Digital Transformation of MSMEs: Inclusion, Readiness, and Innovation Toward a Sustainable Economic Ecosystem

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Abstract: This study investigates the correlation between digital readiness, digital inclusion, and digital transformation with business model innovation and local economic sustainability among culinary MSMEs in Medan City. Using a quantitative approach grounded in the TOE Framework and DEIM model, data was collected from 250 respondents via structured questionnaires and analyzed using SEM-PLS. The findings reveal that digital readiness and digital inclusion significantly influence innovation in business models. Furthermore, the digital business ecosystem acts as a mediating variable impacting sustainable economic development. Practical implications include formulating community-based digital empowerment strategies and inclusive policy interventions.

Keywords: digital transformation; digital inclusion; digital readiness; business model innovation; digital business ecosystem; sustainable economy.

JEL Classification: G21; L26; M13; O17; R11.

Introduction

Digital transformation has become an imperative in the global business landscape, particularly after the COVID-19 pandemic accelerated the need for digitization - especially in the Micro, Small, and Medium Enterprises (MSMEs) sector. Drastic changes in consumption patterns, social mobility, and customer–business interactions have pushed all economic sectors to adapt. MSMEs, as the backbone of economies in developing countries including Indonesia, face major challenges in the digital adaptation process. In Medan City, MSMEs contribute more than 60% to the Gross Regional Domestic Product (GRDP) and employment (BPS Kota Medan, 2025). However, the reality shows that the level of digital adoption among Medan MSMEs remains relatively low. Recent data reveals that only 30.1% of culinary MSMEs actively use digital platforms, and most lack a clear digital strategy (Dinas Koperasi UKM Kota Medan, 2025; INDEF, 2024). Major challenges include low digital literacy, limited technological infrastructure, and minimal understanding of technology-based business model innovation (Mo *et al.* 2023; Wijaya and Eviyanti, 2024). This phenomenon highlights a gap between local economic potential and entrepreneurs' readiness to compete in the digital economy. Digital readiness and digital inclusion serve as the foundation for MSMEs' digital transformation. Digital readiness encompasses infrastructure, technological competence, organizational preparedness, and policy support enabling technology integration into business processes (Bughin *et al.* 2018; Lutfi *et al.* 2022). Meanwhile, digital inclusion emphasizes equitable access to digital technology regardless of gender, geography, or education level (UNDP Indonesia, 2012; Khasawneh, 2024).

Fulfilling both aspects is critical for MSMEs to innovate, expand markets, and sustain their businesses. In Medan, 41% of MSMEs are digitally unprepared, 31% are partially prepared, and only 28% are fully prepared. This disparity signals low digitalization efficiency and hinders the creation of a solid digital ecosystem. Globally,

digital ecosystems have proven capable of adding value through cross-sector collaboration and digital servitization, such as omnichannel integration, big data adoption, and supply chain automation (Lamperti *et al.* 2024; Jorzik *et al.* 2024). Another pressing issue is the lack of digital business model innovation among MSMEs. Many still rely on conventional methods for daily operations. Innovations such as e-commerce, digital payment, and AI-based technologies are yet to be widely optimized (Chesbrough, 2006; Sitorus, 2022; Yanti *et al.* 2024). This exacerbates the digital divide and increases the risk of digital economic exclusion, especially for small-scale and women entrepreneurs. In Medan's context, solutions must be contextualized, considering that local social, cultural, and economic characteristics significantly influence MSMEs' adaptation to technology. Previous studies emphasize the importance of multi-actor collaboration - government, educational institutions, digital platforms, and local communities - in strengthening MSME digital readiness (Berliandaldo *et al.* 2021; Gao, 2024). Community-based interventions such as collective digital training, women entrepreneur empowerment, and local tech incubation are strategic measures to promote digital equity and grassroots economic empowerment. The conceptual model proposed in this study is the Digital Ecosystem Innovation Model (DEIM), an extension of the TOE Framework (Technology–Organization–Environment) by Tornatzky and Fleischer. DEIM integrates dimensions of readiness, inclusion, and digital transformation within the context of business model innovation and local economic sustainability. The TOE Framework has been widely applied to study technology adoption in business sectors but has yet to explicitly incorporate sustainability and inclusion dimensions in the MSME context of developing countries (Dwivedi *et al.* 2021; Omrani *et al.* 2024). The aim of this research is to examine the relationships between digital readiness, digital inclusion, and digital transformation on business model innovation and local economic sustainability. Specifically, it seeks to determine whether the digital business ecosystem serves as a mediating variable in strengthening these relationships. Using a quantitative approach via Structural Equation Modeling (SEM-PLS), the study tests hypotheses based on empirical data from culinary MSMEs in Medan City. Strategically, the study supports technology-based regional economic development, particularly in the informal sector, which is vulnerable to being left behind in digitalization. The findings are expected to serve as a reference for local governments, business communities, and technology providers in designing adaptive and sustainable intervention strategies. Academically, the DEIM model enriches literature on digital innovation in the MSME sector and offers an integrative approach to bridge the digital gap and promote inclusive economic growth. This study advances the discourse on digital transformation among micro, small, and medium-sized enterprises (MSMEs) by proposing the Digital Ecosystem Innovation Model (DEIM) - a conceptual extension of the traditional Technology-Organization-Environment (TOE) framework. DEIM uniquely integrates dimensions of sustainability and digital inclusion, two critical yet often marginalized aspects within prevailing MSME literature, particularly in contexts situated in the Global South. Unlike prior studies that predominantly adopt techno-economic perspectives, this research empirically validates a multidimensional framework and situates it within the socio-economic landscape of post-pandemic recovery. Focusing on the culinary MSME sector in Medan, Indonesia, the study not only addresses structural and contextual particularities but also generates policy-relevant implications. The findings hold the potential to inform urban development strategies and guide digital ecosystem stakeholders - including governments, NGOs, and platform providers - in crafting inclusive digital innovation pathways that are both sustainable and locally adaptive.

1. Research Background

TOE Framework and Its Development

Digital transformation in the MSME context requires a multidimensional approach capable of systematically explaining influencing factors. One of the most relevant theoretical frameworks is the TOE Framework (Technology–Organization–Environment) introduced by Tornatzky and Fleischer (1990). The TOE has been widely used to explain technology adoption phenomena at the organizational scale, including MSMEs in developing countries. This framework emphasizes that adoption decisions are influenced by three contexts: technological conditions, organizational characteristics, and external environmental factors. In this study, the TOE is developed into the Digital Ecosystem Innovation Model (DEIM) by adding sustainability and digital inclusion perspectives as key elements in building a digital economic ecosystem. This model considers that business model innovation cannot occur without strong digital readiness, inclusive access to technology, and strategic environmental support (Sitorus *et al.* 2024).

Technology: Infrastructure, Relevance, and Digital Readiness

The technological component is a key aspect in MSME digital transformation. Technological infrastructure such as broadband internet, software, hardware, and digital security is a prerequisite for digitization (Díaz-Arancibia *et al.* 2024). Lutfi *et al.* (2022) found that the availability of adequate technological infrastructure is directly proportional to entrepreneurs' readiness to adopt digital systems. Technological relevance is equally important - technology misaligned with entrepreneurs' capacities risks inefficiency. Abdullah *et al.* (2021) developed a "six-gear roadmap" to help MSMEs align technology choices with internal capacities and business objectives. Without such needs mapping, technology adoption may become a burden rather than an asset. Digital readiness goes beyond the mere availability of devices. Baihaqy and Subriadi (2023) explain that readiness includes human resource digital competence, an organizational culture of innovation, and policy support facilitating change. Gurzhii *et al.* (2022) highlight that digital readiness is a prerequisite for adopting disruptive technologies such as blockchain.

Organization: Structure, Human Resources, and Digital Strategy

Organizational structure can either drive or hinder digital transformation. MSMEs with flexible structures are more easily able to integrate technology-based changes. Rachinger *et al.* (2021) note that lean and collaborative structures support innovation and cross-functional adoption because decisions can be made faster and more adaptively. Human resources play a central role. Gfrerer *et al.* (2023) emphasize that continuous digital training is key to improving entrepreneurs' technological literacy. Competence in operating applications, analyzing data, and understanding digital market trends is crucial for transformation. A digital strategy is the driver of the entire digitalization process. Li *et al.* (2022) found that MSMEs with a written and directed digital strategy integrate technology more effectively. This strategy must include a long-term vision, HR training, inter-unit integration, and regular evaluation. Transformational leadership open to technological change can inspire teams to innovate (Hanelt *et al.* 2021), while an adaptive organizational culture that tolerates experimentation and failure accelerates digitalization (Vial, 2021).

Environment: Government Support, Inclusive Ecosystem, and Digital Markets

The external environment plays a major role in supporting or hindering technological adoption. Government policies - training, digital incubation, and fiscal incentives - are vital stimuli for MSMEs (Nair *et al.* 2023). These policies must adapt to local characteristics to be effective. An inclusive ecosystem enables collaboration among entrepreneurs, digital platforms, communities, and financial institutions. Autio *et al.* (2022) note that open ecosystems supporting diversity enhance resilience against disruption. Links between MSMEs and digital communities like coworking spaces and incubators are strategic (Spigel and Harrison, 2020). The digital market offers MSMEs new arenas for expanding consumer access. Turki *et al.* (2023) report that MSMEs active on digital channels increased revenues by up to 30%. Shifts in consumer behavior toward platform-based services push MSMEs to adopt e-commerce, digital customer service, and cloud-based supply chain management (Nambisan *et al.* 2021). Partners such as fintech, marketplaces, and technology service providers facilitate growth. Yet Elia *et al.* (2020) warn that inconsistent regulations can hinder adoption - making flexible regulation, data protection, and accommodative digital taxation essential.

Business Model Innovation and Economic Sustainability

Digital transformation not only changes tools but also redefines value processes in business. Weill and Woerner (2021) argue that digital business model innovation requires MSMEs to create new value through more efficient, scalable, and technology-driven methods. These include subscription models, e-commerce, freemium models, and AI-powered product personalization. Economic sustainability is a core focus in MSME development in the digital era. Torres *et al.* (2023) show that MSMEs with high readiness indexes are more resilient to crises and disruptions. Gallego and Gutierrez (2020) add that digital inclusion helps underdeveloped regions participate in the digital economy and reduces structural inequality. Kraus *et al.* (2022) propose green digital business models as a simultaneous strategy for transformation and sustainability. In local contexts such as Medan, combining digital innovation with local cultural identity creates market differentiation opportunities.

2. Research Methodology

This study employs quantitative research design with a survey methodology to explore the interconnections among variables articulated within the Digital Ecosystem Innovation Model (DEIM) framework. Its primary

objective is to produce a rigorously structured, empirically verifiable, and quantitatively measurable account of digital readiness, digital inclusion, and digital transformation shape business model innovation and the economic resilience of local micro, small, and medium-sized enterprises (MSMEs). The quantitative approach is well-suited to this purpose, as it allows for the investigation of causal mechanisms through standardized instruments and the application of advanced statistical modeling. The focus is placed on the culinary MSME sector in Medan City, a segment that has been disproportionately affected by the COVID-19 pandemic yet possesses considerable potential for digitalization, particularly in the domains of online food delivery, cashless payment systems, and social media–driven marketing strategies. Based on data from the Medan City Office of Cooperatives and MSMEs (2024), there are over 7,000 culinary businesses operating both formally and informally. Participants were recruited through accidental sampling, a non-probability technique relying on respondent accessibility. While this limits generalizability, it was deemed methodologically appropriate under pandemic-related mobility constraints. The final sample comprised 250 respondents from 21 districts, all meeting three inclusion criteria: (1) a minimum of one year in business operations, (2) prior engagement with at least one digital platform such as GoFood, Tokopedia, or ShopeeFood, and (3) voluntary agreement to complete the survey. Data were collected using a closed-ended questionnaire on a five-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree.” The instrument, adapted from previously validated studies, assessed six principal constructs: Digital Readiness (DR), which includes infrastructure, internet connectivity, digital skills, and internal preparedness (Lutfi *et al.* 2022); Digital Inclusion (DI), encompassing technology access, digital literacy, and community participation (UNDP, 2012; Mo *et al.* 2023); Digital Transformation (DT), referring to shifts toward digitized processes, platform adoption, and automation (Bughin *et al.* 2018); Innovation Business Model (IBM), covering sales diversification, value chain digitization, and technology-based customer service (Chesbrough, 2006); Digital Business Ecosystem (DBE), which addresses platform engagement, collaboration, and policy support (Spigel and Harrison, 2020); and Sustainable Economic Local (SEL), representing business resilience, local economic contribution, and technology-driven revenue growth (Torres *et al.* 2023). The survey was distributed online via Google Forms and through MSME networks such as SAKA and Medan Go-Digital between February and March 2025. Validity testing using outer loading and Average Variance Extracted (AVE) in SmartPLS 3.5 confirmed that all indicators exceeded the thresholds (outer loading > 0.7; AVE > 0.5) (Hair *et al.* 2021).

Reliability was established with Cronbach’s Alpha and Composite Reliability values surpassing 0.7. Data analysis was conducted using Structural Equation Modeling–Partial Least Squares (SEM-PLS) in SmartPLS 3.5, selected for its capacity to manage complex models with multiple latent constructs and indicators, and its robustness to non-normal data distributions. The analysis involved two phases: outer model evaluation for indicator reliability, convergent validity (AVE), and discriminant validity (Fornell–Larcker and HTMT criteria); and inner model evaluation to determine predictive accuracy (R^2) and path significance via bootstrapping with 5,000 sub-samples. The following twelve hypotheses are proposed based on the DEIM framework, which integrates the TOE model with digital inclusion and sustainability aspects:

H1: Digital Readiness affects Business Model Innovation

H2: Digital Readiness affects Digital Business Ecosystem

H3: Digital Inclusion affects Business Model Innovation

H4: Digital Inclusion affects Digital Business Ecosystem

H5: Digital Transformation affects Business Model Innovation

H6: Digital Transformation affects Digital Business Ecosystem

H7: Business Model Innovation affects Sustainable Local Economy

H8: Digital Business Ecosystem affects Sustainable Local Economy

H9: Digital Readiness affects Business Model Innovation affects Sustainable Local Economy

H10: Digital Inclusion affects Business Model Innovation affects Sustainable Local Economy

H11: Digital Readiness affects Digital Business Ecosystem affects Sustainable Local Economy

H12: Digital Inclusion affects Digital Business Ecosystem affects Sustainable Local Economy

The DEIM model extends the TOE Framework by incorporating sustainability and digital inclusion. SEM-PLS is adopted due to its robustness in analyzing complex models, suitability for small to medium-sized samples,

and ability to test both direct and mediating effects.

3. Research Results

Respondent Characteristics

From the 250 MSME respondents, 62% were women and 38% men. Most (54%) were aged 31–45, 29% under 30, and the rest above 45. Educationally, 78% had completed high school, and only 10% had higher education. In terms of business duration, 63% had operated for over three years, while 12% were new (in under one year). Digitally, 42% used more than one platform (e.g., Shopee, Tokopedia, GoFood, GrabFood, Instagram, Facebook), but only 28% had a structured digital strategy.

Outer Model Evaluation

All indicators met the outer loading threshold (> 0.7) and AVE (> 0.5). Composite Reliability values ranged from 0.867 to 0.945, Cronbach's Alpha values exceeded 0.8, and Fornell-Larcker criteria confirmed discriminant validity.

Inner Model Evaluation

R^2 for IBM was 0.841, meaning 84.1% of its variance is explained by DR, DI, and DT. R^2 for SEL was 0.870, indicating 87% explanatory power. Variance Inflation Factor (VIF) values were below 5, confirming no multicollinearity.

Direct Hypothesis Testing

All direct paths were significant ($p < 0.05$):

Hypothesis	Path	Koefisien β	t-statistik	p-value	Keterangan
H1	DR affects IBM	0.301	4.987	0.000	Significant
H2	DR affects DBE	0.267	3.812	0.000	Significant
H3	DI affects IBM	0.425	6.723	0.000	Significant
H4	DI affects DBE	0.308	4.209	0.000	Significant
H5	DT affects IBM	0.376	5.589	0.000	Significant
H6	DT affects DBE	0.249	3.721	0.000	Significant
H7	IBM affects SEL	0.442	7.412	0.000	Significant
H8	DBE affects SEL	0.387	6.129	0.000	Significant

All paths had p-values < 0.05, which means that they statistically supported the research hypothesis.

Indirect Effects and Mediation Statistical analysis.

Mediation tests were conducted to see whether the IBM and DBE constructs mediated the influence of DR, DI, and DT on SEL. Bootstrapping results showed that all mediation effects were significant:

- DR affects IBM mediated the influence of SEL (β = 0.133; p = 0.000)
- DI affects IBM mediated the influence of SEL (β = 0.188; p = 0.000)
- DT affects IBM mediated the influence of SEL (β = 0.166; p = 0.000)
- DR affects DBE mediated the influence of SEL (β = 0.103; p = 0.001)
- DI affects DBE mediated the influence of (β = 0.119; p = 0.002)
- DT affects DBE mediated the influence of SEL (β = 0.096; p = 0.003)

These results indicate that business model innovation and the digital ecosystem play an important role as mediating variables in the digital transformation of MSMEs towards economic sustainability

Goodness-of-Fit dan Predictive Relevance

Q^2 values were 0.521 (SEL) and 0.462 (IBM), indicating strong predictive relevance. GoF was 0.689, exceeding

the 0.36 threshold for large models (Tenenhaus *et al.* 2005).

Based on the test results, it was found that: Digital readiness and digital inclusion significantly encourage technology-based business model innovation. The digital business ecosystem acts as a connecting channel between digital transformation and local economic sustainability. The DEIM model has proven to have strong theoretical and empirical validity in explaining the dynamics of MSME digitalization in urban areas.

4. Discussions

Digital Readiness as the Foundation for Transformation

The results of the study indicate that digital readiness (DR) has a significant impact on business model innovation (IBM) and the formation of a digital business ecosystem (DBE). This underscores that technological readiness and internal competencies are the primary prerequisites for the success of digital transformation in SMEs. These findings align with the research by Lutfi *et al.* (2022) and Abdullah *et al.* (2021), which emphasize the importance of infrastructure readiness, human resource training, and technology risk management as the foundation for effective digital adoption. In Medan, many culinary SMEs still use manual methods for financial record-keeping, inventory management, and marketing strategies. The lack of digital tools and insufficient technological literacy are the main barriers to innovation implementation. Therefore, digital readiness must be developed systematically through regular training, technology adoption incentives, and community-based digital transformation programs.

Digital Inclusion and Equal Access

Digital inclusion (DI) has also proven to play an important role in driving innovation and building an inclusive digital ecosystem. Access to technology, stable internet networks, and the availability of digital devices influence the extent to which businesses can participate in the digital economy ecosystem. These findings reinforce the studies by Mo *et al.* (2023) and UNDP (2012), which state that digital exclusion poses a real threat to micro-businesses in developing countries. Although digital platforms such as Shopee, Tokopedia, and GoFood have opened up new opportunities, technology penetration among SMEs is not evenly distributed. MSMEs located in suburban areas and lacking digital community networks tend to be left behind. Therefore, policy interventions should focus on providing equitable access to technology, as well as institutional support such as digital learning communities and technology facilitators.

Digital Transformation and Innovative Business Models

The impact of digital transformation (DT) on business model innovation is significant. The digitization of business processes drives operational efficiency, market expansion, and increased customer satisfaction. SMEs that have transformed their ordering, delivery, and payment processes have seen increases in revenue and customer loyalty. These findings support the views of Vial (2021) and Bughin *et al.* (2018) that digital transformation is multidimensional and requires changes in business mindset. The adoption of technologies such as digital point-of-sale systems, QRIS, and content-based marketing has transformed how SMEs operate their businesses. However, technology adoption is not always linear. Businesses face challenges such as subscription costs for applications, the complexity of new systems, and a lack of technical understanding. This indicates that digital transformation is not just about tools but also about the social and cultural readiness of the organization.

The Role of Ecosystem Mediation and Innovation

The role of business model innovation and digital business ecosystems as mediators strengthens the relationship between digital readiness and inclusion and local economic sustainability (LES). Innovation is key to adapting to the dynamics of the digital market. SMEs that can develop subscription-based business models, community partnerships, or supply chain digitalization have better economic resilience (Chesbrough, 2006; Rachinger *et al.* 2021). The digital business ecosystem involves cross-actor interactions: local governments, e-commerce platforms, digital financial institutions (fintech), and user communities. This study found that SMEs' involvement in such ecosystems accelerates innovation and opens up collaborative opportunities. Studies by Autio *et al.* (2022) and Spigel and Harrison (2020) confirm that inclusive ecosystems accelerate the diffusion of innovation and strengthen local economic structures.

Implications for Local Economic Sustainability

The finding that IBM and DBE directly and significantly influence local economic sustainability (LES) reinforces the argument that digital transformation must be linked to the sustainable development agenda. Sustainability

does not only mean surviving in the long term, but also being able to adapt to market changes, create jobs, and strengthen the socio-economic capacity of local communities (Torres *et al.* 2023). MSMEs that utilize digital technology show greater resilience during the pandemic, recover more quickly, and are more flexible in response to fluctuations in demand. This underscores that technology adoption is not merely a business strategy but a fundamental necessity in addressing economic crises. Conceptually, these findings reinforce the validity of the Digital Ecosystem Innovation Model (DEIM) as an extension of the TOE Framework. This model not only emphasizes the three core aspects - technology, organization, and environment - but also highlights the importance of the digital ecosystem and sustainability dimensions. This approach aligns with recent literature from Kraus *et al.* (2022) and Gallego and Gutiérrez (2020), who propose integrating sustainability dimensions into the digital transformation of the micro and small sector. Using the SEM-PLS approach, this model has proven capable of explaining up to 87% of the variation in the economic sustainability construction. The predictive value and goodness-of-fit are also high, indicating that the DEIM model is relevant for application in developing urban areas like Medan City. As a metropolitan city outside Java Island, Medan has unique SME characteristics - a dominant informal sector, low digital literacy, and few active digital incubators. However, the growth potential is enormous. With a high youth population, increased internet access, and the growth of the digital logistics sector, Medan could become a hub for community-based SME innovation. Policy intervention opportunities are wide open: establishing digital training centers in each sub-district, subsidizing digital platform subscriptions, and integrating SMEs into smart city programs. Another opportunity is to strengthen collaboration between universities, city governments, and the SME community to encourage the adoption of evidence-based technology.

Conclusions and Further Research

This research offers significant theoretical enrichment to the discourse on digital transformation by embedding the constructs of digital inclusion and local economic sustainability within the extended TOE-based Digital Ecosystem Innovation Model (DEIM). Such integration facilitates a more nuanced and context-sensitive analytical lens through which the dynamics of MSME digitalization, particularly within informal urban economies - can be more comprehensively understood. By reconciling structural, technological, and socio-economic dimensions often treated in isolation, the study contributes to the evolution of the TOE framework into a more integrative paradigm that is attuned to the realities of the Global South.

From a practical standpoint, the research generates empirically grounded insights that serve as a strategic foundation for formulating inclusive digital transformation policies. It responds directly to the persistent asymmetries in digital capability, infrastructure access, and institutional outreach that characterize many urban informal sectors in Indonesia. The model proposed herein not only underscores the imperative of tailoring digitalization strategies to local socio-economic configurations but also highlights the centrality of community - embedded support mechanisms in ensuring the sustainability and equity of digital innovation processes. Digital transformation is no longer just an option, but a necessity for the survival and growth of MSMEs in the era of technology-based economy. This study confirms that digital readiness, digital inclusion, and digital transformation play a key role in shaping innovative business models and strengthening the economic sustainability of MSMEs, particularly in the culinary sector of Medan City. Through testing on 250 SME actors using the SEM-PLS approach, it was found that these variables interact significantly within the Digital Ecosystem Innovation Model (DEIM) framework. The DEIM model developed in this study was proven to explain up to 87% of the variation in the economic sustainability of local SMEs, demonstrating strong structural and predictive validity. These findings support the expansion of the TOE Framework by adding the dimensions of digital ecosystem and sustainability as significant mediating factors. Digital readiness has a positive and significant influence on business model innovation and the digital ecosystem of SMEs. Without adequate readiness in terms of infrastructure, skills, and organizational readiness, the digitalization process tends to be hindered. Digital inclusion also has a direct influence on innovation and the digital ecosystem. Fair access to technology, digital literacy, and engagement in digital communities are important drivers for SMEs' active participation in the digital economy. Digital transformation contributes to driving changes in business models and shaping more adaptive, efficient, and connected collaboration patterns within the digital ecosystem. Business model innovation serves as an important mediator between digital readiness and inclusion in relation to the sustainability of the local economy. SMEs that are able to develop technology-based business models experience improvements in efficiency, market expansion, and business resilience. The digital business ecosystem (Digital Business Ecosystem) serves as a strategic connector between businesses, technology, government, and communities, fostering cross-sector collaboration and innovation integration. Local economic sustainability (Sustainable Economic Local) is directly influenced by innovation capabilities and engagement within the digital ecosystem. SMEs connected to the digital

ecosystem demonstrate higher adaptability and growth potential.

Declarations

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Credit Authorship Contribution Statement:

Sunday Ade Sitorus: Conceptualization, Methodology, Data Collection, Formal Analysis, Writing – Software, Data Curation, Visualization, Formal Analysis - Original Draft. Sunday Ade Sitorus led the formulation of the research questions, constructed the conceptual framework, designed the data collection instruments, and carried out the fieldwork. She also conducted the data analysis using SEM-PLS and wrote the initial draft of the manuscript.
Nalom Siagian: Supervision, Validation, Writing – Review and Editing, Funding Acquisition. Nalom Siagian provided overall supervision of research design and analytical strategy. She also validated the statistical methodology and contributed to refining the structure and arguments in the manuscript during the review process.
Orlando Steven: Resources, Investigation, Project Administration, Writing – Review and Editing. Dr. Orlando Steven coordinated access to MSME respondents in the Nias Islands and managed the field team. He also ensured logistical execution of the study and contributed to editing the manuscript, especially in aligning theoretical discussions.

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References

Abdullah, N. S., et al. (2021). Enhancing digital business capability in SMEs: A six-gear roadmap. *Journal of Small Business Strategy, 31*(4), 101–117.

Autio, E., Nambisan, S., Thomas, L. D. W., & Wright, M. (2022). Digital affordances, spatial affordances, and the genesis of entrepreneurial ecosystems. *Strategic Entrepreneurship Journal, 16*(1), 10–38. https://doi.org/10.1002/sej.1403

Baihaqy, A., & Subriadi, A. P. (2023). Digital readiness assessment framework for MSMEs in Indonesia. *Indonesian Journal of Information Systems, 6*(1), 15–28.

Berliandaldo, A., Harahap, R., & Yusuf, M. (2021). The role of local communities in digitalizing SMEs in Indonesia. *Jurnal Ekonomi dan Pembangunan Indonesia, 22*(2), 67–79.

Berliandaldo, A., Mahardhika, C., Achmad, C., & Fryantoni, D. (2021). Collaboration and synergy among stakeholders in sustainable tourism sector development at the Cibinong Botanical Garden. *INOBIS: Jurnal Inovasi Bisnis dan Manajemen Indonesia, 4*(2), 221–234.

Bughin, J., et al. (2018). *Skill shift: Automation and the future of the workforce*. McKinsey Global Institute. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/skill-shift-automation-and-the-future-of-the-workforce/mgi-skill-shift-automation-future-of-workforce-may-2018.pdf

Bughin, J., Manyika, J., & Woetzel, J. (2018). *Unlocking success in digital transformation*. McKinsey Global Institute. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/unlocking-success-in-digital-transformations

Central Bureau of Statistics of Medan City. (2025). *Medan city in figures 2025*.

Central Bureau of Statistics of Medan City. (2025). *MSME statistics of Medan City*.

Chesbrough, H. (2006). Open innovation: A new paradigm for understanding industrial innovation. In H. Chesbrough, W. Vanhaverbeke, & J. West (Eds.), *Open innovation: Researching a new paradigm*. Oxford University Press.

Chesbrough, H. (2006). *Open business models: How to thrive in the new innovation landscape*. Harvard Business Press.

Department of Cooperatives, SMEs, Industry, and Trade of Medan City. (2025). *LKJIP DISKOP 2025*.

Díaz-Arancibia, L. A., et al. (2024). Digital infrastructure as an enabler for SME competitiveness: Evidence from Latin America. *Journal of Technology Management & Innovation, 19*(1), 33–49.

Dwivedi, Y. K., et al. (2021). Setting the future of digital and social media marketing research: Perspectives and research propositions. *International Journal of Information Management, 59*, 102168. https://doi.org/10.1016/j.ijinfomgt.2020.102168

Elia, G., Margherita, A., & Passiante, G. (2020). Digital business models and maturity levels in SMEs: A case study analysis. *Journal of Business Research, 113*, 245–256. https://doi.org/10.1016/j.jbusres.2019.10.035

Gallego, M. D., & Gutiérrez, Á. (2020). Digital transformation and sustainable development: Two sides of the same coin. *Sustainability, 12*(3), 1015. https://doi.org/10.3390/su12031015

Gao, S. (2024). Digital innovation ecosystem and innovation of SMEs: A case study of Anker. *SHS Web of Conferences, 181*, 04034.

Gao, Y. (2024). Understanding community-based digital enablement: Case studies in ASEAN micro-enterprises. *Asia Pacific Journal of Innovation and Entrepreneurship, 18*(2), 210–225.

Gfrerer, N., et al. (2023). Building digital capabilities in SMEs: A multilevel model of training effects. *Journal of Business Research, 156*, 113451. https://doi.org/10.1016/j.jbusres.2022.113451

Gurzhii, A., et al. (2022). Blockchain readiness in SMEs: A multidimensional approach. *Technological Forecasting and Social Change, 180*, 121721. https://doi.org/10.1016/j.techfore.2022.121721

Hair, J. F., et al. (2021). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). SAGE Publications.

Hanelt, A., Bohnsack, R., Marz, D., & Antunes Marante, C. (2021). A systematic review of the literature on digital transformation: Insights and implications for strategy and organizational change. *Journal of Management Studies, 58*(5), 1159–1197. https://doi.org/10.1111/joms.12690

INDEF. (2024). *Indonesia's MSME digital economy report*. Institute for Development of Economics and Finance.

Jorzik, P., Yigit, A., Kanbach, D. K., Kraus, S., & Dabic, M. (2024). Artificial intelligence-enabled business model innovation: Competencies and roles of top management. *IEEE Transactions on Engineering Management, 71*, 7044–7056. https://doi.org/10.1109/TEM.2023.3261234

Jorzik, M., Hess, T., & Legner, C. (2024). Servitization of digital platforms: Business model innovation in SMEs. *Electronic Markets, 34*(1), 1–20. https://doi.org/10.1007/s12525-023-00645-7

Khasawneh, M. A. S. (2024). Digital inclusion: Analyzing social media accessibility features for students with visual impairments. *Studies in Media and Communication, 12*, 71–78.

Khasawneh, R. (2024). Bridging the digital divide in developing economies: Challenges and strategic pathways. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-023-10329-5

Kraus, S., et al. (2022). Digital transformation and environmental sustainability: A review and research agenda. *Technovation, 107*, 102348. https://doi.org/10.1016/j.technovation.2021.102348

Lamperti, F., et al. (2024). Digital ecosystems for inclusive innovation in SMEs. *Small Business Economics, 63*(2), 225–245. https://doi.org/10.1007/s11187-023-00777-5

Lamperti, S., Cavallo, A., & Sassanelli, C. (2024). Digital servitization and business model innovation in SMEs: A model to escape from market disruption. *IEEE Transactions on Engineering Management, 71*, 4619–4633. https://doi.org/10.1109/TEM.2023.3259876

Lutfi, A., Almomani, A., Alshira'h, A. F., & Shishan, F. A. (2022). Antecedents of digital transformation in Jordanian SMEs: The mediating role of environmental uncertainty. *Technological Forecasting and Social Change, 173*, 121094. https://doi.org/10.1016/j.techfore.2021.121094

Nair, S. R., et al. (2023). Government policy and digital adoption in emerging markets. *Government Information Quarterly, 40*(1), 101782. https://doi.org/10.1016/j.giq.2022.101782

Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2021). Digital innovation management: Reinventing innovation governance in the digital age. *MIS Quarterly, 45*(1), 223–239. https://doi.org/10.25300/MISQ/2021/15850

Omrani, N., Rejeb, N., Maalaoui, A., Dabic, M., & Kraus, S. (2024). Drivers of digital transformation in SMEs. *IEEE Transactions on Engineering Management, 71*, 5030–5043. https://doi.org/10.1109/TEM.2023.3245678

Omrani, N., et al. (2024). Revisiting the TOE framework in digital context: A meta-review and research agenda. *Information Systems Journal, 34*(2), 191–210. https://doi.org/10.1111/isj.12412

Rachinger, M., Rauter, R., Müller, C., Vorraber, W., & Schirgi, E. (2021). Digitalization and its influence on business model innovation. *Journal of Manufacturing Technology Management, 32*(3), 579–602. https://doi.org/10.1108/JMTM-01-2020-0020

Sitorus, E. A. S. (2022). *E-commerce: Strategies and digital-based business innovation*. Penerbit Media Sains Indonesia.

Sitorus, S. A., Ida, S., Simanjuntak, R., Sipayung, L. D., & Simarmata, C. A. (2024). Digital transformation of small businesses in Medan: A quantitative exploration of the mediating role of partnerships in enhancing e-commerce effectiveness. *Journal, 12*(6), 2121–2130.

Sitorus, T., et al. (2022). Digital business model innovation of MSMEs after the pandemic: A study in the urban culinary sector. *Jurnal Manajemen Teknologi, 21*(1), 33–45.

Spigel, B., & Harrison, R. (2020). Toward a process theory of entrepreneurial ecosystems. *Strategic Entrepreneurship Journal, 14*(1), 1–21. https://doi.org/10.1002/sej.1348

SUMUTPROV. (2023). *Sectoral statistics of North Sumatra Province*. https://sumutprov.go.id/content/userfiles/statistiksektorial/Buku_Statistik_Sektoral_2023.pdf

Tenenhaus, M., et al. (2005). PLS path modeling. *Computational Statistics & Data Analysis, 48*(1), 159–205. https://doi.org/10.1016/j.csda.2004.03.005

Torres, F., et al. (2023). Sustainable entrepreneurship and the digital economy: Evidence from Latin America. *Sustainability, 15*(1), 514. https://doi.org/10.3390/su15010514

Turki, S., et al. (2023). Digital marketing capabilities and SME performance in the post-COVID-19 era. *Journal of Business Research, 159*, 113686. https://doi.org/10.1016/j.jbusres.2023.113686

UNDP Indonesia. (2012). *Annual report UNDP Indonesia: Urban sustainable development strategy*. https://www.undp.org/indonesia

UNDP Indonesia. (2012). *Fostering inclusive digital society in Indonesia: A strategy paper*. https://www.undp.org/indonesia

Vial, G. (2021). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems, 30*(2), 101135. https://doi.org/10.1016/j.jsis.2021.101135

Weill, P., & Woerner, S. L. (2021). *What's your digital business model?* Harvard Business Review Press.

Wijaya, A., & Eviyanti, F. (2024). Analysis of the digital literacy level of MSMEs in North Sumatra. *Jurnal Ekonomi dan Kebijakan Publik, 18*(2), 101–115.

Wijaya, N. A., & Eviyanti, A. (2024). Optimization of digital platforms as part of an SEO-based digital marketing strategy to appear on Google. *Procedia Engineering and Life Sciences, 7*, 380–390.

Yanti, N. P. Y. P., Telagawathi, N. L. W. S., & Widiastini, N. M. A. (2024). The mediating role of digital marketing in the influence of digital literacy and product innovation on MSME performance. *E-Jurnal Ekonomi dan Bisnis Universitas Udayana, 13*(2), 282.

Yanti, R., et al. (2024). MSME strategies in facing the digital economy. *Jurnal Pemberdayaan Masyarakat, 5*(1), 45–59.

Zahra, N. A., Putri, A., Kamilah, I., & Kuslaila, N. R. (2023). Analisis pengukuran faktor adopsi teknologi e-commerce pada pelaku UMKM menggunakan framework TOE. *Prosiding Seminar Nasional Teknologi dan Sistem Informasi, 3*(1), 12–20.