

An Empirical Analysis of Motivation and Challenges of Industry 4.0 Adoption in Malaysian ICT SMEs

Nurulizwa Abdul Rashid^{1*}, Yasmin Dania Khairul Hisham², Samer Ali Al-Shami³, Haslinda Musa⁴, Aini Khalida Muslim⁵, Md Fauzi Ahmad⁶

^{1*} Faculty of Technology Management and Technopreneurship, Universiti Teknikal Malaysia Melaka, Centre of Technopreneurship Development, 75450 Ayer Keroh, Melaka, Malaysia

² Faculty of Technology Management and Technopreneurship, Universiti Teknikal Malaysia Melaka, Centre of Technopreneurship Development, 75450 Ayer Keroh, Melaka, Malaysia

³ Institut Pengurusan Teknologi dan Keusahawanan, Universiti Teknikal Malaysia Melaka, Centre of Technopreneurship Development, 75450 Ayer Keroh, Melaka, Malaysia

⁴ Faculty of Technology Management and Technopreneurship, Universiti Teknikal Malaysia Melaka, Centre of Technopreneurship Development, 75450 Ayer Keroh, Melaka, Malaysia

⁵ Faculty of Technology Management and Technopreneurship, Universiti Teknikal Malaysia Melaka, Centre of Technopreneurship Development, 75450 Ayer Keroh, Melaka, Malaysia

⁶ Department of Production and Operations Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, Malaysia

^{1*} nurulizwa@utem.edu.my; ² yasmind.work@gmail.com; ³ samerali@utem.edu.my; ⁴ haslindamusa@utem.edu.my;

⁵ aini.khalida@utem.edu.my; ⁶ mohdfauzi@uthm.edu.my

^{1*} <https://orcid.org/0000-0001-6916-6947>; ² <https://orcid.org/0009-0008-0609-100X>; ³ <https://orcid.org/0000-0003-3090-1734>;

⁴ <https://orcid.org/0009-0003-7236-6327>; ⁵ <https://orcid.org/0000-0002-3687-5154>; ⁶ <https://orcid.org/0000-0003-4956-6999>

*Corresponding Author: nurulizwa@utem.edu.my

Abstract: Adoption of Industry 4.0 (IR 4.0) technologies by Malaysian Information and Communication Technology (ICT) small and medium-sized organizations (SMEs) are becoming increasingly important in facilitating digital transformation and long-term economic viability. Adoption in the SME service sector is still uneven despite significant national initiatives encouraging digitalization. 50 managerial-level respondents from ICT SMEs that have implemented at least one IR 4.0 technology were given an online survey as part of a quantitative study design. Descriptive statistics were used to analyze the gathered data to determine adoption trends, important factors, and significant challenges. The results show that the main motivation of IR 4.0 adoption are increased time-to-market, cost savings, customer requirements, and competitive pressure. The findings also show differences in company size, medium-sized enterprises show more advanced and integrated adoption of IR 4.0 technologies, especially in big data analytics and artificial intelligence, whereas micro enterprises concentrate on basic technologies like cloud computing and cybersecurity. The main challenges were found to be low strategy awareness, lack of staff knowledge, and ongoing employee education. These results emphasize how crucial strategic alignment and human capital development are to facilitating successful digital transformation. Policymakers and business professionals can use the study's practical findings to create focused initiatives that increase IR 4.0 adoption and enhance Malaysian ICT SMEs' competitiveness.

Keywords: Challenges IR 4.0, ICT SMEs, and SDG 9: Industry, Innovation, and Infrastructure

1. Introduction



The introduction of the Fourth Industrial Revolution (IR 4.0) has marked a pivotal shift in how businesses operate, leveraging a convergence of disruptive technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data Analytics, Cyber-Physical Systems (CPS), and Cloud Computing to create smart, interconnected systems (Schwab, 2016; Lasi et al., 2014). The integration of IR 4.0 technologies is increasingly associated with business sustainability, a concept that encompasses a firm's long-term ability to remain economically viable, socially responsible, and environmentally sustainable (Morrar et al., 2017). The introduction of IR 4.0 technologies enables firms to transform their operational models, improve customer engagement, and enhance competitiveness regardless size of firm and type of industry. In the new millennia, firm are forcing to embrace IR 4.0 Technologies based on customers' demands and competitive advantages.

In the Malaysian context, Small and Medium Enterprises (SMEs) play a vital role in national development. According to SME Corp Malaysia (2022), SMEs represent 97.4% of total business establishments, contribute approximately 38.4% to GDP, and employ 48.2% of the national workforce. Among these, service-based SMEs constitute a significant portion, covering sectors such as retail, logistics, education, finance, healthcare, hospitality, and ICT (DOSM, 2022). These firms, while agile and adaptable, often face systemic challenges including limited access to advanced technologies, skilled Labor shortages, and constrained financial resources (World Bank, 2020; Saleh & Ndubisi, 2006).

Despite Malaysia's policy push via programs such as Industry4WRD and the MyDIGITAL Blueprint, the digital adoption rate among SMEs particularly in the service sector remains low. According to a study by Rosli and Sidek (2013), most Malaysian SMEs exhibit low technological capability and innovation performance, relying heavily on traditional service delivery models. The World Bank (2020) also reported that less than 15% of Malaysian SMEs have adopted automation or data analytics tools, and even fewer have adopted AI or machine learning due to concerns over complexity, cost, and a lack of digital strategy.

Therefore, this research paper is designed to examine the empirical evidence on the factors and challengers of IR 4.0 technologies adoption among Malaysian ICT SME service companies. The findings provide insights into the critical factors of IR 4.0 adoption, as well as the challengers contributing to its relatively low uptake within this sector. The results of this study offer practical implications for SME managers, particularly from a developing country perspective, as well as for policymakers aiming to facilitate and promote the adoption of IR 4.0 technologies in the developing country perspectives.

2. literature review

A. Malaysia SMES Industry

Small and medium enterprises (SMEs) represent the backbone of Malaysia's economy, and most of them operate in the service sector. According to the official SME definition issued by SME Corporation Malaysia in Fig. 1, firms in the services and other sectors are classified as SMEs if their annual sales turnover does not exceed RM20 million or the number of full-time employees does not exceed 75, with the "OR" rule applied to either criterion (SME Corp, 2020). This definition is used across government agencies and policy frameworks to determine eligibility for SME-related support, incentives, and development programmes. Within this classification, micro, small, and medium service enterprises cover a wide range of activities including retail, hospitality, logistics, professional services, and information and communication technology (ICT).

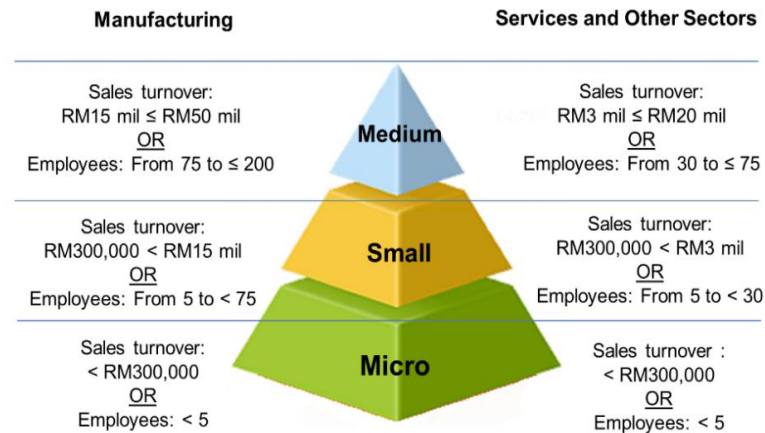


Fig. 1 Malaysian SME definition

SMEs, including microenterprises, have played an important role in fostering growth, employment, and income and have been integral to Malaysia's economic transformation process (Yahya & Mokhtar, 2020). SMEs play a key role in the economic growth of a country, generating employment and contributing to innovation. It's a pillar of efforts to achieve growth at all levels of development and environmental sustainability. SMEs play an important role in achieving Sustainable Development Goals (SDGs) by encouraging firms to achieve sustainable economic growth, creating employment, encouraging innovation, reducing income inequalities, and promoting sustainable industrialization.

In structural terms, Malaysian SMEs are highly concentrated in the service sector as indicated in Fig. 2. SME Corp's profile of SMEs shows that services have consistently accounted for more than 80% of all SME establishments. Earlier statistics indicated that about 89.2% of SMEs were in the services sector (809,126 firms (SME Corp, 2020). More recent micro, small and medium enterprise (MSME) profiles confirm that this dominance has continued: in the 2024 MSME profile, the services sector comprised 84.4% of total MSMEs (917,070 firms), far exceeding manufacturing, construction and agriculture (SME Corp). This clearly indicates that any discussion of SME development in Malaysia is, in practice, largely a discussion about service-based enterprises.

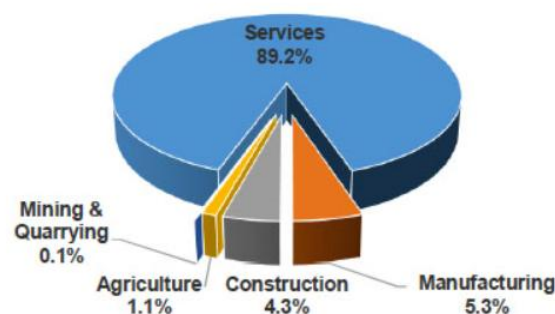


Fig. 2: Percentage of SME profile in Malaysia

ICT service SMEs in Malaysia operate across multiple sub-segments, including software development, system integration, cloud and data centre services, cybersecurity, digital platforms, digital content creation, and various professional and managed services. Many of these SMEs are integrated into Malaysia's digital ecosystem promoted by the Malaysia Digital Economy Corporation (MDEC), which identifies "Digital Services", "Digital Content", and related clusters as core promoted sectors under the Malaysia Digital initiative (Malaysia Digital Economy Corporation,

2022). As SMEs, ICT service firms typically fall within the services-sector SME definition annual sales turnover not exceeding RM20 million or employment not exceeding 75 employees, yet their business models rely heavily on intangible assets such as software, data, digital knowledge, intellectual property, and human capital (SME Corp Malaysia, 2022).

The Information and Communication Technology (ICT) sector has become a major driver of Malaysia's economic development and digital transformation. According to the Department of Statistics Malaysia, the digital economy consists of both the ICT industry and e-commerce activities across all sectors. In 2024, ICT contributed 23.4% (RM451.3 billion) to the national economy, where the ICT industry itself accounted for 13.9% while e-commerce activities from non-ICT industries contributed 9.5%. The sector also demonstrated stronger expansion compared to the overall economy, recording a growth rate of 5.1%, higher than the 3.5% recorded in the previous year (DOSM, 2025).

A. Industry Revolution (IR) Technology Malaysia Plan

Malaysia's commitment to strengthening its industrial and digital economy is reflected in the introduction of the Industry4WRD: National Policy on Industry 4.0, launched in 2018 by the Ministry of International Trade and Industry (MITI). The policy was formulated in response to the accelerating technological transformation occurring globally, driven by cyber-physical systems, automation, artificial intelligence, and advanced data analytics. These developments are reshaping the ways in which industries operate, compete, and create value. Recognising that Malaysia could not remain competitive using traditional production or service models, the government positioned Industry4WRD as a strategic blueprint to steer the nation toward a resilient, inclusive, and technology-driven economy (MITI, 2018). The policy underscores the urgency for Malaysian firms particularly SMEs to adapt to digitalisation to avoid lagging regional players in innovation, productivity, and global value chain participation.

At the core of the Industry4WRD policy is a clear ambition to enhance the country's technological readiness and industrial competitiveness through a structured transformation framework. The policy outlines three pillars, People, Processes and Technology supported by 13 strategic thrusts designed to build a holistic ecosystem that promotes innovation, talent development, technological adoption, and industrial upgrading. This includes initiatives to strengthen digital infrastructure, expand research and development capabilities, improve technology diffusion, and enhance SME support mechanisms. Through these strategic efforts, Industry4WRD aims to elevate Malaysia's position in global manufacturing networks while facilitating the transition of local enterprises into smart, connected, and agile organisations capable of competing in the digital age (MITI, 2018; World Economic Forum, 2020).

In Malaysia, the ICT sector plays a critical role in supporting the transition towards a digital economy and Industry 4.0 transformation. The government has continuously emphasized digitalisation through national initiatives such as the Malaysia Digital Economy Blueprint (MyDIGITAL) introduced by Government of Malaysia and strategic implementation led by Malaysia Digital Economy Corporation. These initiatives aim to increase productivity, improve competitiveness, and encourage businesses to adopt advanced technologies such as cloud computing, Internet of Things (IoT), artificial intelligence, and big data analytics (Economic Planning Unit, 2021; MDEC, 2022).

ICT service firms differ from manufacturing firms because their value creation is largely intangible and knowledge driven. Services are delivered through expertise, problem-solving capability, and continuous technological upgrading rather than physical goods production. As a result, ICT firms depend heavily on skilled human capital, learning capability, and innovation readiness. Rapid technological changes also require these firms to constantly adapt their processes, adopt emerging technologies, and develop dynamic capabilities to remain competitive (Teece, 2018; Vargo & Lusch, 2008).

Furthermore, the ICT sector is one of the most affected industries by Industry 4.0 developments because it functions both as a technology provider and a technology adopter. ICT service firms must implement advanced digital tools internally while simultaneously supporting digital transformation for their clients. This dual role increases

operational complexity and intensifies pressure for continuous innovation and sustainability practices (Frank et al., 2019; Müller et al., 2018).

B. Challenges of IR 4.0 Adoption

Industry 4.0 (IR 4.0) has emerged as a transformative paradigm that integrates advanced digital technologies such as cyber-physical systems, the Internet of Things (IoT), cloud computing, big data analytics, and intelligent automation into industrial and business operations. In theory, these technologies offer substantial benefits to small and medium enterprises (SMEs), including enhanced productivity, improved operational efficiency, greater flexibility, and stronger competitiveness in both domestic and global markets. However, despite these potential advantages, the adoption of Industry 4.0 among SMEs in Malaysia remains relatively modest. A closer examination of the literature reveals that this slow uptake is not the result of a single obstacle but rather a convergence of interconnected financial, knowledge-based, infrastructural, organizational, and environmental challenges.

At the forefront of these challenges are financial constraints, which consistently appear as a dominant concern among Malaysian SMEs. The transition toward Industry 4.0 requires considerable capital investment, encompassing expenditures on digital infrastructure, advanced machinery, specialized software, cybersecurity systems, and ongoing maintenance. For many SMEs operating with limited financial reserves and narrow profit margins, such investments represent a substantial financial commitment that carries significant risk (Islam et al., 2023; Ilias et al., 2025). Compounding this issue is the uncertainty surrounding the return on investment (ROI). SME owners often find it difficult to quantify the tangible and intangible benefits of digital transformation, particularly when outcomes such as efficiency gains or innovation capabilities may only materialize over the long term. As highlighted by Islam et al. (2023), this ambiguity surrounding financial returns frequently leads to cautious decision-making and delayed adoption, thereby slowing the overall pace of digital transformation within the SME sector.

While financial limitations form a visible barrier, underlying knowledge and skills deficiencies further complicate the adoption process. Many SME owners and managers possess limited exposure to Industry 4.0 concepts, resulting in inadequate awareness of how digital technologies can be strategically integrated into their business models (Islam et al., 2023; Bakar et al., 2024). Without a clear understanding of technological possibilities and implementation pathways, digital transformation may be perceived as complex and disruptive rather than as an opportunity for growth. In addition to limited awareness at the managerial level, the shortage of employees with relevant digital competencies poses a significant operational challenge. Ilias et al. (2025) emphasize that skill gaps in areas such as data analytics, automation systems, artificial intelligence, and cloud-based platforms restrict SMEs' readiness to adopt advanced technologies. Consequently, even when financial resources are available, the absence of capable human capital can hinder effective implementation and long-term sustainability.

These internal limitations are further intensified by infrastructural shortcomings. Successful Industry 4.0 implementation depends heavily on reliable high-speed internet connectivity, secure digital networks, interoperable information systems, and technologically advanced production facilities. However, SMEs operating in less-developed regions often encounter insufficient digital infrastructure, which undermines their capacity to adopt and integrate new technologies (Bakar et al., 2024; Ilias et al., 2025). Moreover, technical challenges associated with integrating legacy systems with modern digital platforms add another layer of complexity. Issues related to data collection, system compatibility, and interoperability between various technologies create operational uncertainties and increase implementation costs (Xin-Ren et al., 2023). As a result, SMEs may perceive digital transformation not merely as an investment but as a technically demanding process fraught with implementation risks.

Beyond financial, knowledge, and infrastructural constraints, organizational dynamics also shape the trajectory of Industry 4.0 adoption. Digital transformation often necessitates significant changes in organizational structures, workflows, and employee roles. Such changes can trigger resistance, particularly when employees fear job displacement or lack confidence in their digital capabilities (Bakar et al., 2024; Ilias et al., 2025). Resistance to change is frequently reinforced by the absence of a strong digital culture and limited managerial expertise in leading technological transformation. Wong and Kee (2022) argue that leadership commitment and strategic orientation

toward digitalization are critical determinants of Industry 4.0 readiness. Without visionary leadership and proactive change management, digital initiatives may remain fragmented or superficial, preventing SMEs from fully realizing the transformative potential of Industry 4.0 technologies.

External environmental factors further influence adoption decisions and often compound internal organizational challenges. Market-related uncertainties, including fluctuating customer demand and varying competitive pressures, can reduce the urgency for SMEs to pursue digital transformation (Tayib et al., 2022). In industries where traditional production methods remain viable, the perceived necessity for technological upgrading may be relatively low. Additionally, legal and regulatory requirements associated with digital transformation such as compliance with cybersecurity standards, data protection regulations, and industry-specific technical guidelines can impose additional administrative and financial burdens on SMEs (Ratana Singaram et al., 2023). Although government initiatives have been introduced to encourage digitalization, limited awareness, procedural complexities, and perceived inadequacy of incentives may diminish their effectiveness in accelerating Industry 4.0 adoption (Islam et al., 2023).

Taken together, these interconnected barriers illustrate that Industry 4.0 adoption among SMEs in Malaysia is shaped by a complex interplay of internal limitations and external pressures. Financial risk perceptions limited digital competencies, infrastructural inadequacies, organizational resistance, and environmental uncertainties collectively create a cautious landscape in which transformation progresses gradually rather than rapidly. Addressing these challenges therefore requires more than isolated policy interventions or technological investments. Instead, a coordinated and holistic strategy that integrates financial support, skills development, infrastructure enhancement, leadership strengthening, and regulatory facilitation is essential to enable Malaysian SMEs to navigate the transition toward Industry 4.0 effectively and sustainably. Summary of key challenges of industry 4.0 adoption describe in Table 1.

TABLE I
Summary of key challenges

Category	Key Challenges	Key References
Financial	High implementation and maintenance costs; uncertainty of ROI	Islam et al. (2023); Ilias et al. (2025)
Knowledge & Skills	Limited awareness; digital skill gaps	Islam et al. (2023); Bakar et al. (2024); Ilias et al. (2025)
Infrastructural	Insufficient digital infrastructure; interoperability issues	Bakar et al. (2024); Ilias et al. (2025); Xin-Ren et al. (2023)
Organizational	Resistance to change; lack of digital leadership and culture	Bakar et al. (2024); Ilias et al. (2025); Wong & Kee (2022)
Environmental	Market uncertainty; regulatory challenges; limited government incentives	Tayib et al. (2022); Ratana Singaram et al. (2023); Islam et al. (2023)

3. methodology

This research employed quantitative survey to measure barriers of IR 4.0 Technology adoption among the ICT SMEs in Malaysia. An online survey was designed for data collection and the participants for this study consist of middle management and above and the firms had to be in the ICT service business. Third, the companies should have already embraced one Industry 4.0 (IR 4.0) empowering technology in their businesses. Data collection thru online approach was chosen because online surveys offer flexibility, technological efficiency, speed, timeliness, ease of data entry, convenience, and the ability to obtain large sample sizes in Malaysia. Additionally, online surveys can be distributed and completed electronically, enabling the collection of substantial amounts of data from respondents within a short period. Middle management in service organizations play a key role in devising organizational

strategies; therefore, capturing their perspectives is essential for understanding the barriers associated with Industry 4.0 technology adoption.

The questionnaire used had 45 questions that were led into three major sections. Part A involved gathering of general company background such as the organization characteristics of the study. Part B was designed to measure Industry 4.0 adoption in their respective companies and what is the factors to adopt IR 4.0 technologies. Part C analysed the challenges of the implementation of IR 4.0 technologies. The collected data were analysed using descriptive statistical methods. This approach was employed to systematically summarize and present the characteristics of the respondents and their organization. The findings are reported in terms of frequencies, percentages, and rankings, providing a clear representation of factors and challenges towards the adoption of Industry 4.0 ICT SMEs in Malaysia. Descriptive analysis is appropriate for this study, as its primary objective is to provide empirical evidence and a comprehensive overview IR 4.0 technology adoption within the ICT SME service industry.

4. Data Analysis

A. Sample Description

The study gathered 50 usable responses from managers working within Malaysian ICT SME service firms as indicated in Table II. An examination of their profiles reveals that most participants hold senior leadership positions. Specifically, Managing Directors constitute 58% (29 respondents), General Managers account for 36% (18 respondents), and Chief Executive Officers represent 16% (8 respondents). This composition indicates that the sample is largely made up of individuals with substantial decision-making authority, who are directly engaged in shaping organizational strategies and overseeing operations, including matters related to Industry 4.0 adoption.

Regarding the nature of services offered, most of the companies specialize in Software and System Design, accounting for 38 firms (76%), while the remaining 12 firms (24%) focus on Data Management services. This pattern indicates that many participating organizations are engaged in digital solution development, which is closely aligned with the implementation of Industry 4.0 technologies. In terms of firm size, over half of the organizations are categorized as Small Enterprises, comprising 26 firms (52%). This is followed by 16 firms (32%) classified as Medium Enterprises and 8 firms (16%) identified as Micro Enterprises. These findings imply that Industry 4.0 adoption is more prominent among small and medium-sized ICT firms compared to micro enterprises.

TABLE II
Characteristics of the companies studied

Category	Item Description	Frequency	Percentage (%)
Managerial Position	Managing Director	29	58
	General Manager	18	36
	Chief Executive Officer	8	16
Type of Service Provided	Software and System Design	38	76
	Data Management	12	24
Type of organization	Micro enterprise	8	16
	Small Enterprise	26	52
	Medium Enterprise	16	32

B. IR 4.0 Technologies Adoption by SMEs

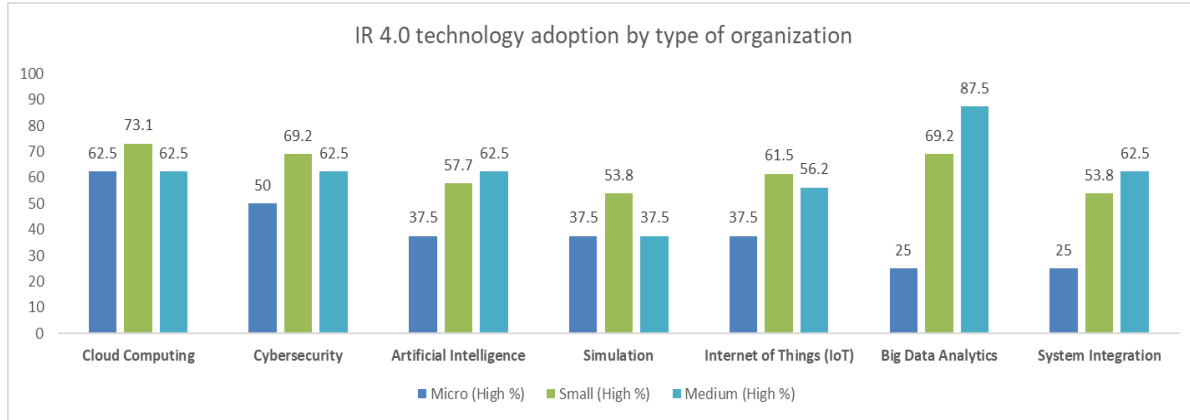


Fig. 3: Percentage of technology adoption by types of organizations

Fig. 3 shows that Micro enterprises demonstrate selective adoption, with the highest implementation observed in Cloud Computing (62.5%) and Cybersecurity (50%), while most other technologies, including Artificial Intelligence, Simulation, and Internet of Things (IoT), remain below 40% high-level implementation. This pattern suggests that Micro enterprises prioritize foundational and cost-efficient digital technologies that support operational continuity and data protection. In contrast, small enterprises exhibit broader adoption across multiple IR 4.0 technologies, led by Cloud Computing (73.1%), followed by Big Data Analytics and Cybersecurity (both 69.2%). The relatively high adoption rates of IoT (61.5%) and Artificial Intelligence (57.7%) further indicate that small enterprises are actively leveraging digital technologies to enhance data-driven decision-making and process efficiency. Medium enterprises show the strongest overall adoption intensity, particularly in Big Data Analytics, which records the highest implementation rate among all organization types (87.5%). Additionally, Artificial Intelligence, Cybersecurity, Cloud Computing, and System Integration each achieve 62.5% high-level implementation, reflecting a more mature and integrated digital transformation strategy. Overall, the findings reveal a progressive pattern of IR 4.0 adoption, where the breadth and depth of technology implementation increase with organizational size, highlighting the role of organizational capacity and resources in driving advanced digital technology uptake.

C. Motivation of IR 4.0 Adoption

TABLE III
Factors influencing the company's use of new digital technologies

Factor of IR 4.0 adoption	Mean	Std. Deviation
Customer requirements	4.62	0.49
To reduce costs	4.44	0.5
Competitors practice new digital technologies	4.28	0.67
To improve time-to-market	4.18	0.75
Conscious strategy around new digital technologies (Industry 4.0)	4	0.57
Lack of qualified workforce	3.6	0.81
Work initiated with input from public advisor system	3.46	0.61
Due to legal requirements/changed legislation	3.06	0.84

The descriptive analysis of the factors influencing the company's use of new digital technologies in Table III shows generally high agreement for demand and strategy-related drivers. Customer requirements recorded the highest mean ($M = 4.62$, $SD = 0.49$), followed by cost reduction ($M = 4.44$, $SD = 0.50$), competitors' practices ($M = 4.28$, $SD = 0.67$), and time-to-market improvement ($M = 4.18$, $SD = 0.75$). In contrast, legal requirements/changed legislation demonstrated a comparatively lower mean ($M = 3.06$, $SD = 0.84$), suggesting weaker agreement relative to other factors.

TABLE IV
Challenges of IR 4.0 adoption

Item	Mean	Std. Deviation
Requires continued education of employees	4.48	0.58
Few human resources (manpower)	3.94	0.79
More focus on operation at the expense of developing the company.	3.92	0.8
Too few financial resources	3.84	0.93
Lack of employee readiness	3.78	1
Lack of understanding of the strategic importance of the new digital technologies	3.7	1.04
Lack of knowledge about the new digital technologies	3.6	1.11
Lack of qualified employee	3.56	0.7
Lack of standard	3.54	0.76
Lack of data protection (cybersecurity)	3.52	0.89
Lack of understanding of the interplay between technology and human beings	3.3	0.95

Remarks: M=Mean, Sd=Standard Deviation

Across all 11 items in Table IV, the mean scores range from 3.30 to 4.48, which indicates respondents generally lean toward moderate-to-high agreement that these are real challenges for Malaysian ICT SMEs. The highest-ranked challenges were "Requires continued education of employees", with a mean score of 4.48 and a standard deviation of 0.58. This result indicates a high level of agreement among respondents and strong consistency in responses, suggesting that continuous employee training and upskilling is perceived as the most critical challenge to IR 4.0 adoption.

The second-highest ranked barrier was "More focus on operation at the expense of developing the company" ($M = 3.92$, $SD = 0.80$). This finding suggests that many organizations prioritize short-term operational activities over long-term digital development, which may hinder IR 4.0 initiatives. Similarly, "Lack of employee readiness" ($M = 3.78$, $SD = 1.00$) and "Lack of understanding of the strategic importance of the new digital technologies" ($M = 3.70$, $SD = 1.04$) were also categorized as high-level barriers. These results indicate that human-related and strategic factors play a significant role in limiting IR 4.0 adoption.

Several items were classified as moderate barriers, with mean values ranging from 3.30 to 3.60. These include lack of knowledge about new digital technologies, lack of qualified employees, lack of standards, and lack of data protection (cybersecurity). Among these, “Lack of knowledge about the new digital technologies” recorded the highest standard deviation ($SD = 1.11$), indicating the greatest variability in responses. This suggests that while some respondents experience significant knowledge gaps, others may already possess adequate digital knowledge. The lowest-ranked barrier was “Lack of understanding of the interplay between technology and human being” ($M = 3.30$, $SD = 0.95$). Although this item recorded the lowest mean score, it remained above the midpoint of the scale, indicating that respondents still perceive it as a relevant challenge.

5. Discussion

The outcomes of this study reveal insight into the diverse nature of Industry 4.0 adoption across Malaysian ICT SMEs. The degree and efficiency of technology usage rise with firm size, according to a distinct pattern. Cloud computing and cybersecurity are examples of simple, affordable technology that micro enterprises typically use to assist data protection and operational continuity. This highlights how their limited technical and financial resources prevent them from investing in more advanced technologies.

On the other hand, small enterprises show greater use of several IR 4.0 technologies, such as artificial intelligence and big data analytics. This implies a rising understanding of the strategic importance of digital technology in increasing productivity, creativity, and competitiveness. The most advanced adoption trend is seen in medium-sized businesses, which consistently integrate several technologies and use big data analytics. Stronger strategic alignment toward digital transformation, improved resource availability, and increased organizational readiness are all indicated by this.

Additionally, the study emphasizes the significance of market-driven and external motivations. The most significant driver was found to be customer requirements, underscoring the growing need for efficient and digitalized service delivery. Adoption of IR 4.0 is not just a technology decision but also an essential strategy for survival in a dynamic market environment, as further highlighted by competitive pressure and cost reduction.

The results, however, show that human-related barriers continue to be the most important ones. Lack of readiness, ongoing employee training, and a lack of strategic awareness show that digital transformation is an organizational and managerial challenge in addition to a technological one. These findings are consistent with previous research highlighting the significance of human capital, leadership dedication, and strategic vision in promoting successful IR 4.0 adoption.

6. Conclusion

In summary, the advantages and challenges of Industry 4.0 adoption among Malaysian ICT SMEs are empirically supported by this study. The results show that although consumer demands, competitive pressures, and efficiency gains are increasingly driving businesses, total adoption is still inconsistent across company sizes. While smaller businesses continue to concentrate on basic technologies, larger SMEs demonstrate more advanced and integrated adoption. Most importantly, the analysis shows that the main challenges to adoption are mostly strategic and human in nature rather than just financial or technological. The successful implementation of IR 4.0 technologies is severely limited by problems including ongoing employee training, a lack of readiness, and a lack of strategic awareness.

The findings reveal that achieving the objectives of SDG 9 is not solely a matter of technological acquisition but one of human and strategic readiness. The prevalence of challenges such as digital skill gaps and the need for continued employee education suggests that the "infrastructure" required for success includes human capital as much as physical technology. Therefore, to fulfil the promise of SDG 9, it is recommended that policymakers and industry leaders adopt a comprehensive strategy. This must integrate technical investment with robust talent development and strategic alignment, transforming ICT SMEs into smart, connected, and agile organizations capable of driving Malaysia's long-term sustainable industrial growth.

Overall, the findings highlight that a comprehensive strategy that incorporates technology investment, human capital development, and strategic alignment is necessary for a successful digital transformation. Policymakers and SME managers can use these findings to build focused programs that would enhance the competitiveness of Malaysia's ICT SME sector and advance the adoption of Industry 4.0.

7. Future research and limitation

Numerous limitations apply to this study. First, the results may not be as broadly applicable to the larger population of Malaysian ICT SMEs due to the small sample size of only 50 respondents. Second, the study's descriptive analysis methodology limits the capacity to determine significant correlations between variables. To more thoroughly analyse the connections between adoption results, challenges, and drivers, future research may employ indirect statistical methods like regression or structural equation modelling.

Furthermore, the study's specific focus on ICT service SMEs may restrict the findings' applicability to other industries like manufacturing or logistics. To provide a more thorough knowledge of IR 4.0 implementation in Malaysia, future study could perform comparative studies across other industries.

Additionally, this study focuses mostly on organizational-level issues, with little research of external influences like technology infrastructure, ecosystem support, and governmental regulations. These aspects could be included in future studies to create a more comprehensive framework. To observe the implementation of IR 4.0 over time and evaluate its long-term effects on organizational performance and sustainability, longitudinal studies are also advised.

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