in change (Ametefe et al., 2025; Prabahar & Jerome, 2023; Li, 2024). Good governance strengthens planning, openness, and flexibility (Boateng, 2023). Leadership drives digital transformation by enabling innovation, technology adoption, and performance improvement (Nguyen et al., 2021; Lin, 2023).

Table 1 summarises empirical research that consistently demonstrates that leadership styles, especially transformational and digital leadership, have a beneficial impact on technology adoption in healthcare. However, contextual disparities across industries and company sizes produce divergent outcomes, highlighting the need for a comparative examination at the MSME level.

Table 1 - Summary of studies on leadership and technology adoption

Study	Focus of the study	Key Findings	Leadership style / traits examined
Senadjki (2023)	Impact of digital leadership on firm performance	Positive relationship between digital leadership and effective digital transformation	Digital leadership
Khaw et al. (2022)	A systematic review of leadership and technology adoption	Transformational leadership improves employee productivity and satisfaction	Transformational Leadership
Mihardjo et al. (2019)	Digital Leadership in Business Model Innovation	Digital leadership drives business model innovation and customer experience orientation	Digital leadership
Zulu & Khosrowshahi (2021)	Digital leadership in the construction industry	Transformational leaders enable successful digital transformation	Transformational Leadership
Lin (2023)	Strategic insight into digital transformation	Leaders with strategic insight and guiding ability navigate the complexities of technology	Strategic and Digital Leadership

1.2 Theoretical gaps and inconsistent findings

Even as more research on leadership and infrastructure emerges, the results remain ambiguous. Some researchers have stated that technical infrastructure, such as broadband and ICT access, is the most important factor in digital transformation. Others have stated that leadership vision and culture are the most important factors. This discrepancy indicates that neither technology nor behavioural variables alone are sufficient. A comprehensive knowledge infrastructure framework is essential, integrating leadership's role in promoting knowledge generation with infrastructure's function in facilitating knowledge dissemination.

A strong digital infrastructure aids technological preparedness, efficiency, and competition. Previous research indicates that IT architecture supports decision-making and creativity, while technology adoption increases organisational agility through tools such as AI. However, old systems slow down development. A good information infrastructure also aids operations and the environment (Lyu et al., 2022). According to Huang (2024), broadband access is associated with greater IoT adoption. For MSMEs, investing in digital infrastructure makes it easier to embrace new technologies and become more resilient in the face of crises.

Siemens, Amazon, and DBS Bank are examples of large companies that have made significant investments in digital infrastructure, such as IoT, AI, and cloud computing, to improve their operations and customer experience. However, these examples are from situations with abundant resources. It is still unclear whether they would work for MSMEs in poor countries like Malaysia, which lacks many resources. This shows the importance of having real-world proof in these situations (see Table 2).

Table 2 - Examples of successful transformations driven by digital investments

Industry	Organisation	Digital investments	Key Results
Manufacturing	Siemens	IoT, digital twins, automation	Optimised production, reduced costs, improved product quality
Retail	Amazon.com	Big Data Analytics, Artificial Intelligence, IoT Devices	Enhanced supply chain efficiency, improved customer experience
Healthcare	Cleveland Clinic	Telemedicine, AI diagnostics,	Improved patient care, streamlined administration, remote consultation
Agriculture	John Deere	IoT, GPS-guided machinery, AI analytics	Increased crop yields, optimised resources, reduced environmental impact
Finances	DBS Bank	AI, Blockchain, Cloud Computing	Streamlined banking processes, improved customer service,
Construction	Skanska	Building Information Modelling (BIM), IoT Sensors	Accurate project planning, real-time monitoring, and reduced waste
Education	Khan Academy	Digital Learning Platforms, AI Personalisation	Accessible education, personalised learning, global scalability

1.3 Research opportunities in MSME readiness

Given the complex interactions among leadership, digital infrastructure, and readiness, structural equation modelling (SEM) is an appropriate method for capturing direct and mediated effects. SEM's ability to model latent constructs is particularly valuable for MSME research, where multidimensionality and measurement errors are standard. The literature reveals three unresolved issues.

1. This study integrates transformational leadership, dynamic capability, and upper-echelons perspectives into a single LIRM that clarifies how leadership traits and infrastructure interact to shape readiness.
2. Examining sectoral differences between manufacturing and service MSMEs, given persistent readiness gaps suggesting unequal knowledge-infrastructure maturity.
3. Providing empirical validation from developing Asia-Pacific economies, where leadership–infrastructure interactions remain underexplored.

1.4 Digital maturity in SMEs

A recent study reconceptualised preparedness as digital maturity, a multifaceted construct encompassing technical, organisational, and human-learning components. Quenum et al. (2025) put forward a concept that shows how technological infrastructure and a leadership-driven culture function together. Similarly, research on Industry 5.0 readiness underscores that maturity is contingent not only on infrastructure but also on transformative leadership and ongoing learning. These results underscore the need to investigate how leadership fosters knowledge-sharing norms that facilitate digital progress. In emerging economies such as Malaysia, ecosystem fragmentation and resource asymmetry exacerbate these problems. Leadership and infrastructure must be integrated to achieve maturity.

1.5 Conceptual framework and hypothesis development

This study introduces the Leadership–Knowledge Infrastructure Preparedness Model (LKIRM), which builds upon Transformational Leadership Theory (Bass & Avolio, 1993), Digital Capability Theory (Teece et al., 1997), and Utilisation Effectiveness Theory (Hambrick & Mason, 1984). The model elucidates the combined impact of leadership and digital infrastructure on the digital preparedness of micro, small, and medium enterprises

(MSMEs) in India. Transformational leadership inspires change by providing vision and intellectual stimulation, enabling companies to develop and adapt to new circumstances (Nguyen et al., 2021; Mihardjo et al., 2019). DCT connects a leader's vision to a company's capacity to identify, leverage, and transform resources (Vrchota et al., 2019; Teece et al., 1997). UET elucidates the influence of leaders' cognition and values on strategic investments in digital infrastructure, transforming vision into structural preparedness (Hambrick & Mason, 1984).

In this approach, leadership works on two levels: behavioural and strategic. It directly improves readiness by motivating and aligning people and indirectly by shaping the development of digital infrastructure, which makes it easier for people to share information and use new technologies (Hossin, 2023; Lyu et al., 2022). Digital infrastructure, including the Internet of Things (IoT), cloud computing, and high-speed Internet, reflects the leadership's strategic vision (Huang, 2024). This interaction exemplifies the dynamic relationship between behavioural competencies and technical frameworks that facilitate MSME development (Li, 2024; Rahim et al., 2021).

Empirical data substantiate that transformational and digital leadership improve adaptation, engagement, and technology adoption (Khaw et al., 2022; Lin, 2023; Senadjki, 2023; Zulu & Khosrowshahi, 2021). In resource-constrained MSMEs, leadership alone may be inadequate without supplementary infrastructure (Cotrino et al., 2020). The LKIRM asserts that leadership and infrastructure interact synergistically to influence the preparedness for digital transformation.

Therefore, the following hypotheses are proposed:

H1: Transformational leadership positively affects digital preparedness by clarifying goals, allocating resources more effectively, and motivating employees.

H2: Digital infrastructure enhances digital readiness by providing people with the tools required to adopt and integrate new technologies.

H3: Digital infrastructure serves as an intermediary in the interaction between transformational leadership and digital readiness, in which leadership enhances readiness by strengthening infrastructure capabilities.

The LKIRM builds on earlier models by providing a mechanism-based, multi-level explanation of MSMEs' readiness. It defines transformational leadership as a behavioural micro-foundation that generates dynamic capabilities that manifest via digital infrastructure as organisational knowledge enablers. This theoretical framework clarifies not only the impact of leadership on preparedness but also the mechanisms through which this influence occurs by connecting behavioural intent with technical capability.

Figure 1 - Leadership infrastructure readiness model (LIRM)

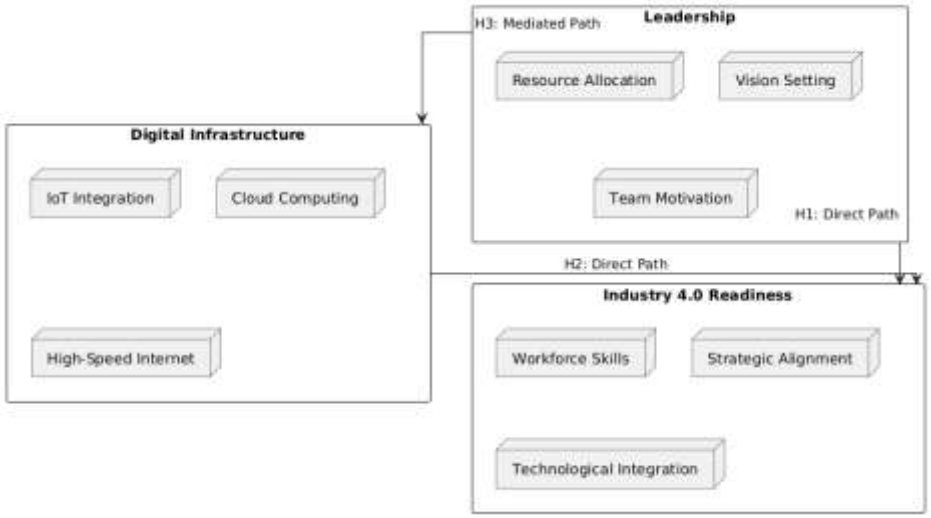


Table 3 - Conceptual framework and hypotheses of the LIRM

Path / Relationship	Theoretical Basis	Description	Hypothesis
Leadership → Industry 4.0 Readiness	Transformational Leadership Theory (Bass & Avolio, 1993); Dynamic Capabilities Theory (Teece et al., 1997); supported by Nguyen et al. (2021), Mihardjo et al. (2019), and Vrchota et al. (2019)	Leadership enhances Industry 4.0 readiness by clarifying vision, aligning resources, and motivating teams to adopt digital transformation	H1:
Digital Infrastructure → Industry 4.0 Readiness	Dynamic Capabilities Theory (Teece et al., 1997); supported by Lyu et al. (2022), Huang (2024), and Rahim et al. (2021)	Robust digital infrastructure provides technological capabilities, such as IoT, cloud computing, and connectivity, that directly support readiness.	H2:
Leadership → Digital Infrastructure → Industry 4.0 Readiness	Upper Echelons Theory (Hambrick & Mason, 1984); Transformational Leadership Theory (Bass & Avolio, 1993); supported by Putra et al. (2023), Hossin (2023), and Saleem et al. (2020)	Leadership decisions and cognitive orientations drive investments in digital infrastructure, which	H3:

3 METHODOLOGY

3.1 Sample and Data Collection

This study uses a quantitative, cross-sectional survey methodology to investigate the combined influence of transformational leadership and digital infrastructure on the digital preparedness of Malaysian MSMEs. This approach is suitable because it immediately gathers perceptual data from decision-makers accountable for resource allocation and technology adoption. A variance-based Structural Equation Modelling (PLS-SEM) methodology was used, enabling the concurrent estimation of reflective and formative constructs and the examination of mediation effects within a predictive framework. PLS-SEM is well known for being a good fit for exploratory models with medium-sized samples and non-normally distributed data (Hair et al., 2014).

3.2 The population and the process of sampling

The target demographic consisted of MSMEs in Malaysia's manufacturing and service sectors, as defined by SME Corporation Malaysia (small = 50 workers; medium = 50–250 employees). A stratified random sampling method ensured that each industry (manufacturing/service), area (north, central, south, and east coast), and business size was equally represented. The sample frame was obtained from various government sources, including Malaysian Manufacturers, SME Corp Malaysia, and regional chambers of commerce.

We contacted 1,200 companies and received 500 valid responses (response rate of 41.7%). Each response came from a senior decision-maker (owner-manager or top executive) who had been with the organisation for at least three years, ensuring that the answers were based on their personal experiences with leadership behaviour and digital preparedness. The selected sample surpassed the tenfold criterion and the statistical power requirement advocated for PLS-SEM, ensuring model stability.

3.3 Collecting data and following ethical guidelines

Data were collected from August to October 2024 using a standardised questionnaire distributed online and in person. All participants provided informed consent. Respondents were guaranteed anonymity and secrecy, with no individually identifiable information collected (Arifin, 2018).

3.4 Measurement and operationalisation of constructs

All constructs were assessed using validated multi-item measures modified from previous studies (see Table 4). Items for Transformational Leadership were based on Bass and Avolio (1993), while indicators for Digital Infrastructure were based on Lyu et al. (2022) and Huang (2024). Finally, Vrchota & Pech (2019) provided the metrics for Digital Readiness. A five-point Likert scale was used to rate items (1 = strongly disagree → 5 = strongly agree). In line with conceptual logic, leadership and preparation were seen as reflecting constructions, whereas digital infrastructure was seen as formative, embodying a composite technical potential. Indicator purification kept items with outside loadings of 0.40 or higher. We used Cronbach's > 0.70, Composite Reliability > 0.70, Average Variance Extracted (AVE) > 0.50, and HTMT < 0.85 to assess reliability and validity. Collinearity diagnostics verified indicator independence (VIF < 3.3). Table 4 summarises the sources and the measurement characteristics.

Table 4 - Constructs and sources

Construct	Source & Indicators	Scale Type
Transformational Leadership	Bass & Avolio (1993)	Reflective
Digital Infrastructure	Lyu et al. (2022); Huang (2024)	Formative
Digital Readiness	Vrchota & Pech (2019)	Reflective

3.5 Data screening and bias diagnostics

Non-response bias was tested using Armstrong and Overton's (1977) extrapolation method; early and late respondent means did not differ significantly ($p > 0.05$). Standard method bias was examined through Harman's single-factor test (most significant factor = 32.6%) and full-collinearity VIF < 3.3, confirming that standard method variance was not problematic (Podsakoff et al., 2003).

The control variables (firm size, years of operation, and sector) were retained in the model to test robustness (Rahim et al., 2021).

3.6 Analytical procedure

Data analysis followed a three-stage PLS-SEM approach using SmartPLS 4.0:

1. Measurement Model Assessment – Reliability and validity were verified using the AVE, CR, Cronbach's α, and HTMT criteria. For the formative indicators (digital infrastructure), outer weight significance and collinearity were evaluated (VIF < 5).
2. Structural Model Testing – Direct and mediating paths were estimated using bootstrapping (5,000 resamples, two-tailed $p < 0.05$). Predictive and explanatory power were assessed via R^2, f^2, and Q^2 (blindfolding) analyses. Model fit was examined using SRMR < 0.08, following Hair et al. (2021). Mediation significance was evaluated using bootstrapped confidence intervals (Baier et al., 2020).
3. Robustness and Multi-Group Analysis – Out-of-sample predictive accuracy was validated through PLSpredict, and multi-group analysis (MGA) was used to test sectoral differences (manufacturing vs services). Measurement invariance was confirmed using the MICOM procedure ($p > 0.05$).

3.7 Ethical considerations and data availability

This research followed the ethical guidelines of the *****, which granted formal clearance (Approval No. *****). Participants received detailed consent forms explaining the study's aims, the voluntary nature of participation, and confidentiality. No personally identifying data was collected, and all responses were anonymised and securely stored in compliance with the Declaration of Helsinki and Malaysian social-science standards. These procedures ensured compliance with participant rights, data integrity, and KMRP's ethical publication requirements (Arifin, 2018).

4 RESULTS

4.1 Model Fit and Explanatory Power

The Leadership–Knowledge Infrastructure Readiness Model (LKIRM) was tested using PLS-SEM in SmartPLS 4.0. The global model exhibited a satisfactory fit (SRMR = 0.045 < 0.08), indicating an acceptable residual structure. The model demonstrated a strong explanatory power.

- ✓ Transformational leadership and digital infrastructure jointly explained 62.6% of the variance in digital readiness ($R^2 = 0.626$).
- ✓ Leadership alone explained 25.4 % of the variance in digital infrastructure ($R^2 = 0.254$).
- ✓ Both R^2 values exceed the 0.26 threshold for substantial explanatory power (Hair et al., 2021), confirming that leadership and infrastructure are meaningful predictors of MSME DT.

4.2 Respondent Profile

Table 5 summarises the respondent characteristics. The sample (n = 500) comprised 54% manufacturing, 39% service, and 7% technology-based MSMEs. Most were small- or medium-sized enterprises with more than 10 years of operation. The respondents represented managerial, operational, technical, and support functions, providing balanced organisational perspectives.

Table 5 - Demographic Profile of Respondent MSMEs (n = 500)

Variable	Category	Frequency (%)
Firm Size	Micro (1–9 employees)	14
	Small (10–49 employees)	54
	Medium (50–250 employes)	32
Sector (Sub-sector)	Food Product	18
	Rubber & Plastic	15
	Fabricated Metal Products	13
	Machinery & Equipment	13
	Chemicals & Chemical Products	7
	Basic Metals	5
	Beverages	5
	Others (< 5 % each)	24
Years of Operation	< 3 years	4
	10–20 years	33
	> 20 years	35
Education	Degree	6
	Other qualification	40
Expertise	Support	32
	Operations	28
	Management	25
	Technical	15

Note: Sectoral proportions mirror the Industry4WRD Baseline Report (SIRI 2021)

4.3 Descriptive Statistics and Measurement Quality

Table 6 - Descriptive statistics of constructs

Construct	Mean	SD
Leadership	4.02	0.54
Digital Infrastructure	3.89	0.65
Digital Readiness	3.95	0.60

The reliability and validity were satisfactory (Table 7). Cronbach's $\alpha > 0.80$, Composite Reliability > 0.87, and AVE > 0.63confirm convergent validity. HTMT < 0.85 verified discriminant validity, and VIF < 3.0 ruled out multicollinearity.

Table 7 - Reliability and Validity of Constructs

Construct	Cronbach's α	CR	AVE
Leadership (L)	0.85	0.89	0.68
Digital Infrastructure (DI)	0.84	0.88	0.63
Digital Readiness (DR)	0.83	0.88	0.67

A re-estimation excluding the two lower-loading indicators (IR1 and IR2) produced a negligible change ($\Delta\beta < 0.02$), confirming the robustness.

4.4 Structural Model and Hypothesis Testing

Bootstrapping (5,000 resamples, two-tailed $p < 0.05$) revealed significant path coefficients for all hypotheses (Table 9).

Table 8 - Structural Path Coefficients and Hypothesis Testing

Hypothesis	Path	β	t	p	f^2	Result
H1	Leadership → Digital Readiness	0.45	6.87	< 0.001	0.27	**Supported**
H2	Digital Infrastructure → Digital Readiness	0.45	6.32	< 0.001	0.25	**Supported**
H3	Leadership → Digital Infrastructure	0.50	7.91	< 0.001	0.29	**Supported**

The effect sizes ($f^2 = 0.25–0.29$) indicate medium-to-large effects, implying that leadership and infrastructure have a substantial influence on readiness. The predictive relevance ($Q^2 = 0.39 > 0$) further confirmed the model's predictive capability.

Interpretation:

- ✓ *H1* → Transformational leadership directly enhances digital readiness; leaders' vision and motivation translate into organisational preparedness.

- ✓ *H2* → Digital infrastructure directly boosts readiness; connectivity and platform integration enable technology adoption.
- ✓ *H3* → Leadership also improves infrastructure capability, demonstrating a behavioural-catalyst effect.

4.5 Mediation Analysis

Digital infrastructure was tested as a mediator between leadership and readiness in this study (Table 9). The bootstrapped indirect effects were significant ($\beta = 0.18$, $p < 0.001$). The direct effect remained positive ($\beta = 0.45$, $p < 0.001$), resulting in a total effect of $\beta = 0.63$. The Variance Accounted For (VAF = 28.5 %) supports partial mediation, implying that leadership fosters digital readiness both directly and indirectly via infrastructure development.

These findings validate the behavioural–technological mechanism proposed in the LKIRM: leadership vision stimulates investments in knowledge infrastructure, which then translates into technological capabilities that enhance readiness.

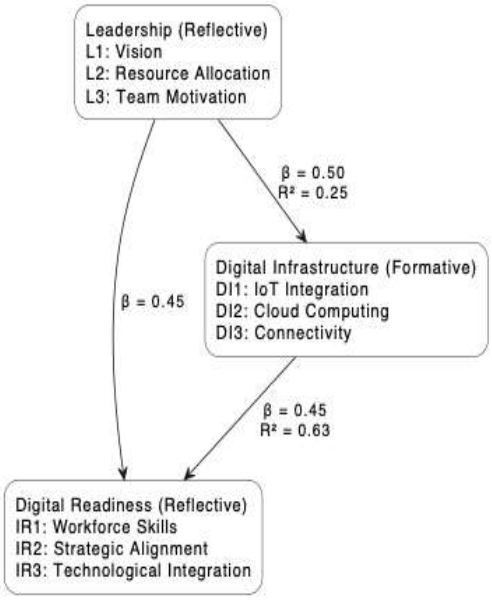
Table 9 - Mediation effects

Effect Type	Path	β	p	Mediation
Direct	Leadership → Digital Readiness	0.45	< 0.001	—
Indirect	Leadership → Digital Infrastructure → Digital Readiness	0.18	< 0.001	Partial
Tota	Leadership → Digital Readiness	0.63	< 0.001	—

4.6 Sectoral differences (manufacturing vs services)

MGA confirmed measurement invariance (MICOM $p > 0.05$). Manufacturing MSMEs exhibited slightly higher readiness (mean = 4.08) and a more decisive leadership → readiness path ($\beta = 0.48$) than service firms ($\beta = 0.39$); however, the difference was not statistically significant ($p = 0.068$). This suggests that leadership–infrastructure dynamics operate similarly across sectors, although manufacturing firms exhibit greater digital maturity. Figure 2 shows the validated LKIRM. Leadership exerts both direct and indirect effects on readiness through digital infrastructure, jointly explaining more than 60% of the variance in MSME digital readiness ($R^2 = 0.63$, SRMR = 0.045**). The model substantiates the proposition that transformational leadership activates knowledge-based and technological capabilities, aligning the behavioural and structural digital transformation enablers.

Figure 2 - Empirical representation of the LIRM SEM model



4.7 Predictive and Robustness Assessment

The PLS predict procedure indicated that the PLS-SEM model achieved lower RMSE values than the linear benchmarks, confirming strong out-of-sample predictive accuracy. Sensitivity tests with control variables (firm size, age, and sector) did not materially change the path coefficients ($\Delta\beta < 0.03$). These results demonstrate the robustness and stability of the estimated relationship.

5 DISCUSSION

This study aimed to analyse the interplay between transformational leadership and digital infrastructure in influencing the digital preparedness of Malaysian MSMEs. The results provide substantial empirical validation of the proposed LKIRM and enhance understanding of the interplay between behavioural and structural capacities in facilitating digital transformation.

5.1 Interpreting Key Findings

The findings validate the significant direct influence of transformative leadership on digital preparedness (H1). Leaders who communicate a vision, give staff authority, and use resources wisely make their organisations more prepared for Industry 4.0. This aligns with Bass and Avolio (1993) and Nguyen et al. (2021), who showed that leaders' behaviour is an important factor in technological advancement.

Digital infrastructure also has a significant direct effect on preparedness (H2). MSMEs can easily collaborate and exchange information through reliable connections, IoT platforms and cloud computing (Lyu et al., 2022; Huang, 2024). This emphasises the idea that technology turns a leader's vision into action.

The mediation analysis (H3) showed that digital infrastructure partially mediated the influence of leadership on preparedness. Leadership encourages investment in infrastructure and cultivates a culture that promotes knowledge exchange and digital experimentation. This partial mediation shows that leadership not only inspires people but also embeds learning into the organisation's structure. This supports Dynamic Capabilities Theory (Teece et al., 1997) by demonstrating that leaders use technical assets to activate routines for detecting, seizing, and reconfiguring.

These findings substantiate the behavioural-technological duality of digital transformation: transformational leadership provides cognitive and motivational drive, whereas digital infrastructure solidifies these intentions within systems and processes. The substantial predictive significance ($Q^2 = 0.39$) further demonstrates that the LKIRM encapsulates the critical processes of MSME digital readiness.

5.2 Theoretical Contributions

This research expands the current body of knowledge in several ways, including through an integrative theoretical model. The LKIRM provides a cohesive framework by integrating Transformational Leadership Theory, Dynamic Capabilities Theory, and Upper Echelons Theory, elucidating the co-evolution of human cognition and organizational infrastructure in shaping readiness.

Micro-foundations of Dynamic Capabilities. The findings indicate that leadership cognition and values serve as micro-foundations for capacity reconfiguration (Hambrick & Mason, 1984). Leadership choices thus represent behavioral precursors of technical capabilities. The approach rethinks digital preparedness as a mix of knowledge generation (leadership) and knowledge enablement (infrastructure), grounded in the Knowledge-Based View. This connects the intention behind behavior with the implementation of technology.

Contextual Evidence from Emerging Economies. The Malaysian MSME environment offers empirical insights into leadership-infrastructure interactions with resource limitations, enriching the underrepresented Asia-Pacific literature.

5.3 Managerial Implications – What This Means for Decision-Makers

Leadership Development as a Strategic Investment. Owner-managers should prioritise leadership training in their digital strategy. Programs that help people articulate their vision, communicate about change, and build a digital mindset may accelerate the transition.

Align Leadership with Infrastructure Planning. Digital initiatives work best when the strategic goals and the technology's ability to meet them evolve in tandem. MSMEs should establish "digital steering teams" that bring together representatives from different departments to ensure that IT implementation aligns with leadership direction.

Fostered Knowledge Infrastructure Culture. Infrastructure includes more than just hardware; it also includes knowledge systems such as document archives, CRM systems, and cloud-based collaborative applications that help people learn. To preserve the organisation's memory and promote creativity, leaders should make these platforms a part of the organisation.

Targeted Sectoral Support. To keep up with their manufacturing counterparts, MSMEs in the service sector need targeted support measures, including training in digital skills and shared service infrastructure. Public agencies can create incentives and programs to promote skills specific to each area.

Policy Implications. Government agencies should collaborate to fund leadership development programs, including entrepreneurial boot camps, with digital infrastructure funding. Integrated policies would strengthen national digital ecosystems and facilitate regional readiness.

For example, Malaysian MSMEs that adopted cloud-based ERP systems after participating in leadership-vision workshops (2023 SME Digital Catalyst Program) saw improvements in decision accuracy and process efficiency. These stories show that when transformative leadership is combined with infrastructure investment, several advantages are gained.

CONCLUSIONS AND LIMITATIONS

This study investigated the interplay between transformational leadership and digital infrastructure in shaping MSMEs' digital preparedness in Malaysia. Based on Transformational Leadership, Dynamic Capabilities, and Upper Echelons theories, the verified Leadership–Knowledge Infrastructure Preparedness Model (LKIRM) demonstrates that leadership enhances preparedness directly and indirectly via digital infrastructure. The partial mediation effect validates the behavioural-technological synergy: visionary leadership fosters investment in knowledge systems that transform strategic intent into digital capabilities. The LKIRM combines behavioural and structural perspectives, placing leadership cognition at the heart of dynamic capacities and expanding the Knowledge-Based View to MSMEs in emerging economies.

For a company to be competitive, it must simultaneously invest in leadership development and digital infrastructure. In this way, the manager's vision can be put into action. Limitations: (1) the cross-sectional methodology constrains causal inferences; (2) self-reported data may introduce bias; and (3) the findings are specific to the Malaysian context.

Future research: Longitudinal and multi-level studies might elucidate the evolution of leadership behaviours in relation to digital maturity; comparative analyses across ASEAN sectors may uncover contextual subtleties; and the incorporation of mediators such as organisational culture or learning orientation would enhance the model.

Transformational leadership is the driving force behind MSME digitalisation, and knowledge infrastructure is the framework that enables it. Together, they transform digital dreams into digital skills.

Statements & Declarations

Competing Interests

The authors declare that they have no competing financial or non-financial interests related to this study.

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Ethical approval

This study received ethical approval from the Ethical Review Committee, Pakistan (1 April 2024).

Data Availability

Data supporting the findings of this study, including responses from the structured survey, are confidential owing to the confidential nature of participant data. However, the data will be available from the corresponding author upon reasonable requests.

REFERENCES

Ametefe, M. D., Adamu, A. G., Umaru, F. A., & Ametefe, F.G. (2025). Impact of leadership on SME performance: A systematic review of its role in the enterprise. *Journal of the International Council for Small Business*, 1–3. https://doi.org/10.1080/26437015.2024.2443764

Amayreh, K. T. (2023). The Influence of Managerial Competencies on the Performance of Small and Medium Companies in Jordan. *International Journal of Academic Research in Accounting, Finance, and Management Sciences*, 13(2). https://doi.org/10.6007/ijarafms/v13-i2/17635

Arifin, S. R. M. (2018). Ethical considerations in qualitative studies International Journal of Care Scholars, 1(2), 30–33.

Armstrong, J. S., & Overton, T. S. (1977). Estimating nonresponse bias in mail surveys. *Journal of Marketing Research*, 14(3), 396–402.

Baier, A. L., Kline, A. C., & Feeny, N. C. (2020). Therapeutic alliance as a mediator of change: A systematic review and research evaluation. *Clinical psychology review*, 82, 101921.

Bass, B. M. & Avolio, B. J. (1993). Transformational leadership and organisational culture. *Public Administration Quarterly*, 112–121.

Boateng, P. (2023). Enhancing Organisational Agility using Agile Complexity Leadership. *Journal of Human Resource Management – HR Advances and Developments*, 2023(2), 135–143. https://doi.org/10.46287/ixxv8743

Bortnar, M.K. & Pucihar, A. (2021). Multi-Attribute Assessment of Digital Maturity of MSMEs. *Electronics*, 10(8), 885. https://doi.org/10.3390/electronics10080885

Bajic, B., Rikalovic, A., Suzic, N. & Piuri, V. (2020). Industry 4.0 Implementation Challenges and Opportunities: A managerial perspective. *IEEE Systems Journal*, 15(1), 546–559.

Brown, T. A. (2015). Confirmatory factor analysis for applied research. Guilford Publications.

Castro, M. P. & Zermeo, M.G.G. (2020). Being an Entrepreneur Post-COVID-19: Resilience in Times of Crisis: A Systematic Literature Review. *Journal of Entrepreneurship in Emerging Economies*, 13(4), 721–746. https://doi.org/10.1108/jeee-07-2020-0246

Cotrino, A., Pérez, M. S. & González-Gaya, C. (2020). Industry 4.0 Roadmap: Implementation for small and medium enterprises. *Applied Sciences*, 10(23), 8566. https://doi.org/10.3390/app10238566

Firman, F., Ekawarna, E., Anra, Y., & Setiawan, B. (2022). Influence of interpersonal conflict and social norms on the lecturer's organisational conflict and occupational stress. *International Journal of Instruction*, 15(4), 645–666. https://doi.org/10.29333/iji.2022.15435a

Gani, A., Imtiaz, N., Rathakrishnan, M. & Krishnasamy, H. N. (2020). A pilot test to establish the validity and reliability of qualitative interviews in the blended learning course for English proficiency. *Journal of Critical Reviews*, 7(05), 140–143.

Garzoni, A., Turi, I. D., Secundo, G., & Vecchio, P.D. (2020). Fostering Digital Transformation of MSMEs: A Four-Level Approach. Management Decision, 58(8), 1543–1562. https://doi.org/10.1108/md-07-2019-0939

Hambrick, D. C., & Mason, P. A. (1984). Upper echelons: The organisation as a reflection of its top managers. *Academy of Management Review*, 9(2), 193–206.

Hossin, M. M. (2023). Understanding the concept of MSMEs in driving economic growth and development in Bangladesh. *International Journal of Finance Economics and Business*, 2(3), 195–204. https://doi.org/10.56225/ijfeb.v2i3.147

Huang, C. (2024). The Economic Impact and Application Challenges of IoT Technology in the Smart Home and Infrastructure. *Journal of Innovation and Development*, 6(1), 35–39. https://doi.org/10.54097/y54jkp60

Hussain, A., Akbar, M., Shahzad, A., Poulová, P., Akbar, A., & Hassan, R. (2022). E-Commerce and MSME Performance: The Moderating Influence of Entrepreneurial Competencies Administrative Sciences, 12(1), 13. https://doi.org/10.3390/admsci12010013

Ingaldi, M., & Ulewicz, R. (2019). Problems with the implementation of Industry 4.0 in companies from the MSME sector. *Sustainability*, 12(1), 217. https://doi.org/10.3390/su12010217

Iqbal, M. S., Rahim, Z. A., Alshammari, A. M. K., & Iftikhar, H. (2024). Innovative strategies for overcoming barriers to technology adoption in small and medium-sized enterprises. *Journal of the International Council for Small Business*, 5(4), 331–344. https://doi.org/10.1080/26437015.2024.2367440.

Iqbal, M. S., Rahim, Z. A., & Ohshima, N. (2023). Enhancing Workforce Performance and Applications to Industry 5.0 with Malaysia's 5G Conceptual Framework. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 31(3), 282–289.

Iqbal, M. S. & Rahim, Z. A. (2025). Driving emerging technology adoption in Malaysian micro-, small, and medium-sized enterprises: A strategic intervention framework. *Journal of the International Council for Small Business*, 1–24. https://doi.org/10.1080/26437015.2025.2539866.

Iqbal, M. S., Rahim, Z. A., Omerkhel, Q., Iftikhar, H., & Khan, M. F. (2025). Leveraging AI and TRIZ for sustainable innovation in advanced manufacturing. *Discover Applied Sciences*, 7(6). https://doi.org/10.1007/s42452-025-06847-z

Jebb, A. T., Ng, V. & Tay, L. (2021). A review of key advances in Likert scale development: 1995-2019. *Frontiers in Psychology*, 12, 637547.

Kee, D.M.H. & Rahman, N.A. (2020). Entrepreneurial orientation, innovation, and MSME performance: A Study of MSMEs in Malaysia Using PLS-SEM. Gatr Global *Journal of Business Social Sciences Review*, 8(2), 73–80. https://doi.org/10.35609/gjbssr.2020.8.2(1)

Khaw, T. Y., Teoh, A. P., Khalid, S. N. A., & Letchmunan, S. (2022). The Impact of Digital Leadership on Sustainable Performance: A systematic review of the literature. *The Journal of Management Development*, 41(9/10), 514–534. https://doi.org/10.1108/jmd-03-2022-0070

Kuhail, M. A., Alturki, N., Alramlawi, S., & Alhejori, K. (2023). Interacting with Educational Chatbots: A Systematic Review. *Education and Information Technologies*, 28(1), 973–1018.

Lee, Y., Wang, P, Hung, W C, Tang, W H, Chang, Y H, Hu, D., Lu, Y C, Yu, T H, Wu, C C, Chung, F. M., & Hsu, C C (2020). https://doi.org/10.2147/dmso.s237700

Lei, J., Indiran, L., & Kohar, UH A. (2022). The Digital Transformation of MSMEs: The Difference between East and West in China. **I***nternational Journal of Academic Research in Business and Social Sciences*, 12(12). https://doi.org/10.6007/ijarbss/v12-i12/15718

Li, Z. (2024). How Distributed Leadership Affects Social and Emotional Competence in Adolescents: The Chain Mediating Role of Student-Centred Instructional Practices and Teacher Self-Efficacy. *Behavioural Sciences*, 14(2), 133. https://doi.org/10.3390/bs14020133

Lin, F. (2023). Executive Digital Leadership and Knowledge Management Under the Digital Transformation of Enterprises. *Journal of Innovation and Development*, 4(3), 23–26. https://doi.org/10.54097/jid.v4i3.12827

Lyu, Y., Ji, Z., Liang, H., Wang, T., & Zheng, Y. (2022). Has the information infrastructure reduced carbon emissions? Evidence from Panel Data Analysis of Chinese Cities. *Buildings*, 12(5), 619. https://doi.org/10.3390/buildings12050619

Mihardjo, L. W., Sasmoko, S., Alamsjah, F. & Elidjen, E. (2019). Digital Leadership Role in Developing Business Model Innovation and Customer Experience Orientation in Industry 4.0. *Management Science Letters*, 1749-1762. https://doi.org/10.5267/j.msl.2019.6.015

Ng, H. S., & Kee, D.M.H. (2018). The core competency of successful owner-managed MSMEs. *Management Decision*, 56 (1), 252–472. https://doi.org/10.1108/md-12-2016-0877

Nguyen, P., Huynh, H. T. N., Lam, L. N. H., Le, T. B., & Nguyen, N. H. X. (2021). The Impact of Entrepreneurial Leadership on MSMEs' Performance: The Mediating Effects of Organisational Factors, *Heliyon*, 7(6), e07326. https://doi.org/10.1016/j.heliyon.2021.e07326

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioural research: a critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88(5), 879–903

Pósch, K. (2019). Testing Complex Social Theories with Causal Mediation Analysis and G-Computation: Toward a Better Way to Do Causal Structural Equation Modelling. *Sociological Methods & Research*, 50(3), 1376–1406. https://doi.org/10.1177/0049124119826159

Prabahar, I. B. & Jerome, V.B. (2023). The Leadership Styles of Administrators and the Professional Effectiveness of Teachers Enlighten Innovation and Creative Learning Among Educational Institutions. *International Journal of Professional Business Review*, 8(5), e01996. https://doi.org/10.26668/businessreview/2023.v8i5.1996

Putra, R. E., Neswardi, S., Primadona, P., Jumyetti, J., & Yuanita, I. (2023). Impact of Digital Leadership on Small and Medium Enterprises' Resilience: The Mediating Role of Employee Creativity. *Amar (Andalas Management Review)*, 7(1), 35–61. https://doi.org/10.25077/amar.7.1.35-61.2023

Quenum, G. G. Y., Vallée, S., & Ertz, M. (2025). The digital maturity of small- and medium-sized enterprises in the Saguenay-Lac-Saint-Jean region. *Machines*, 13(9), 835. https://doi.org/10.3390/machines13090835

Rahim, Z. A., Rahman, N. A. A., & Iqbal, M. S. (2021). The National Industry 4.0 Policy Performance Review Based on the Industry4WRD Readiness Assessment and Intervention Programme. *International Conference of Reliable Information and Communication Technology*,

Ranatunga, R. V. S. P. K., Priyanath, H. M. S., & Megama, R.G.N. (2021). ICT Usage, Bounded Rationality, and Business Performance of MSMEs in Sri Lanka. *Colombo Business Journal International Journal of Theory and Practice*, 12(1), 54–86. https://doi.org/10.4038/cbj.v12i1.71

Ranatunga, RS, P.K., Priyanath, H. M. S., & RGN, M. (2020). Methods and Rules-of-Thumb in Determining Minimum Sample Size When Applying Structural Equation Modelling: A review. *Journal of Social Science Research*, 15, 102-107. https://doi.org/10.24297/jssr.v15i.8670

Techanamurthy, U., Iqbal, M. S., & Abdul Rahim, Z. (2025). Industry 4.0 readiness and strategic plan failures in smes: a comprehensive analysis. *PLOS One*, 20(5), e0324052. https://doi.org/10.1371/journal.pone.0324052

The Role of ICT in the Performance of MSMEs. (2018). Bappenas Working Papers, 1(1), 92-97. https://doi.org/10.47266/bwp.v1i1.12

Ryu, D.H. & Kim, K.J. (2024). The influence of information privacy concerns and perceived electricity use habits on the intention of using advanced metering infrastructure. *Renewable and Sustainable Energy Reviews*, 189, 113851.

Sakib, M. N., Rabbani, M. R., Hawaldar, I. T., Jabber, M. A., Hossain, J., & Sahabuddin, M. (2022). Entrepreneurial Competencies and MSMEs' Performance in a Developing Economy. *Sustainability*, 14(20), 13643. https://doi.org/10.3390/su142013643

Saleem, A., Aslam, S., Yin, H., & Rao, C. (2020). Principal Leadership Styles and Teacher Job Performance: Viewpoint of Middle Management. *Sustainability*, 12(8), 3390. https://doi.org/10.3390/su12083390

Senadjki, A. (2023). Unlocking the Potential: The Impact of Digital Leadership on Firms' Performance Through Digital Transformation. *Journal of Business and Socio-Economic Development*, 4(2), 161–177. https://doi.org/10.1108/jbsed-06-2023-0050

Sinyuk, T., Panfilova, E. & Pogosyan, R. (2021). Digital Transformation of MSME Business Models as a Factor of Sustainable Socio-Economic Development. *E3S Web of Conferences*, 295, 01028. https://doi.org/10.1051/e3sconf/202129501028

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic management journal*, 18(7), 509–533.

Vrchota, J. & Pech, M. (2019). Readiness of Companies in the Czech Republic to Implement Industry 4.0: Index of Industry 4.0. *Applied Sciences*, 9(24), 5405. https://doi.org/10.3390/app9245405

Vrchota, J., Volek, T. & Novotná, M. (2019). Factors that Introduce Industry 4.0 to MSMES. **Social Sciences**, 8(5), 130. https://doi.org/10.3390/socsci8050130

Yakin, N. (2023). The Mediating Role of Networking Competence in the Relationship Between Market Knowledge Capability and MSMES Performance. *Journal of Entrepreneur & Business*, 4(3), 182–191. https://doi.org/10.24123/jeb.v4i3.5929

Zulu, S. L. & Khosrowshahi, F. (2021). A Taxonomy of Digital Leadership in the Construction Industry Construction Management and Economics, 39(7), 565–578. https://doi.org/10.1080/01446193.2021.1930080