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ASEAN Entrepreneurship Journal (AEJ)

AEJ

Emerging Technology Adoption for Risk Management in Malaysian Manufacturing SMEs: An Integrated TAM–RBV–Institutional Theory Framework

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Abstract:

Digital transformation is rapidly reshaping how manufacturing SMEs manage operational uncertainty, cybersecurity threats, and supply chain disruptions within increasingly complex industrial environments. However, existing studies largely examine emerging technology adoption from isolated technological or operational perspectives, providing limited explanation of how institutional pressures, organizational capabilities, and behavioral evaluations collectively shape resilience-oriented adoption decisions. This study develops an integrated conceptual framework by synthesizing the Technology Acceptance Model, Resource-Based View, and Institutional Theory to explain emerging technology adoption for risk management among Malaysian manufacturing SMEs. The framework proposes that external institutional pressures and internal organizational capabilities influence managerial evaluations of technology usefulness and ease of use, thereby shaping adoption intention and implementation outcomes. The study further reconceptualizes organizational resilience as a digitally enabled strategic capability embedded within organizational transformation processes, rather than merely a reactive disruption outcome. By integrating behavioral, organizational, and institutional perspectives into a unified model, the study contributes to digital transformation and risk management literature while extending current understanding of resilience-oriented technology adoption in manufacturing SMEs. The proposed framework also provides a conceptual foundation for strengthening digitally enabled resilience and technology-driven risk governance within evolving IR4.0 manufacturing ecosystems.

ARTICLE INFORMATION

Received: 18 May 2026
Revised 21 Jul 2026
Accepted: 8 Aug 2026
Published: 15 Aug 2026

Keywords: Emerging Technology Adoption, Risk Management, Manufacturing SMEs, Organizational Resilience, Digital Transformation, Institutional Theory, Malaysia

INTRODUCTION

The accelerating complexity of contemporary manufacturing environments has intensified the strategic importance of technology-enabled risk management within the Fourth Industrial Revolution (IR4.0). Manufacturing firms are increasingly exposed to interconnected operational disruptions, cybersecurity threats, supply chain volatility, regulatory uncertainty, and global market instability, all of which require more adaptive and predictive organizational capabilities (Ivanov et al., 2019; Rodríguez-Espíndola et al., 2022). In this context, emerging technologies (ETs) such as Artificial Intelligence (AI), Big Data Analytics (BDA), Blockchain (BC),

and Cloud Computing (CC) are no longer viewed solely as productivity-enhancing tools, but as strategic mechanisms for strengthening organizational resilience, improving risk visibility, and enabling proactive risk governance (Spieske & Birkel, 2021; Mubarik et al., 2021). Despite growing scholarly attention to digital transformation, existing technology adoption literature continues to emphasize operational efficiency and innovation outcomes, while comparatively limited conceptual attention has been given to the role of ET adoption as a strategic capability for risk management and resilience development, particularly within resource-constrained SME environments.

These concerns are particularly critical within manufacturing small and medium-sized enterprises (SMEs), whose limited financial capacity, technological readiness, and organizational capabilities amplify vulnerability to operational and environmental disruptions (Hassan et al., 2021; Wong et al., 2019). In Malaysia, manufacturing SMEs represent a strategically important industrial segment, yet their adoption of advanced digital technologies remains comparatively low despite extensive governmental digitalization initiatives such as Industry4WRD and MyDIGITAL (Ali et al., 2023; Samsudin et al., 2021). Existing evidence indicates that many SMEs continue to rely on reactive and fragmented risk management approaches that lack predictive and real-time analytical capability (Foli et al., 2023). Consequently, SMEs remain highly exposed to supply chain disruptions, cyber vulnerabilities, production instability, and external shocks, as demonstrated during the COVID-19 pandemic and subsequent global supply chain crises (Abdul Halim et al., 2021; Mubarik et al., 2021). Moreover, the heterogeneous characteristics of AI, BDA, BC, and CC suggest that adoption determinants may differ substantially across technologies, yet existing studies rarely address these distinctions within SME risk management contexts.

From a theoretical perspective, current understanding of ET adoption for risk management remains fragmented and conceptually underdeveloped. Existing studies frequently rely on isolated theoretical perspectives, such as the Technology Acceptance Model (TAM), the Resource-Based View (RBV), or Institutional Theory, to explain technology adoption behavior in digital transformation contexts (Gangwar et al., 2015; Dubey et al., 2019; Kamble et al., 2020). However, the dominance of single-theory approaches has produced fragmented explanations of emerging technology adoption, limiting current understanding of how institutional pressures, organizational capabilities, and behavioral mechanisms interact to shape risk-oriented digital transformation among manufacturing SMEs. While TAM explains behavioral perceptions associated with technology acceptance (Venkatesh et al., 2003), RBV emphasizes internal strategic capabilities such as digital transformation readiness and organizational resilience (Barney, 1991), whereas Institutional Theory explains the influence of regulatory and competitive pressures on organizational decision-making (Scott, 1995; DiMaggio & Powell, 1983). Independently, these theories provide only partial explanations of technology adoption, particularly within manufacturing SMEs, where adoption decisions emerge from the simultaneous interaction of behavioral, organizational, and institutional forces. Furthermore, resilience capability and digital transformation readiness remain insufficiently theorized as mediating organizational mechanisms linking institutional pressures and behavioral intention toward ET adoption for risk management purposes.

In response to these limitations, this paper develops a multi-theoretical framework to explain the determinants of ET adoption for risk management among Malaysian SME manufacturing industries in the IR4.0 era. Specifically, the study integrates the TAM, RBV, and Institutional Theory to provide a more comprehensive explanation of how external institutional pressures and internal organizational capabilities jointly influence technology adoption behavior. The proposed framework conceptualizes ET adoption not merely as technology utilization but as a strategic risk governance capability shaped by government regulations, market pressure, awareness of requirements, digital transformation readiness, and organizational resilience. Within this framework, awareness of requirements refers to SMEs' understanding of the technological, organizational, and

regulatory requirements associated with emerging technology adoption, enabling them to better evaluate and prepare for technology implementation in support of risk management. In doing so, the study advances existing technology adoption literature by positioning resilience and digital transformation as strategic organizational capabilities that strengthen risk management and influence behavioral intention and actual technology use within highly uncertain manufacturing environments.

Accordingly, this study aims to develop an integrated conceptual framework, grounded in the Technology Acceptance Model (TAM), Resource-Based View (RBV), and Institutional Theory, to explain the determinants of emerging technology adoption for risk management among Malaysian manufacturing SMEs.

This study contributes to the literature in several important ways. First, it extends existing ET adoption literature beyond conventional productivity and operational performance perspectives by positioning emerging technology adoption primarily as a strategic capability for risk management and organizational resilience. Second, the study contributes theoretically by integrating behavioral, organizational, and institutional perspectives into a unified conceptual model capable of explaining the multi-level mechanisms underlying ET adoption among manufacturing SMEs. Third, the paper advances current understanding of organizational resilience by conceptualizing resilience not merely as an outcome of disruption management, but as a digitally enabled strategic capability embedded within organizational transformation processes. Practically, the proposed framework offers important implications for SME managers, policymakers, and industrial stakeholders seeking to strengthen digital readiness, resilience capability, and technology-driven risk governance within Malaysia's manufacturing sector. Ultimately, the study provides a conceptual foundation for strengthening resilience, digital readiness, and technology-enabled risk governance among manufacturing SMEs operating within increasingly complex and digitally intensive IR4.0 industrial environments.

THEORETICAL FOUNDATION AND CONCEPTUAL FRAMEWORK

Technology Acceptance Model (TAM)

The Technology Acceptance Model, developed by Fred Davis, remains one of the most foundational frameworks for explaining technology adoption behavior in information systems and organizational research. Grounded in the Theory of Reasoned Action (Fishbein & Ajzen, 1975), TAM posits that technology adoption is primarily driven by two cognitive beliefs: Perceived Usefulness (PU) and Perceived Ease of Use (PEU), which shape Behavioral Intention (BI) and subsequently Actual Use (AU) (Davis, 1989; Venkatesh & Davis, 2000). Within manufacturing SMEs, these cognitive evaluations are particularly critical because adoption decisions are typically made under conditions of resource constraints, technological uncertainty, and operational risk exposure. In the context of IR4.0, emerging technologies such as Artificial Intelligence, Big Data Analytics, Blockchain, and Cloud Computing are increasingly evaluated not only in terms of operational efficiency, but also based on their perceived capability to enhance risk visibility, improve decision accuracy, and strengthen organizational responsiveness to disruptions (Spieske & Birkel, 2021; Rodríguez-Espíndola et al., 2022). Accordingly, TAM provides a behavioral lens for understanding how SME decision-makers cognitively assess the strategic value and usability of emerging technologies within digitally intensive manufacturing environments.

However, the explanatory power of TAM becomes limited when applied to complex organizational settings such as manufacturing SMEs operating under IR4.0 uncertainty. Although TAM effectively captures individual cognitive perceptions of usefulness and ease of use, it provides insufficient explanation of how these perceptions are shaped by broader organizational and institutional conditions,

or how they translate into strategic outcomes such as risk management capability and organizational resilience. In practice, SMEs' perceptions of technology usefulness and ease of use are not formed in isolation, but are structurally influenced by digital transformation readiness, regulatory pressure, competitive intensity, and organizational capability constraints (Wong et al., 2022; Hassan et al., 2023). This suggests that technology acceptance in SMEs is not purely a cognitive evaluation process, but a multi-level phenomenon embedded within organizational and institutional contexts. Furthermore, TAM does not adequately explain how the adoption of emerging technologies contributes to higher-order strategic outcomes such as resilience-building and risk governance capability, which are central to the objectives of this study. Therefore, while TAM provides a necessary behavioral foundation for understanding ET adoption, it is insufficient as a standalone explanation and must be integrated with capability- and institution-based perspectives to fully capture the complexity of technology adoption for risk management in Malaysian manufacturing SMEs.

Resource-Based View (RBV)

The Resource-Based View (RBV), introduced by Barney (1991), explains differences in firm performance through the possession and deployment of internal resources that are valuable, rare, inimitable, and organizationally embedded. Unlike externally focused perspectives, RBV shifts analytical attention to how internal heterogeneity determines a firm's ability to achieve sustained competitive advantage (Chand Singh et al., 2025). In the context of IR4.0, this logic becomes increasingly critical for manufacturing SMEs, where survival and competitiveness depend not only on access to technology but also on the quality of internal capabilities that enable the effective absorption and utilization of emerging technologies (Shibin et al., 2020). In this study, RBV is extended beyond its traditional performance orientation to explain how internal organizational resources shape risk-oriented digital transformation, particularly in enabling SMEs to deploy emerging technologies such as AI, BDA, BC, and CC for risk management purposes. This positioning reframes RBV as a foundational lens for understanding capability-driven risk governance in digital manufacturing environments, rather than merely a theory of competitive advantage.

Despite these advancements, RBV alone does not automatically guarantee successful technology adoption, as resource possession does not necessarily translate into effective utilization without strategic alignment and contextual responsiveness. Empirical evidence suggests that SMEs often fail to convert internal resources into digital transformation outcomes due to gaps in strategic clarity, limited managerial capability, and weak alignment between technological investments and operational risk objectives (Fernandes et al., 2024; Wahyuningsih et al., 2024). Furthermore, trust-related concerns, cybersecurity risks, and implementation complexity associated with emerging technologies such as Blockchain and Artificial Intelligence can weaken the effectiveness of otherwise available resources (Razzaque et al., 2024). This indicates that RBV must be interpreted not only as a structural explanation of internal resources but also as a process-oriented mechanism for resource orchestration in the development of risk management capability. Accordingly, this study positions RBV as a complementary theoretical foundation alongside behavioral (TAM) and institutional perspectives, enabling a more comprehensive explanation of how Malaysian manufacturing SMEs translate internal capabilities into the adoption of emerging technologies for risk management in the IR4.0 era.

Building on this foundation, RBV has evolved through the integration of dynamic capability logic, which emphasizes a firm's ability to reconfigure and renew its resource base in response to environmental turbulence (Teece et al., 1997). In digitally intensive contexts, this evolution extends to digital capabilities

and technology-based resources that determine how effectively firms respond to technological disruption and uncertainty (Bharadwaj et al., 2013; Kaur et al., 2024). However, this study advances RBV further by conceptualizing three internal resource dimensions (Awareness of Requirements (AR), Level of Digital Transformation (LDT), and Organizational Resilience (OR)) as interconnected capability layers that collectively enable risk management-oriented technology adoption. AR reflects cognitive-technical awareness that shapes the recognition of technological necessity; LDT reflects accumulated digital capability and structural readiness for integration; and OR represents adaptive capacity that enables continuity and recovery under disruption. Collectively, these resources form a risk capability architecture that determines the extent to which SMEs can transform digital investments into operational resilience and proactive risk mitigation. Prior research supports this logic by demonstrating that firms with stronger digital capabilities and organizational resilience are better positioned to leverage emerging technologies to reduce uncertainty and enhance operational stability (Rodríguez-Espíndola et al., 2022; Durst et al., 2024).

Institutional Theory

Institutional Theory provides a critical framework for explaining how external environmental pressures shape organizational behavior and influence technology adoption decisions among SMEs. Rooted in the seminal work of DiMaggio and Powell (1983) and further developed by Scott (1995), the theory posits that organizations are embedded within institutional environments governed by coercive, mimetic, and normative pressures that collectively drive organizational isomorphism. Coercive pressures arise from regulatory requirements and formal compliance obligations; mimetic pressures emerge through imitation of successful competitors under conditions of uncertainty; and normative pressures originate from professional standards, industry expectations, and network-based norms (Piaralal et al., 2025). In the context of IR4.0, these pressures increasingly compel manufacturing SMEs to adopt ETs not merely for operational efficiency but also to maintain legitimacy, sustain market relevance, and conform to evolving expectations regarding digital governance and risk management (Balzano et al., 2024; Xing et al., 2024). Consequently, ET adoption among SMEs should not be viewed solely as a rational technological decision, but as an institutional response to external pressures that redefine acceptable organizational practice within digitally intensive industrial environments.

Within Malaysian manufacturing SMEs, institutional pressures have become particularly influential as firms operate under growing regulatory scrutiny, intensified market competition, and increasing digital standardization across supply chains and industrial ecosystems. Coercive pressures associated with cybersecurity regulation, data protection requirements, and industrial compliance frameworks encourage SMEs to adopt technologies that enhance traceability, transparency, and digital auditability, particularly for operational and risk governance processes (Hassan et al., 2021). Simultaneously, mimetic pressures encourage firms to emulate technologically advanced competitors whose digital capabilities signal legitimacy, resilience, and strategic readiness within increasingly volatile markets (Wong et al., 2019; Tan & Lee, 2022). Normative pressures further reinforce this convergence through professional networks, industry associations, and global supply chain expectations that increasingly institutionalize digital transformation as a prerequisite for participation in modern manufacturing ecosystems (Scott, 1995; Rodríguez-Espíndola et al., 2022).

Although Institutional Theory effectively explains why firms experience converging pressures toward ET adoption, it provides limited explanation regarding why some SMEs successfully translate these pressures into effective technological implementation while others fail to do so. Institutional conformity does not

necessarily guarantee organizational readiness, technological capability, or strategic resilience, particularly among resource-constrained SMEs facing implementation uncertainty and capability limitations (Bag et al., 2021; Taib et al., 2024). This limitation is especially critical in the context of risk management, where technology adoption extends beyond symbolic legitimacy and requires substantive organizational capability to strengthen resilience, operational continuity, and risk governance effectiveness. Therefore, while Institutional Theory provides an essential external-perspective explanation of ET adoption, it must be integrated with behavioral and capability-based perspectives to fully explain how Malaysian manufacturing SMEs adopt emerging technologies for risk management under IR4.0 conditions.

Integration of Theories and Conceptual Framework Development

The adoption of emerging technologies for risk management within manufacturing SMEs cannot be adequately explained by a single-theory perspective, as technology adoption in IR4.0 environments is a multi-level organizational phenomenon shaped simultaneously by behavioral evaluations, internal capability conditions, and external institutional pressures. Although TAM explains how SMEs evaluate the usefulness and ease of use of emerging technologies, it provides limited explanation of how such perceptions are formed within resource-constrained and institutionally regulated environments. Similarly, RBV explains how internal capabilities, such as awareness of requirements, digital transformation readiness, and organizational resilience, facilitate technology adoption, yet it pays comparatively less attention to external legitimacy pressures that influence organizational behavior. Institutional Theory complements these limitations by explaining how coercive, mimetic, and normative pressures shape firms' strategic responses toward digital transformation and technology adoption (DiMaggio & Powell, 1983; Barney, 1991; Davis, 1989). Accordingly, integrating TAM, RBV, and Institutional Theory enables the development of a more comprehensive explanation of how Malaysian manufacturing SMEs adopt Artificial Intelligence, Big Data Analytics, Blockchain, and Cloud Computing as strategic mechanisms for risk governance under IR4.0 uncertainty.

The integrated framework proposed in this study positions institutional pressures as external antecedents influencing organizational digital transformation behavior, while RBV-related capabilities represent internal enabling conditions that shape SMEs' readiness to operationalize emerging technologies. These organizational and environmental conditions subsequently influence behavioral evaluations of usefulness and ease of use, which in turn, determine technology adoption intention and actual utilization. Through this theoretical integration, emerging technology adoption is conceptualized not merely as technological implementation but as a strategic risk management capability embedded within broader organizational resilience and institutional adaptation processes (Rodríguez-Espíndola et al., 2022; Spieske & Birkel, 2021; Wong et al., 2022). Therefore, the framework advances existing literature by providing a multi-dimensional explanation of emerging technology adoption that links institutional pressures, organizational capabilities, and behavioral acceptance mechanisms within a unified conceptual structure for manufacturing SMEs operating in digitally disruptive environments.

Although Artificial Intelligence, Big Data Analytics, Blockchain, and Cloud Computing differ in their technological characteristics and implementation requirements, this study conceptualizes them collectively as emerging technologies because they share common strategic roles in strengthening risk management, organizational resilience, and digital transformation within manufacturing SMEs (Rodríguez-Espíndola et al., 2022; Spieske & Birkel, 2021). Rather than examining technology-specific adoption mechanisms, the proposed framework focuses on the common organizational, institutional, and

behavioral determinants that influence emerging technology adoption across these technologies. Therefore, emerging technologies are treated as a higher-order conceptual domain within the proposed framework, with the Technology Acceptance Model, Resource-Based View, and Institutional Theory providing a common theoretical foundation for explaining their adoption for risk management among Malaysian manufacturing SMEs.

Figure 1 presents the integrated conceptual framework linking institutional pressures, organizational capabilities, and technology acceptance mechanisms to explain emerging technology adoption for risk management among Malaysian manufacturing SMEs.

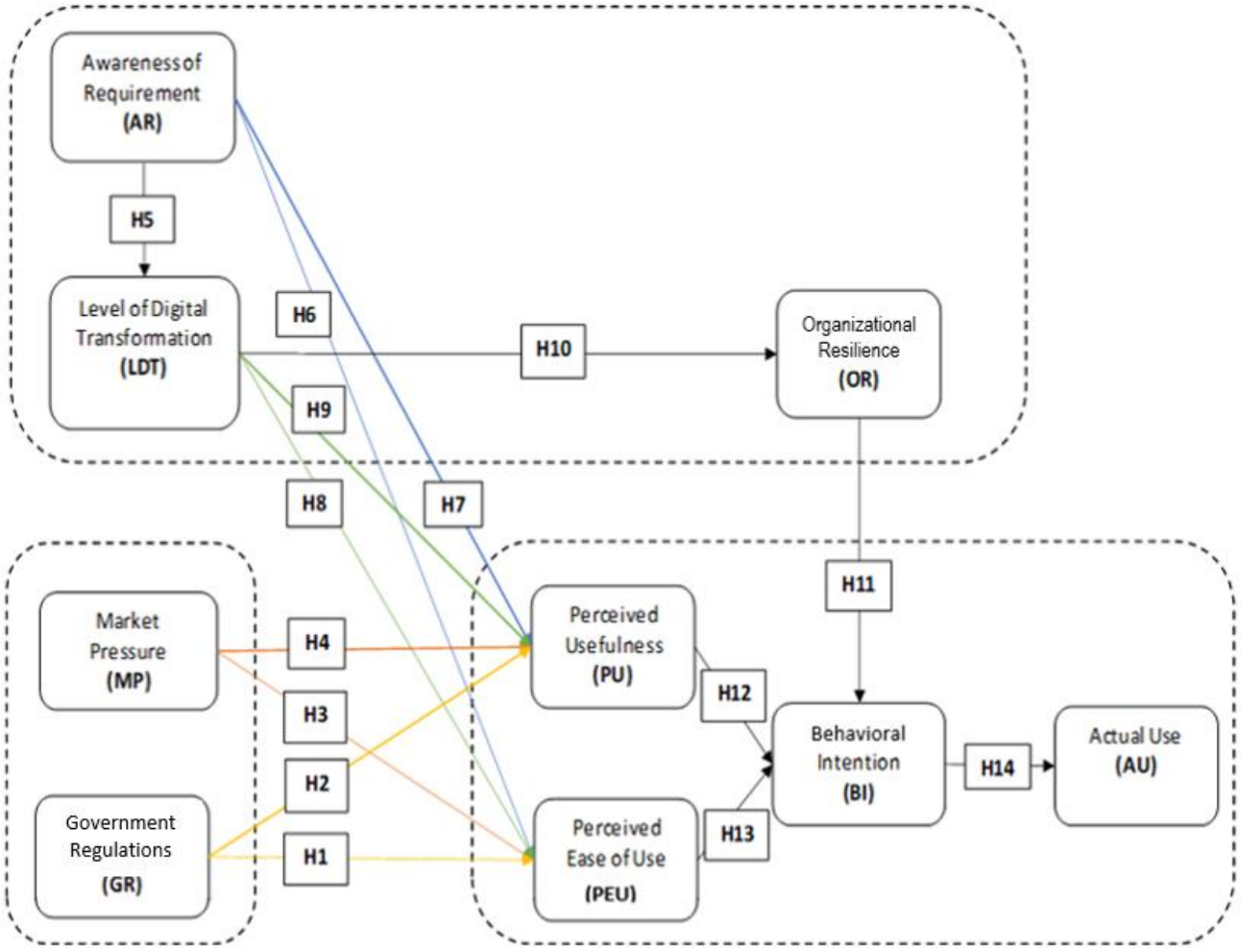

Figure 1: Conceptual Framework

REVIEW OF CORE CONSTRUCT

Technology Acceptance Constructs

Technology acceptance constructs explain how manufacturing SMEs cognitively evaluate and operationalize emerging technologies for risk management within the IR4.0 environment. Within the Technology Acceptance Model (TAM), Perceived Usefulness (PU) reflects the extent to which SMEs believe that emerging technologies can strengthen operational performance, improve decision accuracy, and enhance organizational responsiveness to disruptions, whereas Perceived Ease of Use (PEU) refers

to the extent to which such technologies are perceived as manageable, understandable, and implementable without excessive organizational complexity (Davis, 1989; Venkatesh & Davis, 2000). Within digitally transforming manufacturing SMEs, these cognitive evaluations are particularly important because technologies such as AI, BDA, BC, and CC are increasingly associated with predictive risk monitoring, supply chain visibility, cybersecurity enhancement, and operational continuity (Spieske & Birkel, 2021; Rodríguez-Espíndola et al., 2022; Ghimire et al., 2026). Perceived usefulness strengthens when these technologies demonstrably reduce uncertainty, improve disruption responsiveness, and support proactive risk mitigation, while perceived ease of use becomes more salient when technologies are compatible with existing operational systems and require lower implementation burden under resource-constrained SME conditions (Kamble et al., 2020; Wong et al., 2019).

Within this cognitive evaluation process, PU and PEU jointly shape Behavioral Intention (BI), reflecting SMEs' willingness to commit organizational resources toward emerging technology adoption for risk management purposes. SMEs are more likely to develop strong behavioral intention when digital technologies are perceived as strategically valuable for strengthening resilience, improving operational efficiency, and enhancing risk governance capability (Mubarik et al., 2021; Trivedi & Malik, 2022). However, the translation of behavioral intention into Actual Use (AU) remains a persistent challenge among manufacturing SMEs, particularly in developing economies where implementation barriers frequently constrain digital transformation initiatives. Although firms may recognize the strategic value of AI, BDA, BC, and CC, actual implementation is often hindered by financial limitations, insufficient technical expertise, cybersecurity concerns, and uncertainty regarding implementation outcomes (Gangwar et al., 2015; Katebi et al., 2022). This intention–implementation gap suggests that technology adoption within SMEs extends beyond positive cognitive perceptions alone and depends substantially on organizational readiness, capability development, and sustained support mechanisms for digital transformation (Hassan et al., 2023; Rodríguez-Espíndola et al., 2022). Therefore, the integrated TAM pathway consisting of PU, PEU, BI, and AU provides an important behavioral explanation of how cognitive evaluations toward emerging technologies shape adoption realization for risk management within digitally intensive manufacturing contexts.

Awareness of Requirements

Awareness of Requirements (AR) reflects an SME's organizational capability to recognize, interpret, and evaluate the technological, cybersecurity, operational, and regulatory requirements associated with emerging technology adoption for risk management purposes (Hassan et al., 2021). Within manufacturing SMEs, AR involves understanding how technologies can support operational continuity, improve supply chain visibility, strengthen cybersecurity, and facilitate regulatory compliance within digitally intensive operational settings (Hassan et al., 2021; Rodríguez-Espíndola et al., 2022). SMEs with greater awareness are generally better able to assess implementation requirements, identify technological relevance, and recognize the strategic benefits of ET adoption (Kaur et al., 2024; Pandak et al., 2024). Consequently, higher awareness reduces ambiguity surrounding technological implementation and strengthens Perceived Usefulness (PU) by improving managerial recognition of ETs' capability to mitigate operational risks and enhance decision quality. At the same time, greater familiarity with technological processes and system requirements strengthens Perceived Ease of Use (PEU) by reducing perceived implementation complexity and uncertainty (Ling, 2017).

From a strategic perspective, AR represents an important organizational capability that enhances SMEs' digital preparedness and supports more effective technology evaluation within digitally transforming

manufacturing ecosystems. Manufacturing SMEs with stronger technological and compliance awareness are more likely to proactively identify digital opportunities, anticipate implementation challenges, and allocate organizational resources toward ET adoption initiatives aimed at strengthening resilience and risk governance capability (Mubarik et al., 2021; Saleem et al., 2025). In contrast, limited awareness frequently contributes to implementation hesitation, underestimation of cybersecurity and compliance risks, and resistance toward digital transformation initiatives (Razak et al., 2024). Empirical evidence further suggests that SMEs with higher awareness levels evaluate emerging technologies differently because they are better able to associate ET adoption with long-term operational efficiency, disruption responsiveness, and strategic risk mitigation outcomes (Civelek et al., 2024; Kusi-Sarpong et al., 2021). Accordingly, AR constitutes a foundational organizational capability that shapes how manufacturing SMEs interpret, evaluate, and operationalize emerging technologies for risk management.

Level of Digital Transformation

Level of Digital Transformation (LDT) refers to the extent to which manufacturing SMEs develop, integrate, and embed digital technologies into organizational processes, systems, and structures, reflecting the firm's accumulated digital maturity and infrastructure readiness (Verhoef et al., 2021). Grounded in the Resource-Based View (RBV), LDT is conceptualized as a higher-order organizational capability that enables SMEs to coordinate and deploy digital resources such as AI, BDA, BC, and CC in a coherent and system-wide manner. This capability is reflected in the firm's integration capability, which determines the extent to which digital technologies are connected across functional areas to support information flow, process alignment, and operational coordination in technology-intensive manufacturing ecosystems (Ling, 2017; Civelek et al., 2023).

From an RBV perspective, LDT functions as a dynamic capability that enables SMEs to reconfigure digital and operational resources into risk management and resilience-oriented outcomes. Higher levels of digital transformation strengthen integration capability, allowing firms to achieve real-time visibility, coordinated decision-making, and improved responsiveness to disruptions such as supply chain volatility, cybersecurity threats, and production instability (Kamble et al., 2020; Wang et al., 2023). In this sense, LDT forms the structural foundation through which organizational awareness of technological requirements and resilience capabilities are operationalized, enabling continuous adaptation under digitally driven operational uncertainty. Empirical evidence further indicates that firms with stronger digital transformation capabilities are more effective in leveraging emerging technologies to enhance operational stability and mitigate risk exposure (Rodríguez-Espíndola et al., 2022; Durst et al., 2024).

Organizational Resilience

Organizational Resilience (OR) refers to the extent to which manufacturing SMEs develop adaptive capability to sustain operational continuity, respond effectively to disruptions, and maintain strategic flexibility under conditions of uncertainty (De Matteis et al., 2023). Grounded in the Resource-Based View and dynamic capability logic, OR is conceptualized as an organizational capability that enables firms to anticipate, absorb, and adjust to environmental shocks while maintaining core business functions. Within digitally intensive manufacturing environments characterized by supply chain volatility, cybersecurity threats, and technological turbulence, resilience reflects the firm's capacity to reconfigure internal processes and resource configurations to ensure continuity of operations (Sanchez-Garcia et al., 2023; Kotsios, 2023). This capability is further strengthened through transformational leadership practices that support strategic adaptability, organizational learning, and coordinated responses to disruption (Piaralal et al., 2026). Within this view, OR is not treated as a reactive outcome of disruption,

but as an embedded capability that strengthens organizational stability through structured adaptability and continuous operational adjustment.

From a capability perspective, OR enhances SMEs' ability to operationalize emerging technologies by strengthening disruption response mechanisms and improving strategic flexibility in resource deployment. Resilient SMEs are better positioned to integrate technologies such as Artificial Intelligence, Big Data Analytics, Blockchain, and Cloud Computing into their operational systems because they possess the adaptive capacity required to manage implementation uncertainty and technological complexity (Mubarik et al., 2021; Spieske & Birkel, 2021). This capability supports more effective real-time decision-making, risk monitoring, and recovery coordination during operational disturbances, thereby reinforcing continuity and reducing vulnerability to external shocks (Rodríguez-Espíndola et al., 2022; Wieland & Durach, 2021). Accordingly, OR functions as a strategic capability that enables SMEs to transform digital and technological resources into sustained operational resilience, making it a critical determinant of effective emerging technology adoption for risk management in volatile digital manufacturing ecosystems (Sotamaa et al., 2025; Lestari et al., 2024).

Market Pressure

Market Pressure (MP) represents the intensity of competitive, industry, and value-chain forces that compel manufacturing SMEs to accelerate the adoption of emerging technologies to sustain legitimacy and competitiveness in rapidly digitalizing markets (Hassan et al., 2021). In IR4.0 environments, competitive intensity is increasingly shaped by digitally advanced rivals, platform-based business models, and technology-enabled operational benchmarking, where firm performance is continuously evaluated through efficiency, responsiveness, and transparency. Within this context, MP functions as a cognitive and strategic trigger that strengthens the perceived necessity of emerging technologies by reinforcing their strategic usefulness for cost efficiency, operational responsiveness, and market relevance, while simultaneously reducing perceived complexity through exposure to industry-wide digital standardization and diffusion effects (Hassan et al., 2021; Bresciani et al., 2021).

From a mimetic and demand-driven perspective, uncertainty in highly competitive environments encourages SMEs to imitate the digital strategies of leading firms to reduce strategic ambiguity and signal legitimacy within their industry ecosystem. Such imitation is particularly evident in the adoption of new technologies, where early adopters establish behavioral benchmarks that shape industry norms and accelerate the diffusion of technology across supply chains and customer networks (Nambisan et al., 2017; Bhuiyan et al., 2024). In parallel, escalating expectations from customers and supply chain partners for traceability, real-time responsiveness, and operational transparency further intensify adoption pressure by embedding digital capability as a minimum requirement for participation in modern value networks. Accordingly, Market Pressure operates as an external acceleration mechanism that drives emerging technology adoption through competitive urgency, mimetic learning, and demand-side digital expectations in rapidly digitalizing manufacturing ecosystems (Kamalaldin et al., 2020).

Government Regulations

Government Regulations (GR) constitute coercive institutional pressures that set mandatory compliance boundaries for data governance, cybersecurity, traceability, and operational transparency within manufacturing SMEs (Zhu & Kraemer, 2005). In digitally regulated business environments, these pressures are intensified through evolving digital economy policies and sector-specific regulatory

frameworks that define minimum standards for secure, auditable, and data-driven operations (Ministry of Investment, Trade and Industry [MITI], 2021). Rather than functioning solely as external constraints, GR generates legitimacy risk for non-compliance, thereby shaping how SMEs evaluate emerging technologies as necessary instruments for meeting institutional requirements (Zhu et al., 2023). In this sense, regulatory pressure strengthens the perceived usefulness of emerging technologies by positioning them as essential tools for compliance assurance, while also reducing implementation ambiguity through standardized reporting structures and formalized digital governance requirements (Scott, 1995; Zhu & Kraemer, 2005).

From a coercive institutional perspective, GR accelerates the adoption of emerging technologies by embedding compliance obligations into core operational processes, particularly in areas requiring real-time monitoring, traceable transactions, and secure data management. SMEs are therefore compelled to integrate technologies to meet regulatory requirements for auditability, cybersecurity resilience, and supply chain traceability (Hassan et al., 2021; Lee et al., 2020). This compliance-driven transformation is further reinforced by blockchain-enabled traceability systems and cloud-based governance infrastructures, which allow firms to reduce regulatory uncertainty while improving operational accountability and reporting efficiency (Köhler & Pizzol, 2020; MITI, 2021). Accordingly, Government Regulations function as a dual institutional mechanism that simultaneously constrains organizational discretion and enables strategic digital transformation by converting compliance requirements into technology adoption imperatives that enhance legitimacy, operational control, and long-term risk governance capability (Zhu et al., 2023).

DISCUSSION AND HYPOTHESES DEVELOPMENT

This study integrates the Technology Acceptance Model (TAM), Resource-Based View (RBV), and Institutional Theory (IT) to explain how manufacturing SMEs adopt emerging technologies for risk management within digitally transforming industrial ecosystems. The integration of these theoretical perspectives provides a multi-level explanation of technology adoption by linking external institutional pressures, internal organizational capabilities, and cognitive technology evaluations into a unified framework. Institutional Theory explains how external forces, such as Government Regulations (GR) and Market Pressure (MP), shape organizational responses to digital transformation by influencing firms' perceptions of technological legitimacy, strategic necessity, and competitive relevance (DiMaggio & Powell, 1983; Scott, 1995). Within manufacturing SMEs, coercive regulatory requirements related to cybersecurity, traceability, and digital compliance increasingly encourage firms to evaluate advanced digital technologies as necessary mechanisms for operational continuity and governance improvement (Hassan et al., 2021; Zhu et al., 2023). Simultaneously, competitive intensity and pressure from supply chain partners prompt firms to imitate successful digital practices within the industry ecosystem, thereby strengthening perceptions of the usefulness and manageability of technology adoption (Bhuiyan et al., 2024). These institutional pressures are therefore expected to influence both Perceived Ease of Use (PEU) and Perceived Usefulness (PU) in the adoption of digital technology for risk management purposes.

From the RBV perspective, the successful adoption of digital technologies depends substantially on firms' internal capabilities and strategic resource configurations (Barney, 1991; Teece et al., 1997). In this study, Awareness of Requirements (AR), Level of Digital Transformation (LDT), and Organizational Resilience (OR) are conceptualized as organizational capabilities that support SMEs' digital preparedness and adaptive capacity. AR reflects the firm's ability to recognize technological, operational, cybersecurity, and compliance

requirements associated with digital technology implementation, thereby reducing implementation ambiguity and strengthening managerial understanding of technological relevance (Kaur et al., 2024). Firms with stronger awareness are expected to evaluate digital technologies more positively because they are better able to identify strategic benefits and operational compatibility, thereby enhancing PEU and PU (Ling, 2017; Wong et al., 2019). Furthermore, RBV suggests that awareness alone is insufficient unless translated into broader organizational transformation capability. Consequently, LDT functions as a mediating organizational mechanism through which awareness is operationalized into resilience-oriented digital capability, enabling firms to integrate IR4.0 technologies more effectively across operational systems and processes (Rodríguez-Espíndola et al., 2022; Durst et al., 2024).

The framework further proposes that higher levels of digital transformation strengthen SMEs' capability to operationalize digital technologies by improving digital integration, infrastructure readiness, and organizational adaptability. Digitally mature SMEs are more likely to perceive digital technologies as useful and manageable because prior digital investments reduce technological complexity, improve interoperability, and facilitate organizational learning (Kamble et al., 2020; Raman et al, 2025; Wang et al., 2023). At the same time, LDT directly strengthens Organizational Resilience by enhancing firms' capability to anticipate disruptions, coordinate responses, and maintain operational continuity under uncertainty (El Baz & Ruel, 2021; Yang et al., 2022). Organizational resilience subsequently serves as an adaptive capability that supports sustained Behavioral Intention (BI) toward technology adoption, as resilient firms are generally better prepared to manage implementation uncertainty and technological change (Lohmer et al., 2020; Mubarik et al., 2021). Accordingly, OR is expected to mediate the relationship between LDT and Behavioral Intention to use emerging technologies, reinforcing the strategic role of resilience within technology-intensive manufacturing settings.

Consistent with TAM, the framework also explains how cognitive evaluations of digital technologies influence adoption behavior and implementation. PU and PEU jointly shape SMEs' Behavioral Intention to adopt emerging technologies by influencing managerial perceptions regarding technological value, usability, and operational benefit (Supramaniam et al., 2025). Technologies perceived as strategically beneficial for risk mitigation, operational visibility, and decision quality are more likely to elicit stronger adoption intentions, particularly when implementation complexity is perceived as manageable in resource-constrained SME settings (Spieske & Birkel, 2021; Rodríguez-Espíndola et al., 2022). However, the transition from intention to Actual Use (AU) frequently remains constrained by financial limitations, technical capability gaps, and implementation uncertainty among SMEs (Gangwar et al., 2015; Katebi et al., 2022). Therefore, BI is proposed as a mediating mechanism linking PU and PEU to AU, reflecting the sequential process by which cognitive acceptance translates into practical technology implementation in manufacturing SMEs. Thus, the integrated framework extends conventional TAM-based technology adoption research by embedding cognitive evaluations within organizational capability and institutional contexts. This integration provides a more comprehensive explanation of how manufacturing SMEs operationalize emerging technologies for risk management amid digital uncertainty and environmental volatility.

Based on the integrated theoretical arguments discussed above, this study proposes the following hypotheses:

H1: Government Regulations have a positive and significant effect on the Perceived Ease of Use of emerging technologies.

H2: Government Regulations have a positive and significant effect on the Perceived Usefulness of emerging technologies.

H3: Market Pressure has a positive and significant effect on the Perceived Ease of Use of emerging technologies.

H4: Market Pressure has a positive and significant effect on the Perceived Usefulness of emerging technologies.

H5: The Level of Digital Transformation mediates the relationship between Awareness of Requirements and Organizational Resilience.

H6: Awareness of Requirements has a positive and significant effect on the Perceived Ease of Use of emerging technologies.

H7: Awareness of Requirements has a positive and significant effect on the Perceived Usefulness of emerging technologies.

H8: The Level of Digital Transformation has a positive and significant effect on the Perceived Ease of Use of emerging technologies.

H9: The Level of Digital Transformation has a positive and significant effect on the Perceived Usefulness of emerging technologies.

H10: The Level of Digital Transformation has a positive and significant effect on Organizational Resilience.

H11: Organizational Resilience mediates the relationship between the Level of Digital Transformation and Behavioral Intention to use emerging technologies.

H12: Perceived Usefulness mediates the relationship between the Level of Digital Transformation and Behavioral Intention to use emerging technologies.

H13: Perceived Ease of Use mediates the relationship between the Level of Digital Transformation and Behavioral Intention to use emerging technologies.

H14a: Behavioral Intention mediates the relationship between Perceived Usefulness and Actual Use.

H14b: Behavioral Intention mediates the relationship between Perceived Ease of Use and Actual Use.

Theoretical Contributions

This study contributes to the digital transformation and emerging technology adoption literature by developing an integrated framework that combines the Technology Acceptance Model (TAM), Resource-Based View (RBV), and Institutional Theory (IT) to explain how external institutional pressures, internal organizational capabilities, and cognitive evaluations collectively influence emerging technology adoption for risk management within manufacturing SMEs. Unlike prior studies that examine technology acceptance, organizational capability, or institutional pressure independently, this study explains how Market Pressure (MP) and Government Regulations **(**GR) shape managerial perceptions of Perceived Usefulness (PU) and Perceived Ease of Use (PEU), while Awareness of Requirements (AR), Level of Digital Transformation (LDT), and Organizational Resilience (OR) function as interconnected strategic capabilities that support digital transformation and resilience development in digitally transforming manufacturing environments. By positioning LDT as a mediating organizational capability and OR as a

resilience-oriented strategic mechanism linking digital transformation and behavioral intention, the study extends existing technology adoption literature beyond individual acceptance behavior toward a more integrated organizational and capability-based explanation of emerging technology adoption within Malaysian manufacturing SMEs operating under IR4.0 uncertainty.

Practical Implications

This study provides important practical implications for SME managers, policymakers, and technology providers by highlighting that successful emerging technology adoption for risk management depends not only on technological investment but also on organizational awareness, digital capability development, resilience readiness, and institutional support mechanisms. For manufacturing SMEs, the findings suggest the importance of strengthening awareness regarding technological, cybersecurity, and compliance requirements to improve cognitive evaluations toward emerging technologies and facilitate more effective implementation processes. The study also emphasizes that digital transformation should be treated as a strategic organizational capability encompassing infrastructure integration, workforce preparedness, operational coordination, and resilience-building, rather than a purely technical initiative. For policymakers, the framework underscores the need for clearer regulatory guidance, digital capability programs, training initiatives, and financial support mechanisms that reduce implementation uncertainty and strengthen SME readiness for digital transformation. In parallel, technology providers should develop scalable, user-friendly, and interoperable solutions aligned with the operational realities of resource-constrained manufacturing SMEs to reduce perceived complexity and support sustained technology utilization within increasingly technology-intensive manufacturing ecosystems.

CONCLUSION AND DIRECTIONS FOR FUTURE RESEARCH

This study develops an integrated conceptual framework to explain emerging technology adoption for risk management in Malaysian manufacturing SMEs by synthesizing the Technology Acceptance Model (TAM), the Resource-Based View (RBV), and Institutional Theory (IT). The article advances existing literature by positioning emerging technology adoption beyond operational efficiency considerations and conceptualizing it as a strategic mechanism for strengthening organizational resilience, adaptive capability, and digitally enabled risk governance within increasingly volatile manufacturing environments. By integrating behavioral, organizational, and institutional perspectives, the framework explains how external pressures, internal capabilities, and cognitive evaluations collectively shape technology adoption processes and implementation outcomes in digitally transforming SMEs. The study further contributes by emphasizing that digital transformation capability and organizational resilience function not merely as operational outcomes but as interconnected strategic capabilities that support proactive risk management, organizational continuity, and resilience in evolving industrial ecosystems. Consequently, the proposed framework offers a stronger theoretical basis for understanding how manufacturing SMEs can leverage emerging technologies to strengthen risk management capability by enhancing preparedness and responsiveness under conditions of uncertainty and disruption.

Despite these contributions, the study remains subject to several boundary conditions that provide opportunities for future research development. As the framework is developed within the context of Malaysian manufacturing SMEs, future empirical studies may examine its applicability across different industrial sectors, organizational sizes, and national contexts to strengthen contextual generalizability. In addition, the proposed relationships are conceptually developed and therefore require empirical validation using quantitative, longitudinal, or mixed-method approaches to assess the dynamic interactions among digital transformation capability, resilience development, and technology adoption over time. Future research may also extend the framework by

incorporating additional contextual dimensions, such as digital leadership, organizational culture, technological turbulence, cybersecurity readiness, and ecosystem collaboration capability, to provide a deeper explanation of technology-driven resilience formation. Furthermore, comparative investigations between SMEs operating at different stages of digital maturity may provide richer insights into how emerging technology adoption evolves across varying levels of organizational preparedness and industrial digitalization. Collectively, these future directions may contribute to the refinement of digitally oriented resilience and risk management literature while supporting the development of more adaptive, resilient, and sustainable manufacturing SME ecosystems within evolving IR4.0 industrial environments.

Author Contributions: Rethinasamy Veretharajoo: Writing – original draft preparation, Formal analysis, Conceptualization, Methodology. Shishi Kumar Piaralal: Conceptualization, Methodology, Validation, Supervision, Writing – review and editing. Nur Amalina Zulkefli: Writing – review and editing, Conceptualization, Project administration. Santhi Raghavan: Validation, Resources. Nor Munira Mahmood: Resources.

All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgements: The authors would like to express their sincere appreciation to Open University Malaysia (OUM) for the institutional support provided throughout the development of this manuscript.

Conflicts of Interest: The authors declared no conflicts of interest regarding this work.

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