

Digital Transformation of MSMEs: Adaptation Strategies in the Era of Economy 4.0

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ABSTRACT

Purpose – This study examines how micro, small, and medium enterprises (MSMEs) adapt to digital transformation in the Economy 4.0 era and identifies the conditions under which digital adoption is associated with competitiveness and business resilience.

Methodology – The study uses a systematic integrative literature review reported against PRISMA 2020 principles. A fresh structured search conducted on 27 August 2026 retrieved 62 records through publisher-indexed searches across Elsevier/ScienceDirect, Springer Nature, Emerald, Taylor & Francis, and Wiley/SAGE/MDPI, with 14 additional records identified through backward citation checking. After duplicate removal, publication-window filtering (2020–2025), and title/abstract screening, 35 primary empirical studies were retained. The studies were appraised using MMAT-informed design-specific methodological domains, followed by structured data extraction and thematic synthesis.

Findings – Digital transformation outcomes are conditional rather than automatic. Digital resources, employee capabilities, managerial commitment, organizational agility, business networks, and ecosystem support jointly shape adoption. Digital technologies may support market access, process efficiency, business-model innovation, and resilience, but these outcomes depend on capability development, business-model reconfiguration, digital maturity, and contextual conditions. Persistent constraints include financing, digital skills, infrastructure, organizational resistance, and cybersecurity requirements.

Originality – The review advances an integrative framework linking external pressures and ecosystem support, internal readiness, staged digital adoption, dynamic capability development, business-model reconfiguration, and performance/resilience outcomes. It also explicitly incorporates boundary conditions such as firm size, sector, location, ownership, and digital maturity.

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1. Introduction

The Economy 4.0 era has reshaped global business patterns, including the operational dynamics of micro, small, and medium enterprises (MSMEs). Digital technologies such as the Internet of Things, big-data analytics, artificial intelligence, cloud services, and digital platforms increasingly influence how firms organize transactions, interact with customers, and reconfigure business processes. For MSMEs, digital transformation is therefore better understood as an organizational and capability-building process than as the acquisition of isolated technologies. Empirical studies associate SME digitalization with stronger market responsiveness, innovation, and, in some settings, financial performance; however, these outcomes depend on complementary resources and capabilities rather than technology adoption alone (Eller et al., 2020; Scuotto et al., 2021; Romero & Mammadov, 2024).

The COVID-19 pandemic accelerated digitalization across the MSME sector by altering mobility, customer interaction, and transaction patterns. Indonesian and international evidence shows that firms followed heterogeneous digital-transformation paths rather than a single universal trajectory. Some digitally mature SMEs accelerated broader transformation, whereas firms with liquidity constraints or lower digital literacy concentrated on specific functions such as online sales or relied on digitally capable partners (Priyono et al., 2020). Recent Indonesian evidence likewise suggests that digital strategy and competitive pressure can shape SME performance, but the strength of these relationships varies with organizational conditions (Prihandono et al., 2024).

Digital transformation nevertheless remains constrained by structural and organizational barriers. Financial limitations, employee resistance, shortages of qualified staff, limited knowledge of technology providers, weak digital culture, infrastructure gaps, and cybersecurity requirements can impede adoption and integration (Restrepo-Morales et al., 2024). These barriers indicate that technological availability is only one component of readiness; managerial commitment, human capability, financial capacity, and organizational learning determine whether technology is absorbed into routines and used strategically.

External conditions further shape what MSMEs can realistically achieve. Unequal broadband access, local ecosystem quality, availability of technology partners, institutional support, and business networks influence both the cost and feasibility of digital transformation. Prior reviews emphasize that SME digitalization is contingent on firm-specific baselines and ecosystem conditions rather than being reducible to a standardized technology-adoption sequence (Krismajayanti et al., 2024; Sagala & Őri, 2024).

At the same time, digital technologies create opportunities for market expansion, process integration, customer-value innovation, and new business models when they are aligned with firm capabilities. Dynamic-capability research shows that sensing, learning, seizing, and reconfiguration mechanisms help SMEs translate digital resources into customer value and organizational adaptation (Matarazzo et al., 2021; Khurana et al., 2022). Thus, the relevant question is not whether digitalization is inherently beneficial, but under what conditions MSMEs can convert digital adoption into sustainable business value.

For digital transformation to be feasible, MSMEs require contextual and progressive adaptation strategies. Evidence from Indonesian manufacturing SMEs identifies different transformation paths according to digital maturity, liquidity, digital literacy, and social capital (Priyono et al., 2020). Rather than treating one pathway as universally 'most effective', this evidence supports staged adoption in which firms prioritize market-facing tools, transaction

digitalization, process integration, and more advanced transformation according to their baseline capabilities and resource constraints.

Digital literacy and employee capability remain important, but they are not sufficient in isolation. [Eller et al. \(2020\)](#) show that employee skills and digital strategy are positively associated with digitalization, while neither factor alone guarantees financial performance. Research on digital self-efficacy and professional leadership similarly indicates that entrepreneur- and firm-level characteristics shape the transformation journey ([Malodia et al., 2023](#)). These findings support a complementarity perspective in which human capability must be aligned with technology, leadership, finance, and organizational processes.

From a public-policy perspective, government and ecosystem interventions can reduce adoption barriers, but support is likely to be most effective when differentiated by firm maturity and absorptive capacity. Early-stage firms may require connectivity, basic digital literacy, affordable payment and marketplace adoption, and trusted technical guidance, whereas more digitally mature firms increasingly require cybersecurity, data governance, process integration, analytics, and business-model innovation support. External support should therefore complement, rather than substitute for, internal capability development.

Considering the dynamics of these opportunities and challenges, it is clear that digital transformation requires a comprehensive approach involving human, technological, organizational, and environmental aspects. This article will discuss adaptation strategies that MSMEs can implement to effectively and sustainably carry out digital transformation in the era of economy 4.0. The discussion will focus on driving factors, obstacles, implementation strategies, and relevant policy recommendations to accelerate MSME digitalization. Based on theoretical foundations and empirical evidence from various recent studies, it is hoped that this article will provide a deeper understanding of how MSMEs can adapt and survive through appropriate and effective digital transformation.

Despite the rapid growth of research on MSME digital transformation, three gaps remain. First, evidence is dispersed across studies of readiness, adoption, dynamic capabilities, business-model innovation, ecosystem support, and performance, making it difficult to distinguish antecedents from mechanisms and outcomes. Second, recent empirical findings are heterogeneous rather than uniformly positive: digital orientation can show non-linear performance relationships ([Escoz Barragan & Becker, 2025](#)), transformation cost can weaken performance-related outcomes ([Rahman et al., 2025](#)), strategic foresight does not necessarily predict business-process digitalization ([Alqam & Razzak, 2025](#)), and digital maturity does not automatically strengthen the dynamic-capability–innovation relationship ([Jie et al., 2025](#)). Third, the literature still requires a traceable synthesis that differentiates firm-level empirical evidence from conceptual and secondary-review evidence. These gaps justify a systematic integrative review that both maps convergence and explains conditional or contradictory findings.

To address these gaps, the synthesis is organized through a Technology–Organization–Environment-compatible architecture combined with dynamic-capability logic. Technological conditions and ecosystem pressures define the external opportunity and constraint structure; human, managerial, financial, and organizational resources constitute internal readiness; and dynamic capabilities explain how firms sense opportunities, seize digital options, learn, and reconfigure routines and business models ([Matarazzo et al., 2021](#); [Khurana et al., 2022](#); [Soluk et al., 2023](#)). This architecture allows digital adoption to be treated as a staged process whose

effects on performance and resilience are conditional on complementary capabilities and context.

Accordingly, this study aims to: (1) identify the technological, human, organizational, and environmental factors that drive or constrain MSME digital transformation; (2) synthesize how staged adoption, dynamic capabilities, agility, ecosystem support, and business-model reconfiguration connect digitalization to innovation, performance, and resilience; (3) examine heterogeneity and boundary conditions across firm size, sector, geography, ownership, digital maturity, cost, and capability configurations; and (4) develop an integrative evidence-based framework and differentiated adaptation recommendations for MSME managers and policymakers.

2. Methodology

Review Design and Research Questions

This study adopts a systematic integrative literature review and reports the fresh search and study-selection process against PRISMA 2020 principles (Page et al., 2021). The integrative design was retained because the empirical literature includes qualitative case studies, cross-sectional surveys, mixed-method studies, secondary-data analyses, machine-learning approaches, and configurational methods. Four research questions guided the review: RQ1, which internal and external conditions enable or constrain MSME digital transformation? RQ2, through what staged processes and organizational capabilities is digital adoption converted into operational or strategic change? RQ3, under what boundary conditions does digital transformation relate to innovation, performance, or resilience? RQ4, how can these relationships be integrated into a coherent adaptation framework for MSMEs?

Information Sources and Search Strategy

A fresh structured search was conducted on 27 August 2026 for journal articles published from January 2020 through December 2025. Retrieval used 21 predefined query variants across publisher-indexed channels covering Elsevier/ScienceDirect, Springer Nature, Emerald, Taylor & Francis, and Wiley/SAGE/MDPI, supplemented by backward citation checking from directly relevant studies. The publisher-domain strategy was used to obtain a reproducible, record-level revision search in the available research environment; it should not be interpreted as a native Scopus or Web of Science export. The exact query log, raw-title export, duplicate decisions, screening decisions, exclusion reasons, and included-study register are provided in Supplementary File.

The search combined three concept blocks and publisher-specific variants. The core syntax was: ("digital transformation" OR digitalization OR "digital adoption" OR "digital maturity") AND (MSME OR MSMEs OR SME OR SMEs OR "micro small and medium enterprise" OR "small and medium enterprise") AND (strategy OR adaptation OR readiness OR barrier* OR driver* OR capability OR resilience OR performance OR "business model"). Additional variants paired digital transformation with dynamic capabilities, organizational readiness, business-model innovation, digital orientation, ecosystem support, resilience, barriers, adoption, and performance. Search strings were adapted to publisher-domain indexing while preserving the same concept blocks.

Table 1. Systematic review protocol

Protocol element	Specification
Review framework	Systematic integrative literature review; PRISMA 2020-informed reporting.
Fresh search date	27 August 2026.
Publication window	January 2020–December 2025.
Information channels	Structured publisher-indexed retrieval spanning Elsevier/ScienceDirect, Springer Nature, Emerald, Taylor & Francis, Wiley/SAGE/MDPI; supplemented by backward citation checking.
Search structure	21 predefined query variants built from digital transformation/digitalization/digital adoption/digital maturity + SME/MSME + strategy/adaptation/readiness/barriers/drivers/capabilities/resilience/performance/business model.
Document type	Peer-reviewed journal articles; primary empirical studies form the core evidence set.
Language	English or Indonesian.
Primary inclusion	SME/MSME-specific empirical evidence on digitally enabled organizational change, its determinants, mechanisms, barriers, strategies, capabilities, or outcomes.
Primary exclusion	Outside 2020–2025; substantively unrelated; secondary reviews/bibliometrics; conceptual-only studies; model-only papers without direct firm-level empirical evidence.
Selection outcome	76 records identified; 14 duplicates removed; 17 outside-window records removed; 45 screened; 10 title/abstract exclusions; 35 empirical studies included.
Quality appraisal	MMAT 2018-informed design-specific appraisal of all 35 empirical studies; strengths, limitations, and synthesis weight reported instead of a composite score.
Synthesis	Deductive–inductive thematic synthesis; TOE-compatible conditions + dynamic-capability mechanisms; explicit analysis of heterogeneity, null findings, risks, and boundary conditions.
Transparency	Supplementary File S1 contains the complete query log and record-level screening export; publisher-indexed rather than native Scopus/WoS retrieval is reported as a limitation.

Eligibility Criteria

Studies were eligible for the primary empirical synthesis when they: (1) were peer-reviewed journal articles published between 2020 and 2025; (2) were written in English or Indonesian; (3) focused explicitly on SMEs/MSMEs or reported an SME-specific analysis; (4) examined digital transformation, digitalization, digital adoption, digital maturity, or closely related digitally enabled organizational change; and (5) reported primary empirical evidence or direct firm-level secondary-data evidence relevant to drivers, barriers, adaptation processes, capabilities, business-model change, innovation, performance, or resilience. Secondary systematic reviews, bibliometric reviews, conceptual papers, purely methodological models, and articles without direct SME empirical evidence were excluded from the primary evidence set, although selected reviews were used only for contextual triangulation and backward citation checking. Records outside the 2020–2025 window and substantively unrelated articles were excluded.

Study Selection and Data Management

The fresh search identified 62 records through structured publisher-domain retrieval and 14 additional records through backward citation checking (total $n = 76$). Fourteen duplicate title records were removed, leaving 62 unique records. Seventeen records were then removed because their publication year fell outside the prespecified 2020–2025 window. Forty-five records entered title-and-abstract screening; 10 were excluded because they were secondary reviews, conceptual/theory syntheses, model-development papers without direct firm-level empirical evidence, or specialized barrier-ranking studies outside the primary empirical

scope. The remaining 35 reports were assessed for eligibility using publisher records and abstracts, supplemented by accessible full text where available; all 35 met the prespecified empirical eligibility criteria and were retained. One screening decision was recorded per item in the revision-stage export; no inter-reviewer agreement statistic was calculated, which is acknowledged as a limitation. The complete record-level audit trail is retained in Supplementary File S1.

Methodological Quality Appraisal

The 35 primary empirical studies were appraised using methodological domains informed by the Mixed Methods Appraisal Tool (MMAT), version 2018 (Hong et al., 2018). Because MMAT discourages collapsing heterogeneous designs into a single universal quality score, the appraisal records design/data appropriateness, methodological strengths, principal limitations, and the evidentiary weight assigned in the synthesis. No study was excluded solely because of design type; instead, large representative or well-specified quantitative studies received greater weight for broad association patterns, whereas qualitative and case-based studies were used primarily to explain process mechanisms, context, sequencing, and boundary conditions. Table 3 reports the appraisal transparently for all 35 primary empirical studies.

Data Extraction

A standardized extraction framework captured author and year, country and sector, sample or data source, research design, theoretical lens, digital-transformation construct, principal drivers and barriers, adaptation or capability mechanisms, outcome variables, contradictory or null findings, and study limitations. The record-level screening export was cross-linked with the included-study register so that every study used for a thematic claim can be traced to a retained search record. Secondary reviews were coded separately as contextual sources and were not counted as primary empirical evidence.

Thematic Synthesis and Analytical Framework

The 35-study empirical corpus was synthesized through a combined deductive–inductive thematic approach. Deductive categories reflected technological, human, organizational, and environmental conditions compatible with the Technology–Organization–Environment architecture, while dynamic-capability logic was used to distinguish sensing, seizing, transforming, agility, capability reconfiguration, and business-model mechanisms. Inductive coding captured additional recurring patterns including staged adoption, ecosystem intermediation, digital orientation, transformation cost, data quality, cybersecurity, absorptive capacity, ownership effects, non-linear performance relationships, and sector/location heterogeneity. Convergent and divergent evidence was then compared across designs and contexts to avoid treating digital transformation as a universally beneficial or linear intervention.

Transparency and Reproducibility

The search and study-selection procedures are documented in the Methods section through a description of the search strategy, eligibility criteria, publication window, and screening process. A total of 35 studies satisfied the predefined inclusion criteria and constituted the final evidence base. However, no separate database-native search export or detailed screening audit file was retained. Consequently, reproducibility is limited to the methodological information reported in the manuscript. Furthermore, screening decisions were made through a single-

reviewer decision process rather than independent duplicate screening. These limitations are explicitly acknowledged as potential constraints on the reproducibility and robustness of the review process.

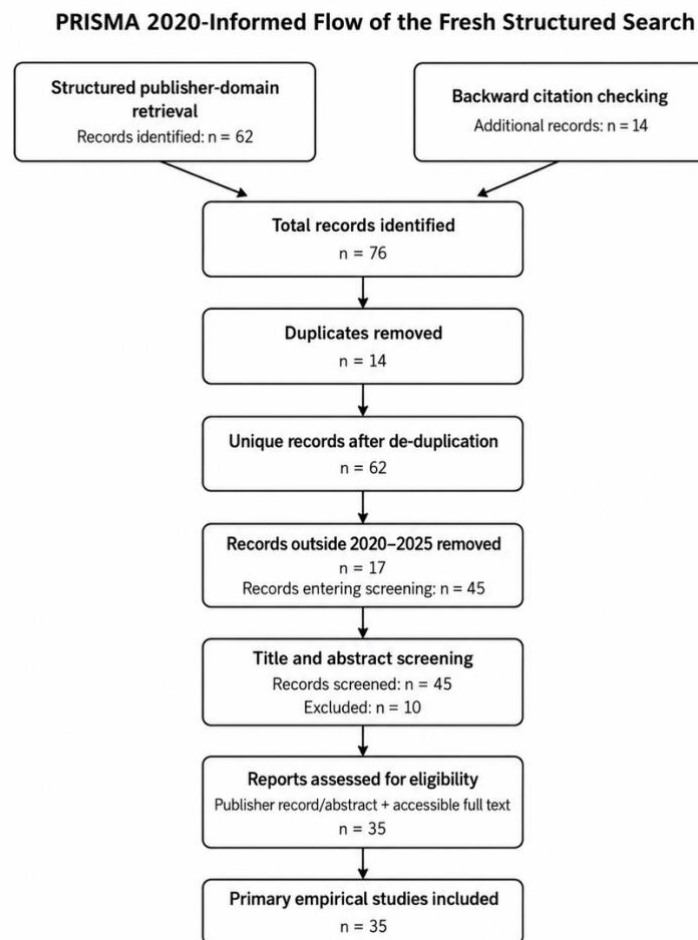


Figure 1. PRISMA 2020-informed flow of the fresh structured search and study-selection process

3. Result and Discussion

Characteristics and Heterogeneity of the Evidence Base

The fresh search produced a substantially broader and more traceable empirical corpus than the provisional revision audit. Thirty-five primary empirical studies published from 2020 to 2025 were retained. The evidence spans Indonesia, China, India, Malaysia, Thailand, Oman, Spain, Italy, Austria, Germany, the United Kingdom, Finland, Australia, and multi-country European samples, with designs ranging from qualitative multiple cases to large secondary datasets, mixed methods, PLS-SEM, probit models, machine learning, fuzzy logic/AHP, and project-taxonomy analyses. This heterogeneity is analytically useful because it permits comparison of mechanisms, associations, and boundary conditions, but it also prevents treatment of effect estimates as directly commensurable. [Table 2](#) therefore emphasizes study context, design, transformation focus, and synthesis contribution rather than pooling incompatible effects.

Table 2. Core studies informing the revised thematic synthesis

Study	Context / data	Design / lens	Digital-transformation focus	Key evidence for synthesis
Eller et al. (2020)	193 Austrian SMEs	Survey; resource-based view	IT, employee skills, digital strategy	Complementary resources support digitalization, but digital strategy or employee skills alone do not automatically translate into financial performance.
Priyono et al. (2020)	7 Indonesian manufacturing SMEs	Multiple case study; dynamic capability	Transformation paths during COVID-19	Three transformation paths vary with digital maturity, liquidity, literacy, and social capital; sequencing is context dependent.
Matarazzo et al. (2021)	6 Italian SMEs; food, fashion, furniture	Multiple case study; dynamic capabilities	Customer value and business-model change	Sensing and learning capabilities trigger transformation and enable new channels and value-creation mechanisms.
Scuotto et al. (2021)	2,156,360 European SMEs	Large-scale quantitative; microfoundations	Individual digital capabilities	Internal digital capabilities relate to growth, innovation, and rapid response to market change.
Andersen et al. (2022)	18 SMEs; 36 interviews	Case study; business-model innovation	Digital business-model experimentation	Opportunity search, urgency, experimentation, and balancing data-driven decisions with intuition shape digital BMI.
Troise et al. (2022)	204 innovative Italian SMEs	Survey; organizational agility	Digital, relational, innovation capabilities	Capabilities strengthen agility, which is associated with financial and innovation performance.
Khurana et al. (2022)	8 Indian SME entrepreneurs	Qualitative case study; dynamic capabilities	Digital transformation and resilience	Sensing, seizing, and transforming interact across entrepreneur, organization, and ecosystem levels; resilience develops as a higher-order capability.
Xie et al. (2022)	325 Chinese manufacturing SMEs	Empirical mediation model	Digital platforms and business-model innovation	Digital platforms support BMI partly through evolutionary and substitutional capability reconfiguration.
Sijabat (2022)	95 Indonesian MSME entrepreneurs	SEM; knowledge-management mediation	Business digitalization and knowledge management	Knowledge-management practices mediate part of the association between business digitalization and performance.
Malodia et al. (2023)	18 interviews + 369 Indian SME entrepreneurs	Mixed method	Digital self-efficacy and leadership	Entrepreneur digital self-efficacy and professional leadership shape the transformation journey; age and firm age are boundary conditions.
Skare et al. (2023)	European DESI and SME datasets	Comparative secondary-data study	Digitalization and business constraints	Digitalization relates to flexibility and fewer concerns about several constraints, while skilled-labour and managerial risks remain.
Soluk et al. (2023)	1,470 British SMEs	Multiple mediation; dynamic capabilities	Networks and non-disruptive digital technology	Business networks support adoption through domain-specific capabilities; capability effects are not uniformly positive.

Study	Context / data	Design / lens	Digital-transformation focus	Key evidence for synthesis
Putritamara et al. (2023)	388 Indonesian beekeeping MSMEs	Cross-sectional SEM; dynamic capabilities	Transformation and business resilience	Dynamic capabilities improve transformation, but the transformation–resilience relationship varies by family-business status.
Anatan & Nur (2023)	Indonesian MSMEs	Quantitative readiness assessment	Readiness for digital transformation	Readiness depends on financial, HR, marketing, operational, and organizational conditions rather than technology access alone.
Merín-Rodríguez et al. (2024)	434 innovative Spanish SMEs	PLS-SEM	DT, BMI, performance	Business-model innovation partially mediates the relationship between digital transformation and performance.
Arroyabe et al. (2024)	3,180 European manufacturing SMEs	Machine-learning analysis	Industry 4.0 and IT security	Cybersecurity issues co-evolve with digital maturity; firms display substantial heterogeneity from early adoption to advanced integration.
Restrepo-Morales et al. (2024)	4,531 SMEs	Fuzzy logic + AHP	Drivers and barriers of digitalization	Recurring barriers include finance, investment costs, resistance, skills, provider knowledge, digital culture, broadband, and IT security.
Prihandono et al. (2024)	171 SME owners in Java, Indonesia	Survey; PLS-SEM	Digital strategy, market competition, transformation	Digital strategy and market competition shape transformation and performance; transformation operates as a mediating mechanism.
Hermann et al. (2024)	210 German SME digital-innovation project reports	Taxonomy development + cluster analysis	Externally supported digital innovation projects	Ten project dimensions and five project types show that external support is heterogeneous and should be matched to project purpose and configuration.
Saeedikiya et al. (2024)	Australian mobility-sector SMEs	Multiple case study; dynamic capabilities	Enablers, barriers, and outcomes of DT	SME transformation depends on dynamic-capability development and sector-specific sensing, seizing, and reconfiguration mechanisms.
Hassan et al. (2024)	1,100 German SMEs	Mannheim Innovation Panel; probit models	Digital diffusion and innovation performance	Digital diffusion positively triggers innovation; absorptive capacity strengthens only selected innovation relationships rather than all outcomes.
Fang et al. (2024)	132 Malaysian SME managers	PLS-SEM; dynamic capabilities	Digital capability and digital BMI	Digital capability supports DBMI, but value-delivery innovation does not significantly improve competitiveness, demonstrating dimensional heterogeneity.
Liu et al. (2024)	262 Chinese SME managers	PLS-SEM; dynamic capabilities	DT, dynamic capabilities, BMI, performance	Digital transformation strengthens selected capability–BMI/performance relationships; BMI functions as a partial mechanism.

Study	Context / data	Design / lens	Digital-transformation focus	Key evidence for synthesis
Romero & Mammadov (2025)	802 Spanish SMEs	Representative CATI survey; multivariate analysis	Holistic determinants of DT	Technological, human, organizational, and relational determinants are complementary and differ between micro firms and larger SMEs.
Kallmuenzer et al. (2025)	7 SME managers across countries/industries	In-depth qualitative interviews	Adoption and performance outcomes	Digitalization outcomes depend on managerial interpretation, implementation fit, and organizational context rather than adoption alone.
Escoz Barragan & Becker (2025)	1,135 SMEs	Website textual + financial data	Digital orientation and performance	Digital orientation shows a non-linear/U-shaped relationship with performance, challenging simple linear-benefit assumptions.
Setiawan et al. (2025)	510 Indonesian MSMEs, Java/Jakarta	PLS-SEM; dynamic/agile capabilities	Digital skills, DT, capabilities, agility	Digital skills feed transformation and capability development; dynamic and agile capabilities jointly shape performance pathways.
Sultan & Riyadh (2025)	96 manufacturing SMEs in China and Indonesia	Semi-structured management survey; canvas model	Digital transformation configuration	Digital transformation configurations vary across canvas dimensions and contexts; technology selection should match organizational needs.
Rahman et al. (2025)	409 Oman SMEs	PLS-SEM; digital dynamic capabilities	DT and environmental performance	Digital sensing/capturing/transforming capabilities support DT, but transformation cost significantly weakens the DT–environmental-performance relationship.
Probohudono et al. (2025)	257 Indonesian MSME owners/managers using digital platforms	PLS-SEM; RBV + dynamic capabilities	Business strategy, innovation and digital IT capabilities	Innovation and digital IT capabilities partially mediate the business-strategy–performance relationship.
Alqam & Razzak (2025)	284 Oman SMEs	PLS-SEM; ORT + dynamic capabilities	Digital readiness, strategic flexibility/foresight, BPD	Digital readiness and strategic flexibility support process digitalization and performance; strategic foresight is non-significant.
Jie et al. (2025)	587 Chinese high-tech SMEs	PLS-SEM	Digital maturity, dynamic capabilities, innovation	Dynamic capabilities mediate digital maturity–innovation performance, but digital maturity does not moderate the capability–innovation relationship.
Boonmee et al. (2025)	Northern Thailand manufacturing SMEs + expert evidence	Mixed analytical approach: AHP/CVI, K-means, PCA	AI readiness, barriers, adoption roadmap	Four readiness profiles reveal heterogeneity; finance, skills, and data quality are major barriers; a four-phase adoption roadmap is proposed.
Seppänen et al. (2025)	22 incumbent SMEs	Multiple case study	Enablers/hindrances and digitized management	Employee skills and expertise have dual roles; skill gaps, resistance, legacy systems, leadership, and human-centric management shape transformation.

Study	Context / data	Design / lens	Digital-transformation focus	Key evidence for synthesis
Hafeez et al. (2025)	Innovation intermediaries, SMEs, and ecosystem actors in Finland	In-depth qualitative interviews; dynamic capabilities	Ecosystem intermediation for SME DT	Intermediaries deploy sensing, seizing, and transforming capabilities to connect SMEs with ecosystem resources and sustain long-term transformation.

The MMAT-informed appraisal was applied to all 35 empirical studies. No universal numerical quality score was calculated because the evidence base contains heterogeneous designs. Instead, Table 3 records design-specific strengths, limitations, and the evidentiary role of each study. Large or representative datasets provide stronger support for broad association or heterogeneity patterns, while qualitative and case-based studies provide stronger explanatory leverage for sequencing, capability development, managerial interpretation, and ecosystem mechanisms. Cross-sectional self-report studies are interpreted as association evidence and are not used to claim causality.

Table 3. MMAT-informed methodological appraisal of empirical core studies

Study	Design / data	MMAT-informed strengths	Principal limitation and synthesis weight
Eller et al. (2020)	Survey; 193 Austrian SMEs	Clear SME sample, resource-based model, direct test of digitalization and financial performance.	Cross-sectional/self-report; moderate association evidence.
Priyono et al. (2020)	Multiple cases; 7 Indonesian manufacturing SMEs	Theoretical sampling and rich process evidence from interviews/observation.	Small crisis-specific sample; mechanism/path evidence.
Matarazzo et al. (2021)	Multiple cases; 6 Italian SMEs	Rich capability-to-customer-value process evidence.	Sector/country cases; mechanism rather than prevalence evidence.
Scuotto et al. (2021)	Large-scale quantitative; 2,156,360 European SMEs	Very large dataset and broad population coverage.	Secondary/aggregate measures constrain firm-level causality; high weight for broad pattern.
Andersen et al. (2022)	18 SMEs; 36 interviews + documents	Triangulation and detailed BMI process evidence.	Context-dependent qualitative design; mechanism evidence.
Troise et al. (2022)	Survey; 204 innovative Italian SMEs	Explicit capability–agility–performance model.	Cross-sectional and innovative-SME focus; moderate association evidence.
Khurana et al. (2022)	Qualitative cases; 8 Indian SME entrepreneurs	Multilevel entrepreneur–organization–ecosystem analysis.	Small crisis-specific sample; resilience-process evidence.
Xie et al. (2022)	325 Chinese manufacturing SMEs; mediation model	Adequate sample and explicit capability-reconfiguration mechanism.	Cross-sectional manufacturing context; moderate-to-strong mechanism evidence.
Sijabat (2022)	SEM; 95 Indonesian entrepreneurs	Direct test of KM mediation in Indonesian MSMEs.	Small self-report cross-sectional sample; moderate contextual evidence.
Malodia et al. (2023)	Mixed method; 18 interviews + 369 survey respondents	Qualitative–quantitative integration and explicit boundary conditions.	Cross-sectional survey component; strong triangulated association evidence.
Skare et al. (2023)	European comparative secondary data	Cross-country scope and standardized digital indicators.	Ecological/aggregate measures; macro-pattern evidence.
Soluk et al. (2023)	Mediation study; 1,470 British SMEs	Large sample and explicit network/capability mechanisms.	Single-country, non-disruptive technology focus; strong within-scope evidence.
Putritamara et al. (2023)	SEM; 388 Indonesian beekeeping MSMEs	Adequate sample and ownership heterogeneity test.	Single sector/cross-sectional; conditional resilience evidence.

Study	Design / data	MMAT-informed strengths	Principal limitation and synthesis weight
Anatan & Nur (2023)	Quantitative readiness assessment; Indonesian MSMEs	Direct Indonesia relevance and multidimensional readiness framing.	Readiness-focused/context specific; contextual evidence.
Merín-Rodríguez et al. (2024)	PLS-SEM; 434 innovative Spanish SMEs	Adequate sample and explicit BMI mediation test.	Innovative-SME sampling/cross-sectional; strong mediation evidence within scope.
Arroyabe et al. (2024)	ML analysis; 3,180 European manufacturing SMEs	Large sample and explicit digital-maturity/security heterogeneity.	Manufacturing/secondary data; high barrier/heterogeneity weight.
Restrepo-Morales et al. (2024)	Fuzzy logic + AHP; 4,531 SMEs	Large sample and multi-criteria driver/barrier analysis.	Method-dependent weighting/cross-sectional; high recurring-barrier evidence.
Prihandono et al. (2024)	PLS-SEM; 171 Java SME owners	Direct test of digital strategy, competition, transformation and performance mediation.	Purposive regional cross-sectional sample; moderate mechanism evidence.
Hermann et al. (2024)	210 German SME project reports; taxonomy/cluster	Practice-derived project data and systematic project-type differentiation.	Externally supported projects/Germany; moderate configuration evidence.
Saeedikiya et al. (2024)	Multiple cases; Australian mobility SMEs	Deep process evidence for SME dynamic capabilities in sectoral transformation.	Small sector-specific case base; mechanism evidence.
Hassan et al. (2024)	1,100 German SMEs; innovation panel/probit	Large standardized dataset and multiple innovation outcomes.	Observational innovation focus; strong association evidence, limited causal claims.
Fang et al. (2024)	PLS-SEM; 132 Malaysian SME managers	Dimension-specific DBMI model including a non-significant outcome path.	Small purposive cross-sectional sample; moderate conditional evidence.
Liu et al. (2024)	PLS-SEM; 262 Chinese SME managers	Explicit dynamic-capability/BMI/performance model with DT moderation.	Cross-sectional single-country; moderate contingency/mechanism evidence.
Romero & Mammadov (2025)	Representative survey; 802 Spanish SMEs	Representative SME evidence and micro-vs-larger-SME comparisons.	Single-country cross-sectional design; strong determinant/heterogeneity evidence.
Kallmuenzer et al. (2025)	7 in-depth SME-manager interviews	Rich managerial interpretation and cross-industry qualitative evidence.	Small manager-perspective sample; mechanism evidence.
Escos Barragan & Becker (2025)	1,135 SMEs; website text + financial data	Non-survey digital-orientation measure linked to financial data; identifies non-linearity.	Observational and online-presence selection; moderate-to-strong non-linear association evidence.
Setiawan et al. (2025)	PLS-SEM; 510 Indonesian MSMEs	Large MSME sample and multi-path capability/agility model.	Cross-sectional Java/Jakarta self-report; strong association/mechanism evidence.
Sultan & Riyadh (2025)	96 manufacturing SMEs; China/Indonesia semi-structured survey	Cross-country comparison and multidimensional canvas assessment.	Small manufacturing-only sample; moderate contextual/configuration evidence.
Rahman et al. (2025)	PLS-SEM; 409 Oman SMEs	Explicit digital dynamic-capability and cost moderation model.	Single-country cross-sectional and environmental outcome; moderate-to-strong boundary-condition evidence.
Probohudono et al. (2025)	PLS-SEM; 257 Indonesian platform-using MSMEs	Direct mediation tests combining RBV and dynamic capabilities.	Purposive platform-user cross-sectional sample; moderate mechanism evidence.
Alqam & Razzak (2025)	PLS-SEM; 284 Oman SMEs	ORT + DCV integration; reports positive, mediating, and null paths.	Single-country cross-sectional design; moderate-to-strong conditional evidence.
Jie et al. (2025)	PLS-SEM; 587 Chinese high-tech SMEs	Large sample, mediation model, and explicit unsupported moderation.	High-tech/single-country/cross-sectional; strong conditional evidence.

Study	Design / data	MMAT-informed strengths	Principal limitation and synthesis weight
Boonmee et al. (2025)	AHP/CVI + K-means/PCA; Northern Thailand manufacturing	Captures readiness heterogeneity and translates barriers into staged roadmap.	AI/manufacturing/regional context and analytical assumptions; contextual heterogeneity evidence.
Seppänen et al. (2025)	Multiple cases; 22 incumbent SMEs	Rich evidence on dual enabling/hindering roles of skills, legacy systems, and management.	Case-based design; mechanism and human-factor evidence.
Hafeez et al. (2025)	In-depth interviews; intermediaries, SMEs, ecosystem actors in Finland	Multi-actor qualitative triangulation of ecosystem sensing/seizing/transforming mechanisms.	Regional/intermediary-centered scope; strong mechanism/context evidence.

Internal Readiness: Resources Are Necessary but Not Sufficient

Across the expanded evidence base, internal readiness emerges as a configuration rather than a single resource. [Eller et al. \(2020\)](#) show that IT resources, employee skills, and digital strategy jointly support digitalization, while individual elements do not automatically generate financial performance. [Romero and Mammadov \(2025\)](#), using a representative sample of 802 Spanish SMEs, similarly show that technological, human, organizational, and relational determinants are complementary and that the configuration differs between micro firms and larger SMEs. Recent evidence sharpens this point: [Setiawan et al. \(2025\)](#) find that digital skills feed transformation through dynamic and agile capabilities among 510 Indonesian MSMEs, whereas [Alqam and Razzak \(2025\)](#) find that digital readiness and strategic flexibility support business-process digitalization but strategic foresight does not. [Seppänen et al. \(2025\)](#) further demonstrate a dual role for human capability: digital expertise enables change, but skill gaps, resistance, and legacy-system dependence can simultaneously impede it. Internal readiness should therefore be conceptualized as aligned technological, human, managerial, financial, and process capacity rather than technology ownership.

Barriers, Risks, and Boundary Conditions

The barrier evidence is multidimensional and includes explicit trade-offs. [Restrepo-Morales et al. \(2024\)](#) identify finance, investment cost, workforce resistance, skill shortages, provider knowledge, broadband, digital culture, and IT-security requirements across 4,531 SMEs. [Arroyabe et al. \(2024\)](#) show that cybersecurity challenges co-evolve with Industry 4.0 maturity. [Rahman et al. \(2025\)](#) provide direct moderation evidence: transformation cost weakens the positive relationship between digital transformation and environmental performance among 409 Omani SMEs. [Boonmee et al. \(2025\)](#) identify financial constraints, workforce skill shortages, and poor data quality as major AI-adoption barriers in Northern Thailand, while [Seppänen et al. \(2025\)](#) emphasize legacy systems and resistance to change. These findings caution against treating higher digitalization as a monotonic benefit. [Escoz Barragan and Becker \(2025\)](#) add a further boundary condition by identifying a U-shaped relationship between digital orientation and performance, suggesting that partial or poorly aligned digital orientation may impose costs before complementary capabilities mature.

Staged Adaptation and Capability Development

The fresh evidence reinforces a staged, configurational view of transformation. [Priyono et al. \(2020\)](#) identify three transformation paths among Indonesian manufacturing SMEs that depend on digital maturity, liquidity, literacy, and social capital. [Hermann et al. \(2024\)](#), analyzing 210 externally supported digital-innovation project reports, distinguish five project types, showing that digital projects vary substantially in purpose, technology, and

implementation configuration. [Sultan and Riyadh \(2025\)](#) similarly observe differentiated digital-transformation profiles across 96 manufacturing SMEs in China and Indonesia. [Boonmee et al. \(2025\)](#) identify four AI-readiness profiles and propose a four-phase pathway from awareness and capacity building to implementation and innovation leadership. Taken together, the evidence does not support a single universal roadmap; it supports a maturity-sensitive sequence in which foundational connectivity, literacy, and process readiness precede more integrated analytics, automation, data governance, and business-model innovation.

Dynamic Capabilities, Agility, and Ecosystem Support

Dynamic capabilities and ecosystem mechanisms explain why similar technologies generate different outcomes. [Matarazzo et al. \(2021\)](#), [Khurana et al. \(2022\)](#), and [Saeedikiya et al. \(2024\)](#) show qualitatively how sensing, seizing, learning, and reconfiguration shape transformation pathways. [Troise et al. \(2022\)](#) and [Setiawan et al. \(2025\)](#) connect capability development to organizational agility and performance, while [Jie et al. \(2025\)](#) show that dynamic capabilities mediate digital maturity–innovation performance but that higher digital maturity does not itself strengthen the capability–innovation link. External support is also capability dependent: [Soluk et al. \(2023\)](#) identify network-mediated domain capabilities, [Hermann et al. \(2024\)](#) show heterogeneity across externally supported project types, and [Hafeez et al. \(2025\)](#) demonstrate that innovation intermediaries require their own sensing, seizing, and transforming capabilities to connect SMEs with ecosystem resources. [Hassan et al. \(2024\)](#) similarly find that absorptive capacity does not moderate every digitalization–innovation relationship. Ecosystem support is therefore best treated as an enabling condition whose value depends on absorption, matching, and implementation capability.

Business-Model Reconfiguration as a Mechanism Linking Digitalization to Performance

Business-model reconfiguration remains a central but non-uniform mechanism connecting digitalization to value creation. [Andersen et al. \(2022\)](#) emphasize experimentation and opportunity search; [Xie et al. \(2022\)](#) show that capability reconfiguration partly mediates the effect of digital platforms on business-model innovation; and [Merín-Rodrigáñez et al. \(2024\)](#) find that business-model innovation partially mediates the digital transformation–performance relationship. New evidence further qualifies this mechanism. [Fang et al. \(2024\)](#) show that digital capability supports several dimensions of digital business-model innovation, but value-delivery innovation does not significantly improve competitiveness in their Malaysian SME sample. [Liu et al. \(2024\)](#) find that digital transformation strengthens selected relationships among dynamic capabilities, business-model innovation, and performance, while [Probohudono et al. \(2025\)](#) show that innovation and digital IT capabilities partially mediate the business-strategy–performance relationship among Indonesian MSMEs. These results support business-model innovation as a mechanism, but not as a single undifferentiated construct with guaranteed performance effects.

Thematic Evidence Matrix

Table 4. Thematic evidence matrix and contradictory findings

Theme	Convergent evidence	Heterogeneity / contradiction	Interpretation
Internal readiness	Eller et al. (2020); Romero & Mammadov (2025); Setiawan et al. (2025); Alqam & Razzak (2025); Seppänen et al. (2025)	Skills or strategy alone do not guarantee performance; strategic foresight is non-significant in Alqam & Razzak; skills can also become a constraint when gaps or resistance persist.	Readiness is a complementary configuration of technology, skills, leadership, finance, process maturity, flexibility, and organizational alignment.

Theme	Convergent evidence	Heterogeneity / contradiction	Interpretation
External support and networks	Khurana et al. (2022); Soluk et al. (2023); Hermann et al. (2024); Hafeez et al. (2025)	Support is heterogeneous and effective only when firms and intermediaries can sense needs, match projects, and absorb external knowledge.	Ecosystem resources enable transformation but do not substitute for internal absorptive and implementation capability.
Staged adoption	Priyono et al. (2020); Hermann et al. (2024); Sultan & Riyadh (2025); Boonmee et al. (2025)	Paths differ by maturity, liquidity, literacy, technology fit, project type, and readiness profile.	Transformation should be progressive and configuration-sensitive rather than standardized.
Capability development and agility	Matarazzo et al. (2021); Troise et al. (2022); Saeedikiya et al. (2024); Setiawan et al. (2025); Jie et al. (2025)	Capability effects are not uniform; Jie et al. find no moderating effect of digital maturity on the capability–innovation link.	Dynamic and agile capabilities convert digital resources into adaptation, but their effect depends on alignment and context.
Business-model innovation	Andersen et al. (2022); Xie et al. (2022); Merín-Rodríguez et al. (2024); Fang et al. (2024); Liu et al. (2024)	BMI frequently mediates value creation, but not all BMI dimensions are significant; Fang et al. report a non-significant value-delivery path.	Business-model reconfiguration is an important, but multidimensional and conditional, mechanism linking digital capability to outcomes.
Innovation and performance	Hassan et al. (2024); Prihandono et al. (2024); Probohudono et al. (2025); Escoz Barragan & Becker (2025); Alqam & Razzak (2025)	Relationships can be mediated, non-linear, or null; digital orientation is U-shaped and strategic foresight is not significant in one study.	Use conditional association language rather than assuming a universal direct digitalization benefit.
Resilience	Khurana et al. (2022); Putritamara et al. (2023); Saeedikiya et al. (2024)	Ownership and sector conditions change the transformation–resilience relationship.	Resilience is a capability-dependent outcome and should not be treated as an automatic consequence of adoption.
Risks, costs, and trade-offs	Restrepo-Morales et al. (2024); Arroyabe et al. (2024); Rahman et al. (2025); Boonmee et al. (2025); Seppänen et al. (2025)	Advanced adoption can increase cybersecurity exposure, transformation cost, data-quality demands, skill shortages, and legacy-system complexity.	Risk governance and transformation cost must be integrated into digital-maturity strategy and policy support.

Integrative Framework for MSME Digital Transformation

The combined 35-study evidence supports an integrative architecture in which external pressure and ecosystem support interact with internal readiness to shape the feasible level, sequence, and pace of digital adoption. Adoption becomes strategically consequential when firms develop sensing, seizing, transforming, absorptive, and agile capabilities and translate them into process integration or business-model reconfiguration. Performance, innovation, and resilience are downstream outcomes rather than automatic consequences of technology adoption. The expanded corpus adds four important boundary conditions to the framework: transformation cost ([Rahman et al., 2025](#)), non-linear digital orientation ([Escoz Barragan & Becker, 2025](#)), selective/null capability effects ([Alqam & Razzak, 2025](#); [Jie et al., 2025](#)), and the dual enabling/constraining role of skills and legacy systems ([Seppänen et al., 2025](#)). Firm size, sector, ownership, location/infrastructure, digital maturity, data quality, cybersecurity readiness, and ecosystem absorptive capacity therefore operate as explicit boundary conditions.

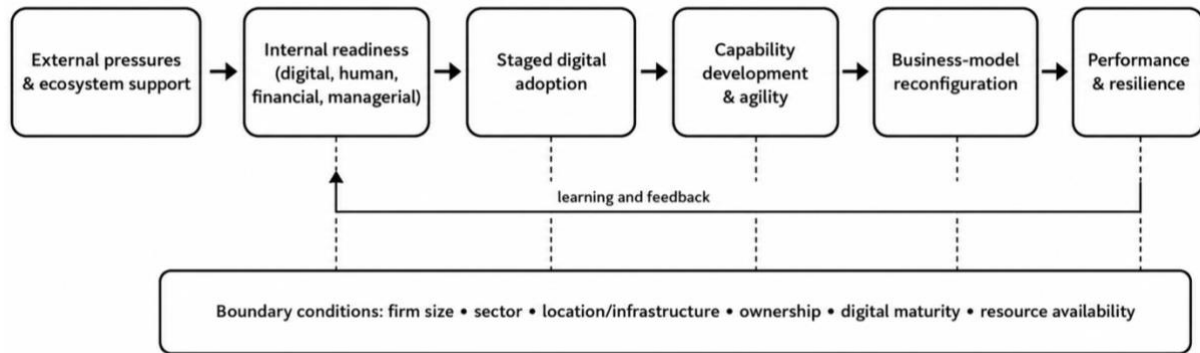


Figure 2. Integrative framework of MSME digital transformation derived from the revised thematic synthesis

Implications for Adaptation Strategy and Policy

The framework implies that adaptation and policy should be differentiated by maturity and constraint profile. Early-stage MSMEs require reliable connectivity, basic digital literacy, affordable devices, digital payments, and foundational data practices. Firms progressing toward integration require process redesign, interoperable systems, leadership development, cybersecurity, data quality, and absorptive capacity. More mature firms require analytics, automation, advanced data governance, ecosystem orchestration, and business-model experimentation. External programs should therefore move beyond generic training: [Hermann et al. \(2024\)](#) and [Hafeez et al. \(2025\)](#) suggest that intermediaries and support units should diagnose project type and firm readiness before matching expertise or technology, while [Rahman et al. \(2025\)](#) indicates that transformation cost must be treated as a boundary condition. Policy evaluation should consequently measure not only adoption counts but also capability development, process integration, security readiness, and realized firm-level outcomes.

4. Conclusion and Suggestion

This systematic integrative review of 35 primary empirical studies indicates that digital transformation in MSMEs is best understood as a capability-building and organizational-change process rather than the simple acquisition of digital tools. The evidence consistently identifies multidimensional internal readiness, staged adoption, dynamic and agile capability development, ecosystem support, and business-model reconfiguration as central mechanisms. However, the fresh synthesis also shows that performance, innovation, and resilience outcomes are conditional: transformation cost, digital maturity, absorptive capacity, ownership, sector, firm size, location, data quality, cybersecurity, leadership, and legacy systems can strengthen, weaken, or alter observed relationships.

The synthesis supports a progressive transformation logic beginning with foundational readiness, followed by market-facing and transaction digitalization, process integration, capability reconfiguration, and where resources and strategic fit permit advanced analytics, automation, and digital business-model innovation. The evidence does not support a universal linear sequence or a universal positive effect. Non-significant and non-linear results, including strategic foresight, selected business-model dimensions, capability moderation, and digital-orientation performance patterns, demonstrate the importance of matching technology intensity to organizational readiness and context.

For MSME managers, the principal implication is to align digital investment with capability development, process needs, risk governance, and measurable value creation. For policymakers and ecosystem intermediaries, support should be segmented by maturity and constraint profile rather than delivered as a generic digitalization package. Early-stage interventions should prioritize connectivity, literacy, affordability, and payment adoption; intermediate interventions should strengthen process integration, leadership, cybersecurity, and data quality; advanced interventions should support analytics, automation, ecosystem orchestration, and business-model experimentation. Future research should prioritize longitudinal transformation pathways, causal evaluations of policy and intermediary programs, sector-specific digital maturity, rural–urban infrastructure inequalities, cybersecurity and platform dependence, transformation financing, and the distinction between perceived and objectively measured performance.

This review has four limitations. First, the fresh revision search used structured publisher-indexed retrieval rather than a native Scopus or Web of Science export; the complete query and record-level log is supplied to make this limitation auditable. Second, one screening decision was recorded per record and no inter-reviewer agreement statistic was available, creating potential selection bias. Third, the evidence base is heterogeneous in design, geography, sector, and outcome measurement, so causal or pooled-effect conclusions are not warranted. Fourth, English/Indonesian language restrictions and the 2020–2025 publication window may omit relevant evidence. These limitations reinforce the need for future database-native, dual-reviewer updates while preserving the present study’s contribution as a transparent, evidence-traceable synthesis of recent empirical SME digital-transformation research.

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