Advanced Industrial and Business Management

Research Article
Volume 1(1), 2025, 84−97
https://doi.org/10.53623/aibm.v1i1.913

Building a Sustainable and Human-Centered Future: Industry 5.0 in Malaysia

H. M. Mahfuzur Rahman[1]*, Chinnasamy Agamudai Nambi Malarvizhi[1], Nasreen Khan[1], Adamu Abbas Adamu[2], Shereen Khan[1]

[1]Faculty of Management, Multimedia University, Cyberjaya, Malaysia
[2]Faculty of Applied Communication, Multimedia University, Cyberjaya, Malaysia

*Correspondence: mahfuzur1435@gmail.com

SUBMITTED: 21 November 2025; REVISED: 23 December 2025; ACCEPTED: 31 December 2025

ABSTRACT: Industry 5.0 prioritized the balance between technology and the social and environmental aspects of industry, as well as the ethical and socially responsible application of advanced technologies. While Industry 4.0 focused exclusively on optimizing industry through technological efficiency, Industry 5.0 promoted the importance of human–machine collaboration within socio-technical systems. Engaging with recent publications, the research evaluated the extent of the digital economy, sustainability, and inclusive stakeholder frameworks in Malaysia, as well as existing implementation gaps. The study revealed that, despite the availability of numerous technologies such as building information modeling, artificial intelligence, the Internet of Things, digital twins, and advanced traceability systems, their adoption remained unstable, technology-centered, and largely confined to dominant large organizations. Environmental degradation within the palm oil sector, the absence of substantial and comprehensive sustainability tools, skills gaps, and limited financial accessibility for small and medium enterprises and smallholders continued to hinder an inclusive transition to Industry 5.0. This study advocated an inclusive socio-technical framework for Industry 5.0 in Malaysia to semi-automate human work through the system design of a circular economy, resilient climate systems, and low-carbon risk mitigation, while prioritizing governance mechanisms for overlooked stakeholder groups. The study proposed innovative financing mechanisms, digital and sustainability co-initiatives, and the rapid adoption of collaborative governance frameworks as primary policy approaches. The dissertation aimed to contribute to emerging Industry 5.0 discourse in developing economies by emphasizing the importance of balancing technological advancement, social justice, and environmental stewardship. It also encouraged further research at the firm, supply chain, and community levels to operationalize Industry 5.0 more effectively.

KEYWORDS: Industry 5.0; sustainability; human-centred works; palm oil; malaysian construction.

1. Introduction

Industry 5.0, with its focus on sustainable and human-centered work, had begun to gain traction across many sectors in Malaysia. Stakeholders increasingly valued technological advancements associated with Industry 5.0 and how these could be utilized to complement societal activities, thereby enhancing economic resilience. As Malaysia worked toward national sustainability, the palm oil and construction industries contributed significantly by providing a range of targeted ecological and economic benefits. The palm oil industry was crucial to the national economy, contributing approximately 5–7% to GDP and requiring sustainable initiatives to remain economically viable and equitable for smallholder farmers [1]. Similarly, the construction sector was being guided toward sustainability through the National Construction Policy, which promoted sustainable building practices [2].

However, the principles of Industry 5.0 could not be implemented without transdisciplinary and transsectoral collaboration that created space for marginalized voices [3]. This approach aligned with Malaysia’s vision of a circular economy, which sought to promote economic and technological advancement while addressing pressing environmental concerns [4]. Although Malaysia was likely to adopt Industry 5.0, the government was required to develop a supportive environment that promoted innovation and sustainability across both existing and emerging systems. Given favorable policies and stakeholder engagement, the country was positioned to progress sustainably while strengthening its status as a developing economy with robust growth potential [5].

Nevertheless, the influence of global sustainability trends and human-centric practices on Industry 5.0 within the manufacturing sector continued to evolve. The Malaysian manufacturing industry was undergoing transformational change, with the construction and palm oil sectors beginning to integrate technological and sustainable practices. For instance, the construction industry had adopted Building Information Modeling (BIM) to streamline processes, enhance project management efficiency, and improve sustainability outcomes [6]. Likewise, the palm oil industry, which occupied a prominent position in Malaysia’s economy, began adopting eco-sustainable practices, particularly in waste management, representing a necessary shift given its historical association with deforestation and greenhouse gas emissions [7].

Industries had already faced an urgent need for innovation prior to the COVID-19 pandemic, a need that was further intensified by the crisis. As noted by [8], organizations in Malaysia attempted to achieve operational continuity during and after the pandemic through the adoption of structured frameworks. The food industry’s commitment to halal certification processes further highlighted the importance of operational efficiency and balanced, integrative marketing strategies aligned with consumer preferences [9]. The transition toward Industry 5.0 therefore extended beyond technological adoption and reflected a broader reorganization of industry aimed at achieving a sustainable and inclusive development balance. Malaysia was well positioned to achieve these objectives, provided that research findings were applied to relevant national systems and structures.

This study focused on the balancing act Malaysia faced in transitioning to Industry 5.0 while addressing persistent socio-economic and environmental challenges. Although Malaysia had advanced significantly in technology and infrastructure, primary industries such as construction and palm oil continued to experience sustainability and social equity concerns. Traditional practices had contributed to social inequities and environmental degradation. For example, the palm oil sector had been widely criticized for deforestation, biodiversity loss, and other environmentally harmful practices, reflecting a systemic failure to balance environmental and economic priorities [10].

Similarly, although the construction sector had begun adopting technological innovations such as BIM, it continued to face challenges in achieving sustainability and innovation. These challenges were largely attributed to limited commitment to quality management, shortages of skilled labor, and the absence of supporting frameworks. Consequently, socio-economic inequities persisted within the sector [11]. Balancing the benefits offered by Industry 5.0 with the challenges it introduced therefore emerged as a core priority for Malaysia, ensuring that economic advancement occurred alongside ecosystem protection.

The study of Industry 5.0 in Malaysia presented multiple avenues for future research. Notably, there remained a lack of empirical studies evaluating the integration of humanistic perspectives within the national context. Existing literature extensively discussed technological advancements, particularly artificial intelligence and the Internet of Things, within Industry 5.0 [12]. However, limited attention had been given to how these technologies could be integrated into Malaysia's socio-economic systems. Moreover, research tended to emphasize economic sustainability while underrepresenting social dimensions. This was evident in the findings of [12], which reported that many Malaysian manufacturing firms did not practice social sustainability, revealing a gap between technological adoption and social objectives central to Industry 5.0 [13].

Additionally, existing studies often overlooked the challenges faced by smallholder farmers in the palm oil sector, despite their importance to social sustainability. While broader socio-economic concerns had been acknowledged, focused analyses of smallholder experiences remained limited. Furthermore, the implications of Industry 5.0 for fostering equitable human–machine collaboration in Malaysia had not been adequately explored [14]. Addressing these gaps was essential for advancing neglected dimensions of sustainability within Malaysian industries.

The objective of this research was to comprehensively analyze the opportunities and challenges presented by Industry 5.0 within the Malaysian manufacturing landscape, particularly in relation to sustainability and human-centered methodologies. The study sought to identify key barriers hindering the effective implementation of Industry 5.0 practices in the palm oil and construction sectors, especially regarding the integration of advanced technologies with local social and economic needs. It also aimed to assess existing levels of stakeholder engagement and collaboration, emphasizing the importance of inclusive dialogue among policymakers, industry leaders, and smallholders. Furthermore, the research explored the implications of emerging technologies for workforce dynamics, focusing on how human–machine collaboration could enhance productivity while promoting social equity. In doing so, the study proposed actionable frameworks and strategies to support economic and social sustainability and align Malaysia's transition with global responsibilities.

By offering insights into sustainable practices, this research contributed to the understanding of Industry 5.0 in Malaysia and explicitly examined gaps within existing industrial frameworks. The study addressed social inequities, environmental innovation, and the adoption of eco-sustainable technologies as best practices for fostering social sustainability [15]. Previous studies had also inadequately emphasized stakeholder participation [16]. This research extended beyond academic inquiry by offering policy-relevant insights aimed at reducing long-standing socio-economic inequities within the palm oil and construction sectors. Moreover, the examination of human–machine interaction sought to promote collaborative practices that enhanced productivity while creating meaningful employment opportunities [17].

As one of the earliest studies of its kind in Malaysia, this research was expected to contribute significantly to scholarly and policy debates on Industry 5.0 and sustainability [18]. The findings may also offer transferable insights for other developing economies, positioning Malaysia as a reference case for sustainable industrial transformation under Industry 5.0 [19].

2. Literature Review

2.1. Transition from Industry 4.0 to 5.0.

The transition from Industry 4.0 to Industry 5.0 marked the emergence of an entirely new industrial paradigm, one that explicitly incorporated sustainability and socio-economic dimensions. The implementation of cyber–physical systems, such as the Internet of Things (IoT), cloud computing, and big data analytics, as characteristic of Industry 4.0, aimed to optimize production, enable seamless connectivity, and enhance operational efficiency [20]. These technologies facilitated large-scale data collection and the automation of manufacturing environments, enabling real-time decision-making and allowing managerial focus to shift toward more complex and strategic tasks. However, the primary emphasis during this era remained largely technological, while the social and ethical implications of technological advancement were frequently overlooked. In contrast, Industry 5.0 sought to integrate advanced technologies with human collaborative effort. Within this paradigm, technology was designed to augment rather than replace human labor [21]. This shift underscored the growing importance of ethical artificial intelligence, as social value was increasingly regarded as more significant than purely economic value. Furthermore, Industry 5.0 emphasized co-creation, an innovation process involving diverse participants such as employees, customers, and suppliers. This collaborative approach aimed to generate innovations that delivered not only economic benefits but also environmentally beneficial outcomes [22]. A core pillar of Industry 5.0 was its strong advocacy for green innovation, which involved the adoption of eco-friendly materials and manufacturing methods that incorporated waste reduction and emissions mitigation. These efforts directly addressed urgent global challenges such as climate change and resource scarcity [23]. Increasingly, enterprises adopted circular economy principles to enhance resource efficiency and extend product life cycles, thereby reducing the overall ecological footprint of industrial activities. The social value of Industry 5.0 was reflected in its emphasis on inclusivity and equitable development. By aiming to reduce technological disparities, Industry 5.0 sought to improve living standards and overall quality of life for all stakeholders involved in industrial ecosystems [24].

2.2. Human-centric work.

Industry 5.0 shifted the focus toward automation-enabled work environments that supported employee engagement, skill development, and ergonomic improvement. Empirical evidence indicated that the integration of automation with ergonomic redesign of work processes resulted in higher productivity and greater employee satisfaction [25]. While automation was essential for improving efficiency in routine and non-complex tasks, human involvement remained critical for managing non-automatable activities that required creativity and innovation. Research demonstrated that effective organizations actively promoted employee participation in decision-making processes and in the redesign of workflows and operational structures. Such participation enabled organizations to harness employees' creativity and contextual knowledge when developing organizational solutions, making participatory design a key determinant of optimal workplace outcomes [26]. Organizations that adopted collaborative strategies reported significant improvements in job satisfaction and organizational commitment, as employees valued having their contributions recognized. Additionally, firms that implemented workplace design strategies aligned with employees' needs experienced notable improvements in employee health and productivity. High standards of workplace ergonomics also yielded economic benefits, including reduced injury rates, lower absenteeism, and enhanced overall productivity.

2.3. Sustainability & circularity.

Life cycle assessment (LCA), sustainability practices, and traceability emerged as critical contributors to the growing integration of sustainability and circularity within the Industry 5.0 paradigm. Advanced approaches such as digital twins, LCA, and supply chain traceability complemented circular production models. Digital twins, in particular, enabled the monitoring and optimization of energy use across production processes, thereby reducing carbon emissions [27]. Enhanced operational efficiency for sustainable practices was achieved by systematically addressing energy-related inefficiencies. Advancements in LCA significantly improved the socio-economic sustainability of goods and services [28]. By evaluating environmental costs across all stages of a product's life cycle, from raw material extraction and production to transportation, usage, and disposal, LCA enabled producers to identify environmentally harmful and economically costly processes. The potential for cost savings increased when inefficiencies were addressed earlier in the production cycle. Moreover, shifting LCA cost considerations downstream to distributors and consumers facilitated faster reductions in environmental emissions and production costs. LCAs also identified opportunities for material reuse, stock optimization, and reduced demand for virgin materials. Sustainable supply chain accountability increasingly relied on technological integration and traceability systems. These systems supported continuous environmental impact assessments (EIA) across entire supply chains [29], enabling firms to verify the authenticity of materials used in sustainable production and to ensure compliance with environmental standards.

2.4. Resilience of post-pandemic.

The COVID-19 pandemic, together with climate change–related disruptions, intensified the relevance of resilience within industrial systems. During this period of adaptation, organizations required rapidly evolving systems, resilient local supply chains, and advanced data analytics to support effective problem management [30]. Resilient industrial systems enabled organizations to adapt operational processes in response to dynamic and uncertain environmental conditions, thereby allowing them to endure and recover during periods of disruption. Operational flexibility emerged as a fundamental component of resilience. The ability to reconfigure production and logistics systems efficiently enabled firms to respond effectively to fluctuating supply and demand conditions. Organizations capable of rapidly reallocating operational resources demonstrated enhanced resilience and sustained operational efficiency during crises [31]. Strengthening collaborative relationships with local suppliers further reduced lead times and enhanced responsiveness to disruptions, reinforcing overall supply chain robustness.

The application of data analytics for risk management further enhanced organizational resilience. Predictive analytics allowed firms to identify potential vulnerabilities in operations and supply chains, thereby enabling proactive rather than reactive risk management. Real-time monitoring systems improved decision-making speed during disruptions, while scenario-based risk assessments supported the development of more robust mitigation strategies [32]. Organizations that had previously adopted adaptive managerial practices experienced less severe operational disruptions and recovered more rapidly, highlighting the strategic importance of resilience-oriented operational models.

2.5. Developing economy context.

The characteristics of developing economies significantly shaped the operational environment of small and medium-sized enterprises (SMEs), which constituted a substantial portion of economic activity in these regions. SMEs in developing economies were typically constrained by limited financial resources, skill shortages, and underdeveloped infrastructure. Despite ongoing economic growth, these constraints reduced SMEs' capacity to innovate and expand sustainably [33]. Weak institutional frameworks further compounded these challenges, limiting long-term SME development and sustainability. Alternative financial models, such as profit-sharing arrangements based on Musharakah principles, were shown to support SME financing without the burdens associated with conventional debt structures [34]. These models aligned financial risk-sharing with ethical considerations and stakeholder welfare, making them particularly suitable for SMEs in resource-constrained environments. Resource-sharing models also played a critical role in alleviating SME constraints by reducing technology acquisition and maintenance costs. Collaborative ecosystems encouraged the sharing of knowledge and information, helping to address skill gaps and enhance organizational capabilities [35]. Evidence indicated that SMEs operating within collaborative networks were more resilient, adaptable, and better positioned to overcome operational challenges. Additionally, shared resources improved market access and reduced supply chain inefficiencies, thereby strengthening SMEs' competitive advantage. The increasing adoption of data-driven decision-making further enhanced SME resilience. Predictive analytics provided insights into market trends, customer behavior, and operational performance, enabling SMEs to make more informed strategic decisions. These insights also supported targeted training initiatives aimed at closing skills gaps and aligning workforce capabilities with evolving industry requirements [36].

3. Methodology

This study adopted a quantitative, cross-sectional survey design to examine the relationships between Industry 5.0 enablers and sustainability outcomes in Malaysia's palm oil and construction sectors. This approach was appropriate for testing hypotheses regarding how human-centric practices, circularity initiatives, and resilience capabilities influenced the implementation of Industry 5.0. The target population comprised stakeholders involved in both sectors, including managers, engineers, sustainability officers, supervisors, and smallholder representatives. A stratified sampling approach was applied to ensure adequate representation across two dimensions: (1) sector (palm oil versus construction) and (2) stakeholder type. Respondents were recruited through industry associations, company networks, and cooperative or smallholder groups.

4. Results and Discussion

4.1. Overview of Industry 5.0 readiness.

The results of this study provided an overview of the sample population and the level of Industry 5.0 readiness in the Malaysian palm oil and construction sectors. The descriptive outcomes indicated the level of technology integration and the adoption of human-centric practices (such as participation and upskilling), circular economy practices (such as waste and loss reduction, traceability), and post-pandemic resilience within these industries. The inferential statistics confirmed that human-centric work, sustainable and circular economy practices, and resilience had positive and significant associations with Industry 5.0 implementation and sustainability performance outcomes. Sectoral comparisons identified which sector was more prepared and which barriers (such as skills, cost, supporting frameworks, and stakeholder collaboration) were more prominent, thereby offering tailored insights for policymakers and industry leaders.

Figure 1 compared the mean Likert-scale (1–5) scores of key Industry 5.0 dimensions across the palm oil and construction sectors. It illustrated which sector reported stronger levels of human-centric work, sustainability and circularity, resilience, technology integration, and overall Industry 5.0 implementation.

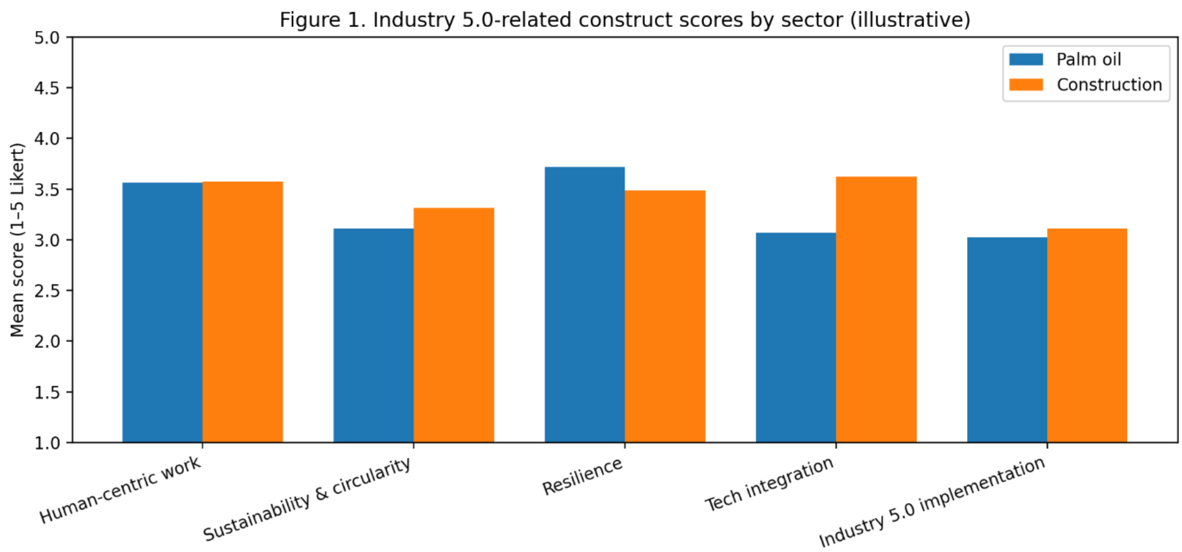

Figure 1. Industry 5.0 related construct sector.

Figure 2 presented the standardized regression coefficients (β) of the main predictors influencing Industry 5.0 implementation. Higher β values indicated stronger effects, demonstrating which factors contributed most to explaining Industry 5.0 implementation outcomes.

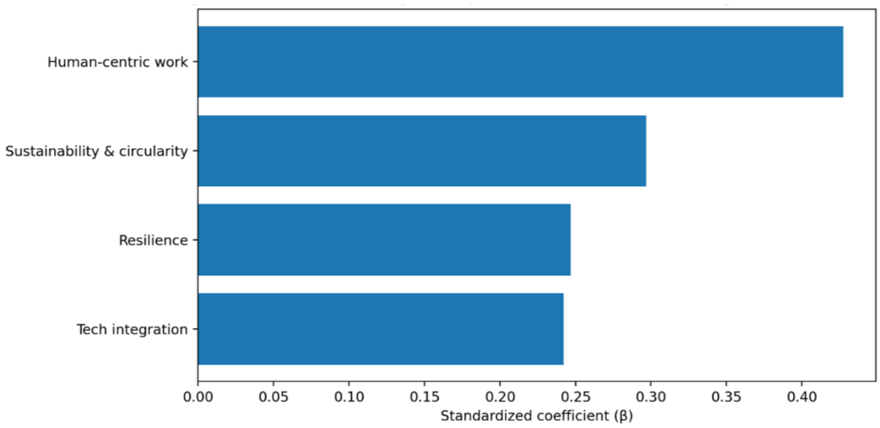

Figure 2. Drivers of Industry 5.0 implementation.

Figure 3 summarized the percentage of respondents reporting major barriers to Industry 5.0 adoption in each sector. It highlighted the dominant constraints, including skills gaps, funding limitations, governance issues, data and traceability infrastructure, and stakeholder engagement, and showed how these barriers differed between the palm oil and construction sectors.

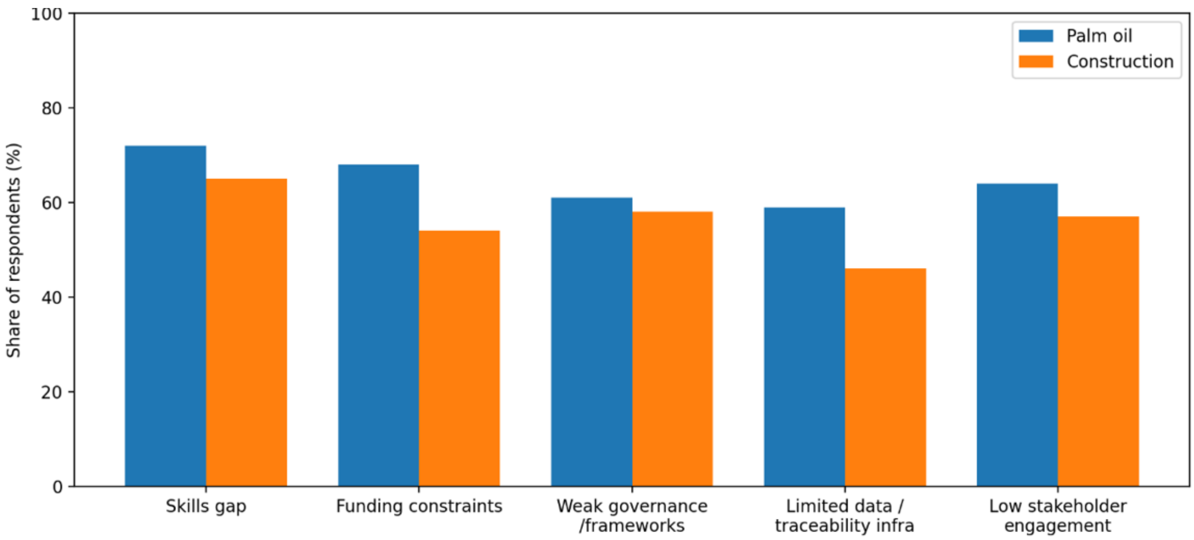

Figure 3. Main barriers to Industry 5.0 adoption by sector.

4.2. Discussion of key findings.

The purpose of this study was to explore the potential of Industry 5.0 as a framework for flexible, human-centric, and sustainable industrial transformation in the Malaysian palm oil and construction industries. Overall, the discussion suggested that there was growing recognition within Malaysian industries of the need to move beyond a purely technocentric Industry 4.0 approach. Nevertheless, the operationalization of human-centricity, sustainability, and resilience remained fragmented and unsystematic. These findings supported the argument that, in developing countries, Industry 5.0 was not merely about introducing advanced technologies, but fundamentally involved redefining socio-technical arrangements and governance-based business models to address persistent environmental and social challenges [13].

The analysis indicated that Industry 4.0-oriented initiatives in Malaysia's processing sectors continued to be driven largely by efficiency and productivity objectives, particularly in manufacturing, palm oil, and construction. Technologies such as BIM and IoT were rarely associated with improved human or societal outcomes, instead functioning primarily to enhance operational control and coordination [6]. In contrast, the Industry 5.0 perspective reframed these technologies as enablers of co-creation, ethical artificial intelligence, and positive societal value [22]. Achieving this shift required deliberate changes in managerial mindsets and policy priorities, as many firms continued to view digitalization as a top-down, automation-driven cost-reduction strategy. Human-centric Industry 5.0 approaches, however, emphasized participatory decision-making, worker empowerment, and community involvement as core principles [28]. This implied a need for organizational redesign that prioritized human creativity and judgment rather than treating workers as residual complements to automated systems.

The findings further highlighted that human-centricity in Malaysia could not be separated from issues of social equity, particularly for smallholders in the palm oil sector and low-skilled workers in construction. While existing literature emphasized the environmental and social controversies surrounding palm oil production, including deforestation and unequal benefit distribution [7], this study extended the discussion by positioning smallholders and marginalized workers as central actors in the Industry 5.0 transition rather than passive beneficiaries. Evidence from the literature suggested that productivity and well-being gains were greatest when automation was combined with redesigned workflows and active worker participation [26]. Accordingly, palm oil plantations, mills, and construction sites were encouraged to involve workers and smallholders in process design and technological decision-making.

In practice, digital tools for traceability and quality management should not have been imposed solely as compliance mechanisms but instead co-developed to reflect local knowledge and constraints. Previous studies documented persistent skills gaps, indicating that without integrated upskilling and reskilling strategies, Industry 5.0 transitions risked exacerbating inequality [37]. In the construction sector, the integration of BIM and other digital tools required enhanced technical and collaborative skills, yet many workers remained excluded from training opportunities due to precarious employment conditions [38]. Genuine human-centricity therefore required inclusive training pathways, supported by public–private partnerships and tailored to SMEs and small construction firms.

Another central finding concerned the gap between sustainability aspirations and the practical implementation of circular economy measures. Although digital twins, life cycle assessment, and traceability systems were recognized as tools for low-carbon production and responsible supply chains, adoption remained uneven and concentrated among larger firms. In the palm oil sector, traceability initiatives were often inaccessible to smallholders due to infrastructure and digital skills limitations [7]. Similarly, many construction SMEs lacked the data and tools needed to assess environmental impacts. These findings reinforced the need for simple, modular technologies that could be adopted more easily by resource-constrained actors [39]. Collaborative platforms for LCA, digital twins, and traceability, governed by industry or public-sector consortia, could help reduce access barriers and promote more inclusive sustainability transitions.

Resilience also emerged as a key theme, particularly in relation to supply chain disruptions and climate risks. While the construction sector demonstrated vulnerabilities related to global supply chain dependencies and just-in-time logistics [13], the palm oil sector faced climate-related risks such as droughts and flooding. The findings suggested that resilience and sustainability should be viewed as complementary rather than competing objectives. Low-carbon and circular practices, including resource efficiency and waste valorization, had the potential to reduce exposure to regulatory and climate-related risks while enhancing long-term legitimacy and stakeholder trust [40].

Finally, the study highlighted that Industry 5.0 in Malaysia should be approached as a governance challenge as much as a technological one. Structural constraints related to finance, infrastructure, and skills continued to shape the trajectories of SMEs and smallholders. Limited access to funding restricted investments in technology, sustainability, and training [14]. Alternative financing mechanisms, including Islamic finance models such as Musharakah, were identified as potential pathways to better align risks and rewards for smaller actors [25]. Shared facilities, cooperative training centers, and improved data analytics capabilities were also identified as mechanisms to enhance SME competitiveness.

Overall, the results suggested that more inclusive, multi-stakeholder governance arrangements were required to align Industry 5.0 principles with national policies and sectoral strategies [4]. Integrating human-centric and sustainability criteria into industrial incentives, public procurement, and education systems was essential. This study contributed to the emerging Industry 5.0 literature by emphasizing its relevance to developing economies and resource-constrained sectors. It concluded that Industry 5.0 extended beyond technological readiness and required systemic transformations in governance, skills development, and stakeholder engagement.

5. Conclusion

Aspects related to the opportunities and challenges associated with the implementation of Industry 5.0 in Malaysia’s construction and palm oil sectors had already been examined in previous studies. Industry 5.0 was not merely an extension of Industry 4.0; rather, it represented a fundamental rethinking of the industrial paradigm that prioritized people, planetary well-being, and the development of climate-resilient economies. In the Malaysian context, the focus needed to shift away from excessive automation and efficiency toward greater inclusiveness and environmental and social balance. Malaysia possessed foundational elements such as BIM and IoT adoption in construction, emerging sustainability policies, and growing awareness of circular economy principles. However, these foundations were unevenly developed and fragmented, particularly favoring larger firms, while persistent gaps remained in skills development, financing, and governance structures. As a result, SMEs, smallholders, and low-skilled workers were often excluded from meaningful participation in Industry 5.0 initiatives, increasing the risk of widening socioeconomic inequalities and environmental degradation. Consequently, a truly human-centric transformation required a highly localized approach. In the palm oil sector, smallholders should not have been treated merely as passive recipients of compliance requirements but rather recognized as equal partners in the innovation of digital traceability systems, sustainability certification processes, and broader change initiatives. Similarly, in the construction sector, digitalization should not have been confined to improving project execution efficiency but should also have encompassed system designs that enhanced workplace ergonomics, supported continuous worker integration, and enabled ongoing skills upgrading. This research further demonstrated the interconnectedness of sustainability, circularity, and resilience, as technologies such as digital twins, life cycle analysis, and data-driven risk management could support low-carbon, resource-efficient operations while simultaneously strengthening operational readiness for disruptions. From a policy perspective, the findings indicated that greater emphasis should have been placed on embedding Industry 5.0 principles into national industrial and sustainability policies, expanding access to targeted financial and fintech solutions for SMEs and smallholder agriculture, strengthening synergies within skills ecosystems linking government, industry, and education, and establishing collaborative frameworks to align stakeholder expectations and develop coherent sectoral roadmaps.

Acknowledgments

The authors acknowledged the assistance of the Editor and Reviewers in supporting the preparation of the article for publication.

Author Contribution

Conceptualization was carried out by H. M. Mahfuzur Rahman and Shereen Khan. The literature review was conducted by H. M. Mahfuzur Rahman, Chinnasamy Agamudai Nambi Malarvizhi, Adamu Abbas Adamu, and Shereen Khan. The discussion section was developed by H. M. Mahfuzur Rahman, Chinnasamy Agamudai Nambi Malarvizhi, Nasreen Khan, and Shereen Khan. The conclusion was prepared by H. M. Mahfuzur Rahman, Nasreen Khan, Adamu Abbas Adamu, and Chinnasamy Agamudai Nambi Malarvizhi. Writing of the manuscript was undertaken by H. M. Mahfuzur Rahman, Adamu Abbas Adamu, and Shereen Khan

Competing Interest

Declare conflicts of interest or state: “The authors declare no conflicts of interest.”

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

[1] Majid, U.; Wasim, A.; Truong, J.; Bakshi, S. (2021). Public trust in governments, health care providers, and the media during pandemics: A systematic review. *Journal of Trust Research*, *11*, 119–141. https://doi.org/10.1080/21515581.2022.2029742.

[2] Babalola, A.; Harinarain, N. (2024). Policy barriers to sustainable construction practice in the Nigerian construction industry: An exploratory factor analysis. *Journal of Engineering, Design and Technology*, *22*, 214–234. https://doi.org/10.1108/JEDT-07-2021-0375.

[3] Lau, J.J.; Cheng, S.M.; Leung, K.; Lee, C.K.; Hachim, A.; Tsang, L. C.; Wu, J.T. (2023). Real-world COVID-19 vaccine effectiveness against the Omicron BA.2 variant in a SARS-CoV-2

infection-naive population. *Nature Medicine*, *29*, 348–357. https://doi.org/10.1038/s41591-023-02219-5.

[4] Ismail, N.A.; Omar, S.V.; Moultrie, H.; Bhyat, Z.; Conradie, F.; Enwerem, M.; Ndjeka, N. et al. (2022). Assessment of epidemiological and genetic characteristics and clinical outcomes of resistance to bedaquiline in patients treated for rifampicin-resistant tuberculosis: A cross-sectional and longitudinal study. *The Lancet Infectious Diseases*, *22*, 496–506. https://doi.org/10.1016/S1473-3099(21)00470-9.

[5] Chin, K.M.; Sitbon, O.; Doelberg, M.; Feldman, J.; Gibbs, J.S.R.; Grünig, E.; Galiè, N., et al. (2021). Three-versus two-drug therapy for patients with newly diagnosed pulmonary arterial hypertension. *Journal of the American College of Cardiology*, *78*, 1393–1403. https://doi.org/10.1016/j.jacc.2021.07.057.

[6] Tanko, E.L.N.; Danguene, P. E.; Tsoungui, P. N. E.; Ganno, S.; Wambo, J. D. T.; Tchoupe, B. G. T.; Nzenti, J. P. (2022). Geochemistry and zircon U–Pb ages of the Paleoproterozoic ultramafic rocks of the Mbi Valley, Boali area, Central African Republic. *Acta Geochimica*, *41*, 515–535. https://doi.org/10.1007/s11631-022-00540-3.

[7] Haw, I.M.; Swink, M.; Zhang, W. (2023). The role of direct equity ownership in supply chains. *Journal of Operations Management*, *69*, 586–615. https://doi.org/10.1002/joom.1224.

[8] Prapinit, P.; Kafi, A.; Osman, N.H.; Melan, M. (2024). IoT in courier services: Impact on customer satisfaction and supply chain sustainability. *International Journal of Sustainable Development & Planning*, *19,* 671–679. https://doi.org/10.18280/ijsdp.190224.

[9] Abdullah, G.; Arifin, A.; Saro'i, M.; Uhai, S. (2024). Assessing the influence of learning styles, instructional strategies, and assessment methods on student engagement in college-level science courses. *International Education Trend Issues*, *2*, 142–150. https://doi.org/10.56442/ieti.v2i2.466.

[10] Hariram, N.P.; Mekha, K.B.; Suganthan, V.; Sudhakar, K. (2023). Sustainalism: An integrated socio-economic-environmental model to address sustainable development and sustainability. *Sustainability*, *15*, 10682. https://doi.org/10.3390/su151310682.

[11] Siti-Dina, R.P.; Er, A.C.; Cheah, W.Y. (2023). Social issues and challenges among oil palm smallholder farmers in Malaysia: Systematic literature review. *Sustainability*, *15*, 3123. https://doi.org/10.3390/su15043123.

[12] Chander, B., Pal, S., De, D., Buyya, R. (2022). Artificial Intelligence-based Internet of Things for Industry 5.0. In Artificial Intelligence-based Internet of Things Systems. Internet of Things. : Pal, S., De, D., Buyya, R., Eds.; Springer: Cham, Switzerland. https://doi.org/10.1007/978-3-030-87059-1_1.

[13] Agote-Garrido, A.; Martín-Gómez, A. M.; Lama-Ruiz, J. R. (2023). Manufacturing system design in Industry 5.0: Incorporating sociotechnical systems and social metabolism for human-centered, sustainable, and resilient production. *Systems*, *11*, 537. https://doi.org/10.3390/systems11110537.

[14] Li, L.; Duan, L. (2025). Human centric innovation at the heart of industry 5.0 – exploring research challenges and opportunities. *International Journal of Production Research*, 1–33. https://doi.org/10.1080/00207543.2025.2462657.

[15] Barajas-Ochoa, A.; Peláez-Ballestas, I.; Ramirez-Trejo, M.; Gradilla-Magaña, P.; Cisneros-Barrios, A.; de Lara, A. M.; Ramos-Remus, C. (2023). Gender representation in rheumatology journals: An assessment of editors, editorial boards, and authors. *Rheumatology International*, *43*, 1811–1819. https://doi.org/10.1007/s00296-023-05390-7.

[16] Morales-Garzón, S.; Parker, L. A.; Hernández-Aguado, I.; González-Moro Tolosana, M.; Pastor-Valero, M.; Chilet-Rosell, E. (2023). Addressing health disparities through community participation: A scoping review of co-creation in public health. *Healthcare*, *11*, 1034. https://doi.org/10.3390/healthcare11071034.

[17] Dimyati, M.; Hermanu, A.I. (2023). Evaluating research efficiency in Indonesian higher education institutions. *Evaluation Review*, *47*, 155–181. https://doi.org/10.1177/0193841x221118181.

[18] Ali, I. (2020). The COVID-19 pandemic: Making sense of rumor and fear: Op-ed. *Medical Anthropology*, *39*, 376–379 https://doi.org/10.1080/01459740.2020.1745481.

[19] Maddi, A.; Maisonobe, M.; Boukacem-Zeghmouri, C. (2025). Geographical and disciplinary coverage of open access journals: OpenAlex, Scopus, and WoS. *PLoS One*, *20*, e0320347. https://doi.org/10.1371/journal.pone.0320347.

[20] Khamisu, M.S.; Paluri, R.A.; Sonwaney, V. (2024). Environmental social and governance (ESG) disclosure motives for environmentally sensitive industry: An emerging economy perspective. *Cogent Business & Management*, *11*, 2322027. https://doi.org/10.1080/23311975.2024.2322027.

[21] Khosravy, M.; Gupta, N.; Pasquali, A.; Dey, N.; Crespo, R.G.; Witkowski, O. (2023). Human-collaborative artificial intelligence along with social values in industry 5.0: A survey of the state-of-the-art. *IEEE Transactions on Cognitive and Developmental Systems*, *16*, 165–176. https://doi.org/10.1109/TCDS.2023.3326192.

[22] Yoopetch, C.; Nimsai, S. (2019). Science mapping the knowledge base on sustainable tourism development, 1990–2018. *Sustainability*, *11*, 3631. https://doi.org/10.3390/su11133631.

[23] Karaosman, H.; Morales-Alonso, G.; Brun, A. (2016). From a systematic literature review to a classification framework: Sustainability integration in fashion operations. *Sustainability*, *9*, 30. https://doi.org/10.3390/su9010030.

[24] Pujotomo, D.; Syed Hassan, S.A.H.; Ma'aram, A.; Sutopo, W. (2023). University–industry collaboration in the technology development and technology commercialization stage: A systematic literature review. *Journal of Applied Research in Higher Education*, *15*, 1276–1306. https://doi.org/10.1108/JARHE-11-2022-0344.

[25] Chen, H. X.; Chen, W.; Liu, X.; Liu, Y.R.; Zhu, S.L. (2017). A review of the open charm and open bottom systems. *Reports on Progress in Physics*, *80*, 076201. https://doi.org/10.1088/1361-6633/aa6420.

[26] Balaji, K. (2025). Human-Centric Innovation: Building Sustainable Organizations for Industry 5.0. In Human-Centric, Sustainable, and Resilient Organizations in the Digital Age; Sakshi, S.D., Ed.; IGI Global Scientific Publishing: New York, USA. pp. 101–124.

[27] Gomide, P.; Patricio, R.; Gancho, S. (2024). Human-Centered design approaches to Industry 4.0 challenges: Directions for future research. *The International Journal of Design Management and Professional Practice*, *19*, 1. https://doi.org/10.18848/2325-162X/CGP/v19i01/1-34.

[28] Bortolini, R.; Rodrigues, R.; Alavi, H.; Vecchia, L.F.D.; Forcada, N. (2022). Digital twins' applications for building energy efficiency: A review. *Energies*, *15*, 7002. https://doi.org/10.3390/en15197002.

[29] Ghoroghi, A.; Rezgui, Y.; Petri, I.; Beach, T. (2022). Advances in application of machine learning to life cycle assessment: A literature review. *The International Journal of Life Cycle Assessment*, *27*, 433–456. https://doi.org/10.1007/s11367-022-02030-3.

[30] Dias, A.; Nezami, S.; Silvestre, J.; Kurda, R.; Silva, R.; Martins, I.; de Brito, J. (2022). Environmental and economic comparison of natural and recycled aggregates using LCA. *Recycling*, *7*, 43. https://doi.org/10.3390/recycling7040043.

[31] McGrath, P.; McCarthy, L.; Marshall, D.; Rehme, J. (2021). Tools and technologies of transparency in sustainable global supply chains. *California Management Review*, *64*, 67–89. https://doi.org/10.1177/0008125621992061.

[32] Vazquez Melendez, E.I.; Bergey, P.; Smith, B. (2024). Blockchain technology for supply chain provenance: increasing supply chain efficiency and consumer trust. *Supply Chain Management: An International Journal*, *29*, 706–730. https://doi.org/10.1108/SCM-04-2023-0203.

[33] Burke, H.; Zhang, A.; Wang, J.X. (2023). Integrating product design and supply chain management for a circular economy. *Production Planning & Control*, *34*, 1097–1113. https://doi.org/10.1080/09537287.2022.2101426.

[34] Ahmed, A.A.; Nazzal, M.A.; Darras, B.M. (2022). Cyber-physical systems as an enabler of circular economy to achieve sustainable development goals: A comprehensive review. *International Journal of Precision Engineering and Manufacturing-Green Technology*, *9*, 955–975. https://doi.org/10.1007/s40684-022-00469-w.
[35] Liaset, I.F.; Fimland, M.S.; Holtermann, A.; Mathiassen, S.E.; Redzovic, S. (2023). Can home care work be organized to promote health among the workers while maintaining productivity? An investigation into stakeholders' perspectives on organizational work redesign concepts based on the goldilocks work principles. *BMC Health Services Research*, *23*, 667. https://doi.org/10.1186/s12913-023-09768-3.
[36] Yu, Z.; Razzaq, A.; Rehman, A.; Shah, A.; Jameel, K.; Mor, R.S. (2022). Disruption in global supply chain and socio-economic shocks: A lesson from COVID-19 for sustainable production and consumption. *Operations Management Research*, *15*, 233–248. https://doi.org/10.1007/s12063-022-00280-x.
[37] Hepfer, M.; Lawrence, T.B. (2022). The heterogeneity of organizational resilience: Exploring functional, operational and strategic resilience. *Organization Theory*, *3*, 26317877221074701. https://doi.org/10.1177/26317877221074701.
[38] Okon, E.M.; Falana, B.M.; Solaja, S.O.; Yakubu, S.O.; Alabi, O.O.; Okikiola, B.T.; Edeme, A.B. (2021). Systematic review of climate change impact research in Nigeria: Implication for sustainable development. *Heliyon*, *7*, e07962. https://doi.org/10.1016/j.heliyon.2021.e07962.
[39] Esan, O.J.; Uzozie, O.T.; Onaghinor, O.; Etukudoh, E.A.; Omisola, J.O. (2023). Agile procurement management in the digital age: A framework for data-driven vendor risk and compliance assessment. *Journal of Frontiers in Multidisciplinary Research*, *4*, 118–125.
[40] Anzolin, G.; Lebdioui, A. (2021). Three dimensions of green industrial policy in the context of climate change and sustainable development. *The European Journal of Development Research*, *33*, 371–405. https://doi.org/10.1057/s41287-020-00352-0.