Sustainability in Industry 4.0: A Malaysian Perspective Through Cultural Value Dimensions

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ABSTRACT

The Fourth Industrial Revolution (Industry 4.0) has revolutionized technological integration across industries, emphasizing smart manufacturing, digital transformation, and intelligent systems. However, the sustainability implications of IR 4.0 remain complex, especially within diverse socio-cultural contexts. This paper explores how Malaysia's unique cultural values influence the country's readiness and capacity to integrate sustainability into Industry 4.0 adoption. Using Hofstede's cultural dimensions as a framework, this study examines the interplay between cultural tendencies and sustainable practices within digital industrial transformation. The findings suggest that cultural values are not merely background factors but pivotal elements in shaping sustainable IR 4.0 readiness in Malaysia.

Keywords— Industrial 4.0 Readiness, Cultural Values Dimensions, Industry 4.0 and Sustainability, Cultural Influences.

INTRODUCTION

The concept of sustainability has become a foundational pillar in modern industrial transformations, particularly in the context of Industry 4.0 (IR 4.0). While IR 4.0 encompasses innovations such as artificial intelligence (AI), the Internet of Things (IoT), cyber-physical systems, and big data analytics, its integration with sustainability goals varies significantly across nations and cultures. In a multi-ethnic, culturally diverse country like Malaysia, the alignment between cultural values and sustainability goals is critical to achieving inclusive and long-term transformation.

This paper investigates the role of cultural value dimensions in influencing sustainable IR 4.0 readiness in Malaysia. It argues that cultural norms, attitudes, and practices can either facilitate or impede sustainable innovation and digitalization. By contextualizing Malaysia's cultural orientation within Hofstede's dimensions, this paper offers insights into how culturally aligned policies and strategies can enhance sustainable outcomes in Industry 4.0 initiatives.

Industry 4.0 And Sustainability

Understanding Industry 4.0

Industry 4.0 (IR 4.0) represents the fourth major transformation of industrial production systems, characterized by the deep integration of digital technologies, cyber–physical systems (CPS), and intelligent data-driven decision-making across the manufacturing value chain. Originating from the German High-Tech Strategy initiative, IR 4.0 extends beyond automation by enabling interconnected, decentralized, and adaptive production environments, commonly referred to as smart factories (Kagermann, Wahlster, & Helbig, 2013).

At its core, Industry 4.0 is underpinned by a suite of enabling technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), Big Data Analytics, Cloud and Edge Computing, autonomous robotics, and additive manufacturing. These technologies collectively facilitate real-time data acquisition, predictive analytics, system self-optimization, and autonomous control, thereby transforming traditional linear production systems into intelligent and responsive networks (Lasi et al., 2014; Xu, Xu, & Li, 2018).

The Internet of Things enables seamless communication between machines, sensors, and systems, allowing physical assets to be monitored and controlled digitally. Artificial Intelligence and machine learning algorithms further enhance this capability by extracting actionable insights from large and complex datasets, supporting predictive maintenance, quality control, and process optimization (Lee, Bagheri, & Kao, 2015). Meanwhile, cloud computing provides scalable computational infrastructure, enabling cross-organizational integration and data sharing, while additive manufacturing introduces design flexibility and material efficiency by enabling on-demand and localized production (Ghobakhloo, 2018).

Despite these technological advantages, the deployment of Industry 4.0 is not value-neutral. Without deliberate alignment with sustainability objectives, digital transformation may exacerbate energy consumption, electronic waste, and social inequalities. Consequently, contemporary research increasingly emphasizes that Industry 4.0 should be conceptualized not merely as a technological revolution, but as a socio-technical paradigm that must be strategically governed to support long-term environmental, economic, and societal goals (Stock & Seliger, 2016).

Sustainability in IR 4.0

Sustainability within the context of Industry 4.0 encompasses the balanced integration of environmental, economic, and social dimensions, consistent with the triple bottom line framework (Elkington, 1997). The convergence of advanced digital technologies with sustainability principles presents both opportunities and challenges, necessitating a holistic and systemic perspective.

From an environmental sustainability standpoint, Industry 4.0 technologies offer significant potential to reduce resource consumption, waste generation, and greenhouse gas emissions. Smart energy management systems, real-time monitoring, and data-driven optimization can improve energy efficiency, reduce material losses, and support circular economy practices such as remanufacturing and recycling (Bonilla et al., 2018; de Sousa Jabbour et al., 2018). However, these benefits must be weighed against the increased energy demand associated with data centers, sensor networks, and digital infrastructure, highlighting the need for green ICT strategies and responsible technology deployment.

Economic sustainability in Industry 4.0 relates to the creation of resilient, adaptable, and cost-efficient production systems capable of responding to market volatility and global disruptions. Digitalization enhances operational flexibility, supply chain transparency, and predictive capabilities, thereby improving long-term competitiveness and reducing systemic risks (Frank, Dalenogare, & Ayala, 2019). Nevertheless, high initial investment costs and technological complexity may create barriers for small and medium-sized enterprises (SMEs), raising concerns about unequal economic benefits and technological dependency.

The social dimension of sustainability is particularly critical in the Industry 4.0 transition. While automation and intelligent systems can improve workplace safety and job quality, they also pose risks related to job displacement, skills mismatches, and workforce polarization. Sustainable implementation therefore requires proactive human capital development, continuous upskilling, and inclusive workforce strategies to ensure that technological advancement contributes to social well-being rather than exclusion (Longo, Padovano, & Umbrello, 2020). Ethical governance, data privacy, and human–machine collaboration further emerge as essential considerations in socially sustainable smart factories.

Importantly, achieving sustainability in Industry 4.0 cannot rely solely on technological solutions. It demands a multi-stakeholder and context-sensitive approach that incorporates organizational culture, institutional frameworks, regulatory support, and societal values. Emerging studies increasingly emphasize the role of cultural and behavioral factors in shaping technology adoption and sustainability outcomes, particularly in developing and emerging economies (Sony & Naik, 2020). As such, Industry 4.0 sustainability should be understood as a dynamic interaction between technology, people, and context, rather than a purely technical optimization problem.

Malaysia's IR 4.0 Landscape

Malaysia's transition towards the Fourth Industrial Revolution (IR 4.0) has been institutionally guided by the introduction of the National Policy on Industry 4.0 (Industry4WRD) in 2018. This policy represents a strategic

national agenda aimed at enhancing the global competitiveness of Malaysia's manufacturing sector through systematic digital transformation, technological upgrading, and innovation-led growth (MITI, 2018). Industry4WRD positions advanced manufacturing as a key driver of economic resilience, with a strong emphasis on productivity enhancement, high-value employment creation, and sustainable industrial development.

The policy framework is structured around several critical enablers, including public–private partnerships, government-led financial incentives, research and development (R&D) facilitation, and talent and skills development programmes. Public–private collaboration plays a central role in accelerating technology diffusion, particularly among small and medium-sized enterprises (SMEs), which constitute the backbone of Malaysia's industrial ecosystem (OECD, 2019). Government incentives such as tax allowances, automation grants, and digitalisation funding schemes are designed to lower the financial barriers associated with adopting advanced technologies, including cyber–physical systems, industrial Internet of Things (IIoT), and data-driven manufacturing platforms (MITI, 2018).

In parallel, substantial investments have been directed towards strengthening national R&D capabilities and innovation infrastructure. Universities, public research institutes, and industry-led innovation hubs have been encouraged to collaborate in developing locally relevant IR 4.0 solutions, thereby reducing dependence on imported technologies and enhancing endogenous technological capacity (Rasiah et al., 2020). Furthermore, human capital development has been prioritised through reskilling and upskilling initiatives, technical and vocational education and training (TVET) reforms, and industry–academia collaboration programmes aimed at preparing the workforce for digitally enabled production environments (World Bank, 2021).

Despite these comprehensive policy efforts, significant structural and contextual gaps persist. Empirical evidence suggests that IR 4.0 adoption in Malaysia remains uneven, particularly among SMEs, where challenges related to high implementation costs, limited digital readiness, and organisational resistance continue to constrain progress (Hamzah et al., 2022). More critically, existing policy instruments tend to prioritise technological efficiency and economic outcomes, while insufficiently integrating environmental sustainability objectives and socio-cultural dimensions into the adoption framework.

From a sustainability perspective, the alignment between IR 4.0 technologies and environmental performance such as energy efficiency, resource optimisation, and emissions reduction has yet to be systematically embedded within readiness assessment models and implementation guidelines (Stock et al., 2018). Additionally, the implicit assumption that technological adoption is culturally neutral overlooks the influence of national and organisational cultural values, including hierarchical structures, collectivist orientations, and risk-avoidance tendencies, which shape decision-making, technology acceptance, and change management practices in Malaysian firms (Hofstede et al., 2010; Salleh et al., 2023).

Consequently, while Malaysia's IR 4.0 landscape is supported by a robust policy foundation and institutional commitment, the disconnect between technological readiness, sustainability imperatives, and cultural compatibility presents a critical research and implementation gap. Addressing this gap requires an integrated evaluation approach that simultaneously considers technological capability, environmental sustainability, and cultural value preferences to ensure that IR 4.0 adoption is not only technologically feasible but also socially embedded and environmentally responsible within the Malaysian context.

RESULT AND DISCUSSION

Hofstede's cultural dimensions theory remains one of the most influential and empirically grounded frameworks for examining how national cultural values shape individual behavior, organizational practices, and institutional decision-making. Developed through large-scale cross-national surveys, the framework conceptualizes culture as "the collective programming of the mind" that distinguishes one group or society from another (Hofstede, Hofstede, & Minkov, 2010). Its enduring relevance lies in its ability to systematically capture deep-seated value orientations that influence governance structures, managerial behavior, risk perception, and technological adoption.

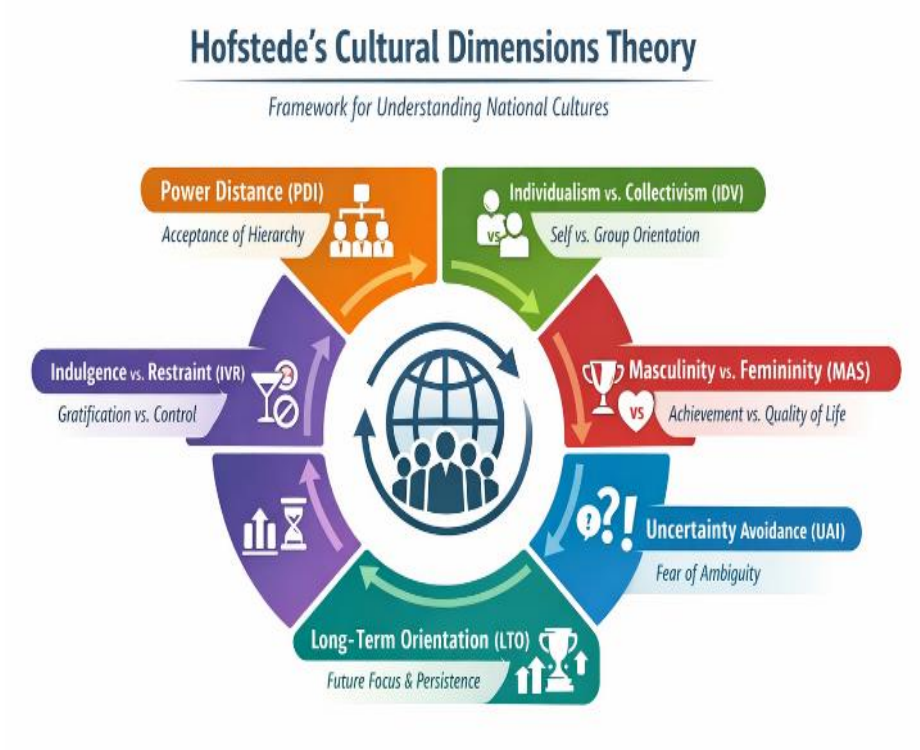

Figure 1. Hoftstede's Cultural Dimensions Theory

The model comprises six core dimensions. Power Distance Index (PDI) reflects the extent to which less powerful members of society accept unequal power distribution and hierarchical order. Individualism versus Collectivism (IDV) captures whether social ties emphasize personal autonomy or group cohesion. Masculinity versus Femininity (MAS) distinguishes between cultures driven by competition, achievement, and material success versus those prioritizing cooperation, well-being, and quality of life. Uncertainty Avoidance Index (UAI) represents societal tolerance for ambiguity, uncertainty, and unstructured situations. Long-Term Orientation (LTO) assesses the degree to which societies emphasize perseverance, thrift, and future-oriented values over short-term traditions and immediate outcomes. Finally, Indulgence versus Restraint (IVR) reflects the extent to which societies allow gratification of basic human desires related to enjoyment and leisure.

Within sustainability and innovation research, Hofstede's framework has been widely applied to explain cross-national variations in environmental policy adoption, organizational sustainability practices, technology diffusion, and strategic decision-making under uncertainty (Beugelsdijk, Kostova, & Roth, 2017; Ringov & Zollo, 2007). Cultural dimensions are thus not merely descriptive constructs, but critical explanatory variables that condition how societies interpret and operationalize concepts such as environmental responsibility, technological readiness, and long-term development.

A. Malaysia's Cultural Profile

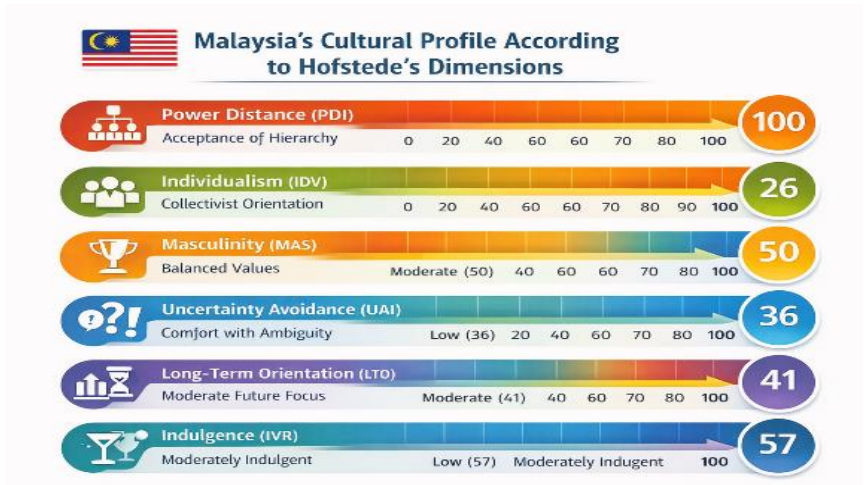

Figure 2. Malaysia's Cultural Profile, Hofstede, Hofstede, and Minkov (2010) and Hofstede Insights (2024).

Malaysia exhibits a distinctive cultural configuration that strongly shapes its approach to sustainability, innovation, and industrial transformation. According to Hofstede Insights, Malaysia records an exceptionally high Power Distance score (PDI = 100), indicating a pronounced acceptance of hierarchical structures and centralized authority. In organizational and policy contexts, this suggests that strategic decisions particularly those related to sustainability initiatives or Industry 4.0 implementation are typically top-down in nature. While such hierarchical alignment can facilitate rapid policy execution when leadership commitment is strong, it may also constrain bottom-up innovation and employee-driven sustainability initiatives if participatory mechanisms are weak.

Malaysia's low Individualism score (IDV = 26) reflects a strongly collectivist orientation, where group harmony, loyalty, and relational obligations are prioritized over individual achievement. This collectivist ethos has important implications for sustainability practices, as environmental responsibility is often framed as a shared social duty rather than an individual moral choice. Consequently, sustainability initiatives that emphasize community well-being, social cohesion, and collective benefit are more likely to gain acceptance than those framed solely in terms of individual incentives or personal accountability.

The country's moderate Masculinity score (MAS = 50) suggests a balance between performance-oriented values and concern for quality of life. This cultural balance creates a favorable context for integrating economic competitiveness with social and environmental considerations, aligning well with the principles of sustainable development. In practice, this implies that Malaysian organizations may be receptive to sustainability strategies that simultaneously enhance productivity, social welfare, and environmental stewardship, rather than prioritizing economic outcomes alone.

Malaysia also demonstrates a relatively low Uncertainty Avoidance score (UAI = 36), indicating a comparatively high tolerance for ambiguity and change. This cultural trait is particularly relevant for technological innovation and digital transformation, as it suggests openness to experimentation, adaptive learning, and incremental change. However, when combined with high power distance, this tolerance for uncertainty often manifests within structured, authority-led innovation processes rather than decentralized experimentation.

With respect to temporal orientation, Malaysia's moderate Long-Term Orientation score (LTO = 41) reflects a pragmatic balance between respect for traditions and a focus on future outcomes. This orientation supports sustainability agendas that emphasize gradual transition, long-term environmental resilience, and intergenerational responsibility, while still accommodating culturally embedded practices and norms. Such a balance is especially critical in emerging economies navigating the trade-offs between rapid industrialization and environmental protection.

Finally, Malaysia's Indulgence score (IVR = 57) suggests a moderately indulgent society, characterized by a controlled yet present emphasis on leisure and personal enjoyment. While this dimension is less frequently examined in sustainability studies, it has implications for consumption patterns, lifestyle-related environmental impacts, and public acceptance of sustainability policies that require behavioral change.

Collectively, Malaysia's cultural profile highlights that sustainability and innovation efforts are deeply embedded within hierarchical governance structures, collectivist social norms, and pragmatic long-term thinking. These cultural characteristics must be explicitly considered when designing frameworks to evaluate Industry 4.0 readiness and environmental sustainability, as culturally incongruent models risk limited adoption and superficial implementation.

B. Cultural Influences on Sustainability in IR 4.0 in Malaysia

Power Distance and Hierarchical Influence

High power distance can impede bottom-up innovation and sustainable practices. In highly hierarchical settings, decisions tend to flow from the top, potentially stifling creative and grassroots approaches to sustainability. However, strong leadership support for sustainability can drive rapid organizational change.

Implication: Sustainability programs must secure top-level endorsement while creating safe spaces for employee input and innovation.

Collectivism and Community Orientation

Malaysia's collectivist orientation can facilitate collaborative sustainability practices. Community-driven initiatives, such as cooperative green projects or shared IoT infrastructure for smart farming, align well with collective values.

Implication: Policies promoting group-based sustainable innovation (e.g., community solar power) may gain greater acceptance and impact.

Masculinity and Value Trade-offs

A balanced masculinity-femininity score implies an openness to both achievement and well-being. This cultural balance allows room for sustainable practices that do not solely prioritize profit but also consider social and environmental impact.

Implication: Framing sustainability as both a competitive advantage and a societal good can resonate well.

Uncertainty Avoidance and Risk-Taking

Low uncertainty avoidance suggests a willingness to experiment with new technologies, including green innovations. Malaysians may be more open to adopting novel IR 4.0 tools that support sustainability.

Implication: Malaysia can be a fertile ground for piloting green tech innovations like AI-based energy management or blockchain in supply chain sustainability.

Long-Term Orientation and Strategic Sustainability

While not extremely high, Malaysia's moderate long-term orientation supports investments in future-focused projects like sustainable infrastructure, education, and green R&D.

Implication: Sustainable IR 4.0 strategies should highlight long-term benefits, such as resilience, cost savings, and global competitiveness.

Indulgence and Behavioral Sustainability

A moderate indulgence score means there's a balance between short-term gratification and long-term restraint. Promoting behavioral changes for sustainability (e.g., energy saving, waste reduction) must appeal to both self-interest and collective good.

Implication: Public awareness campaigns should mix aspirational messaging (e.g., modern, green lifestyles) with moral appeals.

C. Policy and Strategic Recommendations

Policy and strategic interventions for IR 4.0–driven sustainability in Malaysia should be culturally grounded and systemically aligned. Policymakers are encouraged to embed cultural sensitivity into policy design by co-creating IR 4.0 and sustainability initiatives with key stakeholders, ensuring alignment with collectivist norms

and hierarchical structures to enhance acceptance and implementation effectiveness. Given Malaysia's high power-distance orientation, strong top-down leadership from government and industry leaders is critical to legitimising sustainability agendas and cascading pro-environmental values across organisations. At the same time, collectivism can be strategically leveraged by incentivising community-based innovation through grants and public–private partnerships, such as rural IR 4.0 hubs focused on sustainable agriculture and local value creation. To strengthen long-term orientation, sustainability and digital competencies should be systematically integrated into vocational and tertiary education, aligning IR 4.0 technologies with green skills development. Finally, targeted support for experimentation through tax incentives, R&D grants, and regulatory sandboxes can reduce perceived risk and encourage SMEs and startups to pilot sustainable IR 4.0 solutions, thereby accelerating inclusive and environmentally responsible industrial transformation.

D. Challenges and Opportunities

Table 1. Challenges and Opportunities

Challenges	Opportunities
• Resistance to change in hierarchical organizations • Misalignment between short-term business goals and sustainability • Lack of skilled workforce for sustainable IR 4.0 technologies	• Harness cultural collectivism for collaborative innovation • Use policy to nudge top-down leadership toward sustainability • Leverage Malaysia's openness to new technology for green innovation

CONCLUSION

Industry 4.0 offers transformative potential for sustainable development, but its success depends not just on technology, but on the cultural context in which it unfolds. In Malaysia, cultural values such as collectivism, power distance, and long-term orientation shape how sustainability is perceived and practiced. Integrating these cultural dimensions into policy, education, and innovation strategies can bridge the gap between digital transformation and environmental stewardship. As Malaysia advances in IR 4.0, culturally informed sustainability frameworks will be vital in creating inclusive, equitable, and resilient growth.

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