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Research paper



A Conceptual Model for Sustainable Intelligent Systems in Malaysian MSMEs

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Abstract

This study proposes a conceptual model for Sustainable Intelligent Systems (SIS) in Malaysian Micro, Small, and Medium Enterprises (MSMEs), aiming to integrate sustainability principles with intelligent technologies to enhance resilience, efficiency, and environmental responsibility. Grounded in the United Nations' Sustainable Development Goal (SDG) 9: Industry, Innovation, and Infrastructure, the model supports sustainable industrialization and technological innovation within MSMEs. Using a comprehensive review of existing litera-ture, frameworks, and theories, the study identifies gaps in the adoption of intelligent technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and data analytics. The proposed model addresses barriers to technology adoption and emphasizes embedding sustainability into intelligent systems to optimize resource management, strengthen decision-making, and promote long-term competitiveness in the digital economy. This research offers strategic guidance for MSME owners, policymakers, and researchers, providing a roadmap for sustainable digital transformation. Future research is recommended to validate the model through empirical studies and real-world applica-tions. By bridging sustainability and intelligent technology adoption, the study contributes to the theoretical understanding of sustainable intelligent systems and delivers practical insights, reinforcing the role of SIS in driving economic growth, environmental stewardship, and innovation in Malaysia's MSME sector.

Keywords: *Artificial Intelligence, Digital Transformation, Conceptual Model, MSMEs, Sustainable Development Goal (SDG 9), Sustainable Intelligent Systems*

1. Introduction

Micro, Small, and Medium Enterprises (MSMEs) serve as the backbone of Malaysia's economy, contributing significantly to employment, innovation, and overall economic development. However, MSMEs often face challenges in maintaining sustainability while keeping pace with rapid technological advancements [1]. The increasing need for resource efficiency, digital transformation, and environmental responsibility has highlighted the importance of integrating intelligent technologies into MSME operations. To remain competitive and resilient, MSMEs must adopt sustainable intelligent systems that align with global economic and environmental goals [2].

The concept of Sustainable Intelligent Systems (SIS) refers to the integration of smart technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and data analytics with sustainability principles [3]. These systems enable businesses to optimize operations, reduce environmental impact, and enhance long-term economic viability [4]. Despite the potential benefits, many MSMEs in Malaysia struggle with limited technological resources, financial constraints, and a lack of expertise in adopting such systems. Existing research on digital transformation and sustainability often focuses on large enterprises, leaving a gap in understanding how MSMEs can effectively implement these solutions.

This paper aims to bridge that gap by proposing a conceptual model for Sustainable Intelligent Systems in Malaysian MSMEs, providing a strategic framework for integrating sustainability and intelligent technologies. Grounded in the United Nations' Sustainable Development Goal (SDG) 9: Industry, Innovation, and Infrastructure, this study emphasizes the role of technology in promoting sustainable industrialization and economic growth. The proposed model offers practical insights for MSME owners, policymakers, and researchers, facilitating the adoption of intelligent systems for sustainable business development.

The paper is structured as follows: Section 2 provides a literature review on MSMEs, sustainability, and intelligent systems. Section 3 outlines the research methodology. Section 4 presents the proposed conceptual model. Section 5 discusses key findings, implications, and challenges, while Section 6 concludes with recommendations for future research.

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2. Literature review

The rapid advancement of digital technologies and the growing emphasis on sustainability have created new opportunities and challenges for businesses worldwide [5]. For MSMEs in Malaysia, adopting intelligent systems while maintaining sustainable practices is essential for long-term competitiveness and resilience. However, this paper found that many MSMEs face barriers such as limited financial resources, technological constraints, and a lack of expertise. This section explores the existing literature on MSMEs, sustainability, intelligent systems, and conceptual models, highlighting key challenges and research gaps. By reviewing past studies, this paper establishes the foundation for developing a conceptual model for Sustainable Intelligent Systems (SIS) in Malaysian MSMEs.

2.1 Micro, small, and medium enterprises (MSMEs) in Malaysia

In 2022, Malaysia's MSMEs grew by 11.6%, outpacing the national GDP growth of 8.7%, highlighting their increasing role in economic expansion. Their contribution to GDP rose to 38.4%, with a value-added increase to RM580.4 billion, up from RM520.0 billion in 2021 [6]. Their role in driving economic growth, job creation, and industrial development is undeniable.

However, many MSMEs continue to face persistent challenges that hinder their progress, including limited financial resources, technological gaps, and difficulties in implementing sustainable business practices [7]. These barriers often prevent MSMEs from scaling their operations and adapting to an increasingly competitive market.

With the rise of digital transformation and sustainability as global priorities, MSMEs are under increasing pressure to adopt innovative, technology-driven solutions to enhance their competitiveness and ensure long-term viability [8]. The integration of intelligent systems, such as Artificial Intelligence (AI), the Internet of Things (IoT), and big data analytics, has become essential for improving operational efficiency, decision-making, and resource management [9]. However, many MSMEs in Malaysia still struggle with the adoption of these technologies due to high implementation costs, lack of expertise, and uncertainty about long-term benefits.

As Malaysia moves toward a sustainable and digital-driven economy, MSMEs must find ways to balance technological adoption with sustainable business practices. Encouraging government support, financial incentives, and industry collaborations can help MSMEs navigate these challenges [10]. By leveraging intelligent systems and sustainable strategies, MSMEs can enhance their resilience, reduce environmental impact, and remain competitive in the evolving global market [11].

2.2 Sustainable development and MSMEs

Sustainability has emerged as a critical global concern, with increasing emphasis on integrating environmental, social, and economic considerations into business operations. The United Nations' Sustainable Development Goals (SDGs) provide a comprehensive framework for guiding organizations toward sustainable development [12]. Among these, SDG 9: Industry, Innovation, and Infrastructure highlights the necessity of resilient infrastructure, sustainable industrialization, and technological advancements to promote long-term economic growth and environmental responsibility [13]. This goal underscores the role of innovation in fostering sustainability, particularly within industries that rely on resource-intensive processes.

Building on this, the Global Sustainable Development Report in 2023 reinforces the importance of innovation and systemic transformation in achieving sustainable industrial development. It emphasizes that progress on SDG 9 has been uneven, particularly in low- and middle-income countries, where infrastructure gaps and limited technological capacity hinder inclusive growth. The report advocates enhanced investment in research and development, the promotion of digital technologies, and the strengthening of innovation ecosystems to accelerate sustainable industrialization. These insights underscore the need for forward-looking strategies that not only boost economic performance but also address long-term sustainability challenges through innovation-driven solutions [14].

Despite the recognized importance of sustainability, MSMEs continue to face significant challenges in implementing sustainable practices. Research indicates that high costs, limited awareness, and weak regulatory enforcement are primary barriers to sustainability adoption among MSMEs [15]. Many of these businesses operate with constrained financial and technical resources, making it difficult to invest in sustainable solutions. Furthermore, Chong and Kaliappen [15] also stated that the lack of institutional support and inconsistent policy implementation further worsen these challenges, preventing MSMEs from fully integrating sustainability into their operational strategies.

Recent studies suggest that the integration of intelligent systems offers a viable solution for overcoming sustainability-related challenges in MSMEs [16]. Technological advancements such as artificial intelligence (AI), the Internet of Things (IoT), and big data analytics have been identified as key enablers of sustainable business practices [3]. These technologies facilitate enhanced efficiency, optimized resource utilization, and data-driven decision-making, enabling businesses to reduce environmental impact while maintaining profitability. Additionally, the adoption of intelligent systems has been linked to improved regulatory compliance and innovation-driven competitiveness, positioning MSMEs as crucial contributors to sustainable industrialization [3]. Given the potential of intelligent technologies in addressing sustainability barriers, further research is required to explore their implementation in different industrial contexts and assess their long-term impact on business sustainability.

2.3 Intelligent systems and digital transformation

The rapid advancement of intelligent systems, driven by technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), cloud computing, and big data analytics, has transformed business operations across various industries. These technologies have been recognized for their ability to optimize processes, enhance decision-making, and improve overall efficiency [9]. AI, for instance, enables businesses to leverage predictive analytics for demand forecasting and risk assessment, allowing for more informed strategic planning [17]. Similarly, IoT facilitates real-time data collection and monitoring, providing businesses with actionable insights to improve resource management and operational agility [18]. Furthermore, cloud computing has revolutionized data storage and accessibility, enabling organizations to scale their operations flexibly, while big data analytics has allowed businesses to extract valuable patterns from vast datasets, leading to more data-driven decision-making and process automation [19].

Despite these benefits, the adoption of intelligent systems among Malaysian MSMEs remains relatively low compared to larger corporations. Several studies have identified key barriers that hinder digital transformation in MSMEs. High implementation costs remain one of the most significant challenges, as many small businesses struggle with limited financial resources, making it difficult to invest in advanced technologies [20]. Additionally, a lack of digital skills and technical expertise among employees further exacerbates the issue, as many MSMEs lack the necessary training and knowledge to effectively integrate and utilize intelligent systems [20]. Research also high-

lights organizational resistance to change as a crucial factor affecting adoption rates. Many business owners and managers exhibit reluctance toward digital transformation due to concerns over disrupting existing workflows, cybersecurity risks, and uncertainty about return on investment [20].

Given these challenges, scholars emphasize the need for policy interventions, financial incentives, and targeted digital training programs to enhance the adoption of intelligent systems in MSMEs [21]. Government support, such as subsidies and tax incentives, has been suggested as a viable strategy to alleviate cost-related barriers, while industry collaborations and public-private partnerships could help in providing accessible digital skill development programs [22]. Additionally, fostering a pro-digital organizational culture and increasing awareness of the long-term benefits of intelligent technologies may encourage MSMEs to embrace digital transformation more effectively.

2.4 The need for sustainable intelligent systems in Malaysian MSMEs

Over the past decade, research on sustainable intelligent systems in MSMEs has experienced notable growth, reflecting increasing global awareness of environmental sustainability and digital transformation. Initially limited in scope, academic interest in this area began to rise steadily after 2010. According to a systematic literature review by Mick, Kovaleski, and Chiroli [23], the year 2020 marked a significant turning point with the emergence of the first digital transformation roadmaps for MSMEs spurred by the COVID-19 pandemic, which emphasized the need for resilience and accelerated the adoption of digital technologies. Since then, publication activity peaked in 2022, highlighting the growing importance of integrating intelligent technologies such as AI, IoT, and data analytics into sustainable business practices within MSMEs.

Through an extensive review of previous literature, this study found that several theoretical frameworks and conceptual models have been developed to integrate sustainability with intelligent technologies. The Technology-Organization-Environment (TOE) framework suggests that technological adoption is influenced by internal organizational capabilities, external environmental factors, and technological readiness [24]. Additionally, the Triple Bottom Line (TBL) approach emphasizes the importance of balancing economic, environmental, and social dimensions in sustainable business practices [25]. While these models provide valuable insights, this study identifies a research gap regarding a specific focus on MSMEs, particularly in the Malaysian context.

Furthermore, despite the growing interest in sustainability and digital transformation, there remains a notable gap in the literature concerning the intersection of sustainability and intelligent systems for MSMEs in Malaysia. Existing studies predominantly focus on large enterprises, overlooking the unique constraints and opportunities faced by MSMEs. This study seeks to bridge this gap by highlighting the need to develop a conceptual model for Sustainable Intelligent Systems (SIS) in Malaysian SMEs, aligning with Sustainable Development Goal (SDG) 9 to promote sustainable industrialization and technological advancement. Table 1 presents a critical analysis of previous studies related to sustainable intelligent systems.

Table 1: Critical Analysis of Previous Works on Sustainable Intelligent Systems

Author	Framework/Model Used	Key Contributions	Limitations
Drazin [24]	Technology-Organization-Environment (TOE)	Establishes a framework explaining how technological adoption is influenced by organizational capabilities, environmental conditions, and technological readiness.	Lacks SME-specific considerations and does not explicitly address sustainability concerns.
Elkington [25]	Triple Bottom Line (TBL)	Introduces a sustainability framework emphasizing the balance of economic, environmental, and social performance in business operations.	Does not provide an actionable implementation roadmap for SMEs and lacks a technological perspective.
Ghobakhloo and Iranmanesh [26]	Digital Transformation Success in SMEs	Provides strategic guidelines for SMEs to navigate digital transformation in Industry 4.0, with a focus on enhancing operational efficiency.	Primarily focuses on digitalization without integrating sustainability as a core component.
Buteau [21]	Digital Transformation Roadmap for MSMEs	Identifies key enablers and barriers for MSMEs in digital adoption, emphasizing financial access and policy support.	Concentrates on India, limiting global applicability; lacks an explicit sustainability dimension.
Rachakatla and Ravichandran [17]	AI-Driven Business Analytics	Explores the role of artificial intelligence (AI) and big data in enhancing business intelligence and decision-making processes.	Does not explicitly consider the sustainability implications of AI adoption in SMEs.
Atitallah et al. [27]	Microservice paradigm for data analytics in IoT application	Explore on the microservices paradigm allowing to provide several enhancements in terms of independent deployment, modularity, containerization, loose coupling.	Integrating the microservice paradigm into IoT remains a challenge because of the complexity, security and culture change.
Wei, Oluwaseyi, and Chew [28]	Environmental Sustainability Practices in MSMEs	Examines how Malaysian MSMEs adopt environmentally sustainable practices and their impact on business competitiveness.	Focuses primarily on environmental aspects, without integrating intelligent technologies or digital transformation strategies.
Setyaningsih et al. [29]	A conceptual framework for challenges of sustainability implementation for SMEs.	Explore on how sustainability drives SMEs toward sustainable development and offers practical insights.	Focus on the struggling of SMEs with limited resources, knowledge gaps, and complex regulations that hinder effective sustainability efforts.

Based on Table 1, this study identified that the previous works on sustainable intelligent systems reveal a diverse range of frameworks and focus areas, each contributing unique insights while also presenting notable limitations. Drazin [24] introduced the Technology-Organization-Environment (TOE) framework, which is strong in its holistic approach to technological adoption but lacks specificity for MSMEs and omits sustainability considerations. Elkington's [25] Triple Bottom Line (TBL) model significantly advanced sustainability discourse by promoting a balance of economic, environmental, and social goals, yet it falls short in offering practical implementation strategies for MSMEs and neglects technological integration.

Ghobakhloo and Iranmanesh [26] focused on digital transformation success in MSMEs and offered relevant operational strategies. However, their model primarily centers on digitalization without embedding sustainability as a core element. Buteau [21] emphasized financial and policy enablers for MSME digital adoption in India, which is contextually valuable, but its limited geographical scope and lack of explicit sustainability objectives reduce its broader relevance. Rachakatla and Ravichandran [17] explored AI-driven analytics, high-

lighting the potential of intelligent technologies in decision-making, though they did not address the sustainability impacts of AI in MSMEs.

Atitallah et al. [27] provided a detailed technical framework through microservices for IoT, showcasing strengths in modularity and deployment but facing challenges related to security and cultural change, with limited direct applicability to MSME sustainability. Wei, Oluwaseyi, and Chew [28] examined environmental practices among Malaysian MSMEs, offering grounded empirical insights but failing to incorporate intelligent systems or digital strategies. Finally, Setyaningsih et al. [29] presented a conceptual framework that effectively captures the struggles of MSMEs, such as limited resources and regulatory barriers in sustainability efforts, yet it too lacks integration with advanced digital or intelligent technologies.

Conclusively, these studies contribute valuable perspectives but underscore the need for a more integrated approach that bridges sustainability with digital transformation tailored to the MSME context. Building on this idea, this study expands upon established frameworks by emphasizing the need for a new, integrative conceptual model specifically designed for Sustainable Intelligent Systems (SIS) in Malaysian MSMEs. By incorporating insights from the Technology-Organization-Environment (TOE) framework, the Triple Bottom Line (TBL) approach, and existing studies on digital transformation and sustainability, the proposed model aims to bridge the gap between technological adoption and sustainable business practices within the MSME sector.

Unlike conventional models that primarily focus on large enterprises or lack MSME-specific considerations, the proposed SIS model addresses the unique challenges faced by Malaysian MSMEs, such as limited financial resources, digital literacy gaps, and regulatory constraints. Additionally, it aligns with Sustainable Development Goal (SDG) 9, which emphasizes resilient infrastructure, inclusive industrialization, and technological innovation. By integrating artificial intelligence (AI), the Internet of Things (IoT), and data-driven decision-making, this model seeks to enhance MSME operational efficiency, minimize environmental impact, and ensure long-term business viability. The following sections outline the research methodology used to develop this conceptual model and provide an in-depth analysis of its components and practical applications.

3. Methodology

This study employs a conceptual research approach to develop a Sustainable Intelligent Systems (SIS) model for Malaysian MSMEs. The methodology follows a structured process that includes literature study, model design, model development, and model refinement. This approach ensures a systematic construction of the conceptual model, integrating sustainability and intelligent technologies while addressing the specific needs and challenges faced by MSMEs in Malaysia. The research process consists of four main stages, as illustrated in Table 2.

Table 2: Research Methodology Framework

Phase	Activities	Output
Literature Study	• Review existing literature on sustainability and intelligent systems • Identify key challenges and opportunities for MSMEs in Malaysia • Analyze current models and frameworks used in similar contexts	Comprehensive understanding of relevant theories, concepts, and gaps
Model Design	• Define core components of the SIS model • Aligning model elements with MSME needs and sustainability goals • Develop initial conceptual framework	Initial SIS model framework tailored to Malaysian MSMEs
Model Development	• Elaborate on model components and interactions • Integrate intelligent technologies and sustainability elements • Ensure practical relevance through scenario mapping or expert input	Detailed SIS model integrating sustainability and intelligence
Model Refinement	• Validate the model through expert feedback or stakeholder consultation • Refine model structure and components • Ensure adaptability and scalability	Finalized and validated the SIS model for Malaysian MSMEs

The above table shows the structured research process, including literature study, model design, model development, and model refinement. The sequential flow highlights the systematic approach used to develop a Sustainable Intelligent Systems (SIS) model for Malaysian SMEs. The details for each stage are as follows.

3.1 Literature study

A comprehensive review of existing studies on MSMEs, sustainability, intelligent systems, and conceptual models was conducted to establish a strong foundation for this research. Multiple digital sources, such as ScienceDirect, IEEE Xplore, and Google Scholar, were reviewed to help identify key challenges in implementing Sustainable Intelligent Systems (SIS) in MSMEs, including technological limitations, financial constraints, and organizational resistance. Additionally, various theoretical frameworks were examined, such as the Technology-Organization-Environment (TOE) framework, which explores the external and internal factors influencing technology adoption; the Resource-Based View (RBV), which emphasizes the role of firm-specific resources in achieving competitive advantage; and the Triple Bottom Line (TBL) approach, which integrates economic, environmental, and social sustainability. These frameworks provide valuable insights into the factors that drive or hinder the successful adoption of SIS in MSMEs.

3.2 Model design

In the model design phase, the core structure and components of the Sustainable Intelligent Systems (SIS) model are defined. This involves identifying key elements such as sustainability indicators, intelligent technologies, and MSME-specific operational factors. The design process aligns these components with the needs and challenges identified in the literature review to ensure the model's relevance

and applicability. A conceptual framework is then developed to illustrate the interactions among these elements within the SIS model. This framework serves as a foundational blueprint for subsequent development and refinement.

3.3 Model development

The development of the Sustainable Intelligent Systems (SIS) model was grounded in a structured literature review and theoretical synthesis. Relevant academic and empirical studies on MSMEs, sustainability, digital transformation, and intelligent systems were thoroughly reviewed to identify common adoption challenges and success factors. This analysis revealed key barriers such as technological limitations, financial constraints, and organizational inertia that frequently hinder SIS implementation in MSMEs.

To guide the conceptualization of the model, three well-established theoretical frameworks were adopted. The TOE framework examines contextual and structural factors influencing technology adoption, the RBV highlights the role of internal capabilities in sustaining competitive advantage, and the TBL approach ensures alignment with economic, environmental, and social sustainability goals. These frameworks were selected based on their relevance to technology integration and sustainability in small enterprise settings.

Using insights derived from literature and these frameworks, a conceptual SIS model was constructed. The model integrates technological, organizational, environmental, and sustainability dimensions and is specifically tailored to the operational realities of MSMEs. Furthermore, to ensure alignment with international sustainability priorities, the model incorporates SDG 9: Industry, Innovation, and Infrastructure. This inclusion reinforces the model's relevance to both practice and policy by promoting innovation-driven, inclusive industrial development. Overall, this model serves as a structured foundation for analyzing SIS adoption and informs subsequent phases of empirical validation.

3.4 Model refinement

To enhance the conceptual model's relevance and applicability, necessary adjustments were made to ensure it accurately reflects real-world SME challenges and opportunities. The model's components were carefully restructured to better address the specific context of Malaysian MSMEs, considering industry-specific constraints, resource availability, and regulatory considerations. This refinement process aimed to create a more practical and adaptable framework that aligns with the operational realities of MSMEs in Malaysia.

To ensure the model's effectiveness, a final validation was conducted, assessing its potential to serve as a practical and strategic roadmap for MSMEs in adopting sustainable intelligent systems. This validation confirmed that the model offers actionable guidance, supporting businesses in integrating intelligent technologies while maintaining sustainability objectives. Through this process of refinement and validation, the study ensures that the model not only contributes to academic research but also provides MSMEs with a structured and effective approach to digital transformation and sustainability.

4. Proposed conceptual model for sustainable intelligent systems (SIS) in Malaysian MSMEs

The increasing need for sustainability and digital transformation has driven MSMEs to adopt Sustainable Intelligent Systems (SIS). However, the lack of a structured approach hinders successful implementation. This chapter presents a conceptual model designed to integrate intelligent systems with sustainability principles, offering MSMEs a strategic roadmap for SIS adoption.

The proposed conceptual model is designed to facilitate the adoption of Sustainable Intelligent Systems (SIS) in MSMEs by integrating three primary dimensions: technological, organizational, and environmental-sustainability factors such as in Fig. 1. These dimensions work together within the MSME ecosystem to create a holistic, sustainable, and intelligent business model. To begin with, the technological dimension represents the overall role of innovation and digital capabilities in enabling system intelligence and operational effectiveness. In addition, the organizational dimension reflects the internal capacity and strategic alignment needed to support and sustain the adoption of intelligent systems. Moreover, the environmental-sustainability dimension emphasizes the importance of aligning system development with broader ecological and sustainability goals. Collectively, these dimensions form a unified model that highlights the need for a holistic and integrated approach to implementing SIS in MSMEs. By addressing these dimensions simultaneously, the model promotes balanced progress, where technological advancement supports organizational efficiency and environmental responsibility, ultimately fostering long-term viability and competitiveness in an increasingly complex business landscape.



Fig. 1: Sustainable Intelligent System Dimensions

Building upon these three SIS dimensions, the proposed conceptual model for sustainable intelligent systems (SIS) in Malaysian MSME was constructed such as shown in Fig. 2. The model ensures that MSMEs have a high chance to successfully adopt SIS to address the longstanding challenges previously faced by Malaysian MSMEs. This model visually represents the interaction between the key components that drive the successful adoption of Sustainable Intelligent Systems (SIS) in MSMEs. It highlights how technological, organizational, and sustainability factors work together to create a holistic approach to digital transformation.

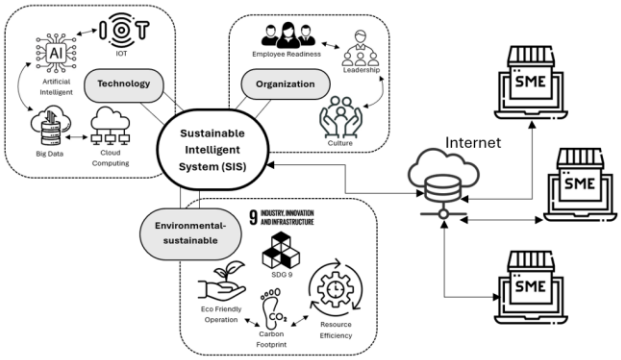


Fig. 2: Proposed Conceptual Model for SIS in MSMEs

The technological factors include the integration of AI, IoT, big data analytics, and cloud computing, which enhance automation, decision-making, and operational efficiency. These technologies serve as the backbone of intelligent systems, enabling MSMEs to optimize business processes and improve overall productivity. They also automate routine tasks, increase accuracy, reduce operational costs, and support more agile business management. For MSMEs, which often operate with limited resources, adopting such technologies can be transformative, providing the tools needed to compete effectively in a rapidly evolving digital economy.

The organizational factors focus on leadership commitment, employee readiness, and a culture of innovation. Strong leadership ensures strategic vision and resource allocation, while employee readiness through upskilling and digital literacy ensures smooth adoption of intelligent systems. An innovation-driven culture encourages continuous improvement and adaptation to emerging technologies. Additionally, cultivating a culture of innovation within the organization encourages experimentation, learning from failure, and proactive adaptation to technological advancements. Without organizational alignment and support, even the most advanced technologies may fail to deliver their full potential.

The sustainability factors align with Sustainable Development Goal (SDG) 9: Industry, Innovation, and Infrastructure, emphasizing eco-friendly operations, carbon footprint reduction, and resource efficiency. By incorporating sustainability-driven innovation, MSMEs can achieve long-term economic growth while minimizing their environmental impact. For example, intelligent systems can monitor energy usage in real time, helping businesses identify areas of excess consumption and implement corrective measures. Sustainable practices not only help protect the environment but also lead to long-term cost savings and improve the company's reputation among environmentally conscious consumers and partners. In the face of increasing environmental regulations and stakeholder expectations, integrating sustainability into core business strategies is becoming a competitive necessity rather than just an ethical choice.

The interaction of these three dimensions within the MSME ecosystem ensures that businesses can seamlessly implement SIS, resulting in enhanced competitiveness, improved efficiency, and long-term sustainability. Rather than treating each factor separately, the framework emphasizes their interdependence: technology needs to be supported by organizational capacity, and both must align with sustainability goals. This integrated approach enables MSMEs to become more efficient, agile, and responsible in their operations. It also enhances competitiveness by allowing businesses to innovate faster, meet regulatory requirements, and respond to market demands for sustainable practices. Ultimately, the framework serves as a strategic roadmap, guiding SMEs in their transition toward a more intelligent and environmentally responsible business model.

5. Discussion

The adoption of Sustainable Intelligent Systems (SIS) in MSMEs is a transformative process that requires a balanced integration of technological advancements, organizational preparedness, and sustainability-driven innovation. This study emphasizes that successful SIS adoption is not merely about implementing new technologies but also about fostering a conducive organizational culture and aligning business strategies with sustainability goals.

Emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), big data analytics, and cloud computing have reshaped business operations by enhancing efficiency, decision-making, and automation [30]. AI-driven automation enables MSMEs to streamline workflows and reduce operational inefficiencies, while IoT devices provide real-time monitoring of assets, optimizing resource utilization [31]. Additionally, cloud-based solutions offer cost-effective scalability, allowing MSMEs to adopt intelligent systems without significant infrastructure investments [32]. However, technological challenges such as high implementation costs, cybersecurity risks, and the digital divide remain significant barriers, particularly for resource-constrained MSMEs [33].

To broaden the scope of intelligent systems for sustainable development, the study further identifies blockchain and edge computing as promising technologies worth exploring. Blockchain enhances transparency and trust in transactions and supply chains, which is particularly valuable for small enterprises seeking to establish credibility [34]. Moreover, edge computing supports real-time data processing at or near the data source, reducing latency and reliance on centralized infrastructure, an advantage for operations in remote or bandwidth-constrained environments [35]. These technologies offer additional pathways for MSMEs to overcome existing limitations and strengthen their digital resilience in an increasingly competitive and connected marketplace.

Beyond technology, the readiness of an organization plays a pivotal role in SIS adoption. Leadership commitment is essential in driving strategic digital transformation, as leaders must allocate resources, set clear objectives, and cultivate a vision that aligns with intelligent system integration [36]. Employee readiness, including digital literacy and adaptability, is equally critical. A workforce resistant to change can impede digital transformation efforts, underscoring the need for continuous training and upskilling programs [37]. Additionally, fostering an innovative-driven culture encourages MSMEs to experiment with new digital solutions and embrace a mindset of continuous improvement [38].

Sustainability-driven innovation is a core component of SIS adoption, ensuring that MSMEs balance economic growth with environmental and social responsibilities. By aligning with Sustainable Development Goal (SDG) 9: Industry, Innovation, and Infrastructure, MSMEs can enhance their resilience while promoting eco-friendly business practices [39]. For example, adopting circular economy principles, such as waste minimization and resource efficiency, can significantly reduce environmental impact [40]. Furthermore, intelligent systems enable businesses to optimize energy consumption and lower carbon footprints through predictive analytics and machine learn-

ing models [41]. However, many MSMEs struggle with regulatory compliance and financial constraints, which hinder their ability to integrate sustainability-focused technologies [42].

Notably, several Malaysian MSMEs have demonstrated how digital transformation and sustainability initiatives can drive significant business growth and operational efficiency. For instance, MR DIY, a leading home improvement retailer, has leveraged data analytics to optimize inventory management, inform store expansion, and tailor offerings such as MR Toys and MR Dollar to specific consumer demands [43]. Similarly, Sambal Nyet by Khairul Aming showcases the power of digital marketing, where a strong social media presence and strategic use of e-commerce platforms transformed a home-based food business into a multimillion-ringgit brand [44]. On the sustainability front, myNEWS, a nationwide convenience store chain, has implemented eco-conscious practices including solar energy adoption, recycling programs, and the use of biodegradable packaging, demonstrating that even in retail, technology and environmental responsibility can go hand in hand [45]. These examples highlight the practical relevance of integrating intelligent systems and sustainability into MSME operations.

6. Conclusion

This study proposes a conceptual model for Sustainable Intelligent Systems (SIS) adoption in MSMEs, integrating technological, organizational, and sustainability factors. The findings highlight that successful SIS implementation requires a combination of advanced technologies (AI, IoT, big data, cloud computing), strong leadership, employee readiness, and sustainability-driven innovation. By aligning with Sustainable Development Goal (SDG) 9: Industry, Innovation, and Infrastructure, MSMEs can enhance operational efficiency while promoting long-term sustainability. The model provides practical insights for SMEs and policymakers, offering a strategic roadmap to facilitate digital transformation and sustainability initiatives.

Despite its contributions, this study has limitations. The conceptual model has not yet been empirically validated, and its applicability outside Malaysia remains uncertain. Additionally, emerging technologies such as blockchain, edge computing, and digital twins were not extensively explored. Future research should validate the model using real-world case studies and surveys, assess its effectiveness across different industries and countries, and examine the role of new digital innovations in enhancing SIS adoption.

To further improve MSME adoption of SIS, future studies should also investigate long-term impacts on business performance, sustainability, and competitiveness. Collaboration between researchers, policymakers, and industry leaders is crucial to developing customized incentives, regulatory frameworks, and training programs that support digital and sustainable transformation. By addressing these areas, MSMEs can strengthen their resilience, improve efficiency, and align with global sustainability goals.

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