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IoT Implementation in Malaysian SMEs: A Strategic Analysis of Enablers and Challenges

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Abstract

This study investigates the patterns and determinants of Internet of Things (IoT) adoption among Malaysian small and medium-sized enterprises (SMEs), examining organizational characteristics and implementation dynamics. Through a comprehensive analysis, the research evaluates critical factors influencing IoT integration, encompassing external pressures, regulatory support mechanisms, technical capabilities, and organizational preparedness. A new research model customized for Malaysian SMEs was developed to outline the key dimensions involved in the survey. The findings demonstrate that organizational age and size significantly influence IoT adoption propensity, with younger and smaller SMEs exhibiting greater inclination toward Industrial and Retail IoT implementations, primarily motivated by operational efficiency imperatives. While middle management emerges as crucial facilitators of IoT deployment, the study reveals significant disparities in workforce engagement and competency development. Implementation challenges persist across multiple dimensions, including financial constraints, technical complexity, and system compatibility issues. These findings underscore the necessity for targeted policy interventions, industry-specific capability development programs, and adaptable IoT solutions. The research highlights the strategic importance of leadership commitment, resource optimization, and ecosystem support in accelerating IoT adoption among Malaysian SMEs.

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I. INTRODUCTION

The Internet of Things (IoT) has emerged as a transformative technological paradigm in modern business environments, offering unprecedented opportunities for operational optimization, productivity enhancement, and competitive advantage. While large enterprises have successfully integrated IoT solutions into their core operations, small and medium-sized enterprises (SMEs) face unique challenges in adoption and implementation. This disparity is particularly evident in developing economies such as Malaysia, where SMEs serve as the backbone of economic growth but encounter significant obstacles to technological transformation, including financial constraints, technical skill gaps, and infrastructure limitations.

Despite the recognized potential of IoT to improve efficiency and enable new business models, the mechanisms by which Malaysian SMEs navigate the IoT adoption journey remain underexplored. To address this gap, the central research question of this paper is: What are the key organizational, technological, and environmental factors influencing IoT adoption among SMEs in Malaysia? The aim of this study is to examine the interplay between these determinants and identify the critical enablers and barriers shaping IoT implementation decisions within the Malaysian SME context.

Through a structured survey targeting diverse SME sectors in Malaysia, this paper presents empirical evidence on how organizational characteristics (such as size, age, and management support), technological readiness (including infrastructure and workforce capability), and external environmental factors (such as market pressure and government support) influence IoT adoption. By integrating these dimensions into a customized Technology-Organization-Environment (TOE) framework tailored for Malaysian SMEs, the study offers a comprehensive analysis that advances theoretical understanding while providing

practical insights for policymakers, industry leaders, and technology providers.

The adoption of IoT in SMEs delivers practical benefits across sectors. For example, retail SMEs use IoT for smart inventory tracking, while manufacturers deploy sensors for predictive maintenance to reduce downtime. In agriculture, IoT enables automated irrigation, improving efficiency and yields. These applications streamline operations, reduce costs, and enhance service delivery. Notably, SMEs using IoT for logistics tracking have achieved faster deliveries and increased customer retention, directly boosting profitability and competitiveness.

Recent research highlights the multifaceted nature of IoT adoption determinants in the SME sector. Organizational factors, particularly leadership commitment and strategic alignment, emerge as crucial enablers of successful IoT implementation. Studies indicate that effective management support not only drives innovation culture but also ensures strategic resource allocation for digital transformation initiatives [1], [2]. The size and resource capacity of SMEs significantly influence adoption propensity, with larger enterprises demonstrating greater capability to invest in IoT infrastructure and expertise [3]. However, smaller Malaysian SMEs often struggle with financial constraints and technical knowledge gaps, creating barriers to adoption [4].

Technological readiness constitutes another critical dimension, encompassing both infrastructure capabilities and human capital development. The availability of robust IT infrastructure, including reliable internet connectivity and compatible systems, forms the foundation for successful IoT integration [5]. Moreover, the technical competency of the workforce plays a vital role in adoption success, emphasizing the importance of targeted training and skill development programs [6], [7]. Research by Parra et al. [8] demonstrates that SMEs investing in employee capability development achieve more effective IoT implementation outcomes.

Within the Malaysian context, these factors intersect with unique local challenges and opportunities, including government initiatives, industry-specific requirements, and market dynamics. This study aims to provide a comprehensive analysis of these interconnected elements, offering insights into effective strategies for accelerating IoT adoption among Malaysian SMEs.

External environmental factors exert significant influence on IoT adoption decisions among SMEs, particularly within Malaysia's dynamic business landscape. Market pressures and evolving customer expectations emerge as primary catalysts for digital transformation. Research indicates that SMEs operating in highly competitive sectors demonstrate a greater propensity to adopt IoT technologies as a strategic imperative for maintaining market competitiveness and meeting sophisticated customer demands [9]. This competitive pressure is especially pronounced in Malaysia's manufacturing and service sectors, where IoT integration often represents a critical differentiator.

Government intervention and regulatory frameworks play a pivotal role in shaping the IoT adoption landscape. The effectiveness of public policy initiatives, including financial incentives, technical support programs, and regulatory measures, significantly influences adoption rates among SMEs [10]. In the Malaysian context, government-led initiatives aimed at reducing financial barriers through grants, subsidies, and tax incentives have demonstrated measurable impacts on IoT implementation across various industry sectors.

However, significant barriers continue to impede widespread IoT adoption among Malaysian SMEs. Financial constraints represent a primary challenge, with many organizations struggling to justify and secure the substantial initial investment required for comprehensive IoT implementation [11]. The financial burden extends beyond hardware acquisition to include system integration, maintenance, and workforce training costs. Furthermore, the technical complexity of IoT solutions presents formidable challenges, particularly for SMEs lacking specialized IT expertise [12]. This technical gap manifests in difficulties with system integration, data management, and cybersecurity measures.

These challenges underscore the critical need for developing accessible, scalable, and cost-effective IoT solutions specifically designed for SME requirements [13]. Such solutions must balance technological sophistication with practical implementation considerations, enabling SMEs to achieve digital transformation goals while effectively managing resource constraints. This necessitates a coordinated approach involving technology providers, government agencies, and industry stakeholders to create an enabling ecosystem for IoT adoption among Malaysian SMEs.

This paper investigates the determinants of IoT adoption among Malaysian SMEs, examining the interplay between organizational characteristics, technological readiness, and external environmental factors. Through a structured survey of Malaysian SMEs, the study analyzes how organizational dimensions (size, age, management support), technological capabilities (infrastructure, technical expertise), and external pressures (market competition, customer demands) influence IoT implementation decisions.

The paper is organized as follows: Section II presents the survey methodology and data collection approach targeting SMEs across various sectors. Section III discusses the findings, revealing how organizational characteristics significantly impact adoption patterns, with particular attention to the distinct behaviors of younger and smaller enterprises. These insights contribute to a deeper understanding of IoT adoption dynamics within Malaysia's SME landscape, enriching both theoretical frameworks and practical implementation strategies.

II. METHODOLOGY

The methodology of this study involves a comprehensive survey targeting small and medium-sized enterprises (SMEs) across Malaysia to investigate factors influencing IoT adoption. The survey began by identifying the main industrial sectors of the respondents and the potential IoT applications to be applied, as shown in Figure 1. The survey was structured around 15 critical dimensions, including organizational size, age, technological readiness, management support, technical knowledge, and external pressures such as competitive market forces as shown in Figure 2. These dimensions were identified through an extensive review of previous studies, which highlighted their relevance in the context of IoT adoption challenges and enablers [14], [15].

Quantitative data were collected using a structured questionnaire that assessed respondents' perceptions of operational efficiency, cost implications, organizational

readiness, and competitive pressures. A Likert scale was utilized to measure the level of agreement with statements across these dimensions, ensuring a standardized data collection approach. Similar methods have been successfully applied in related studies to gauge the technological readiness of SMEs for IoT [16], [17]. The data analysis involved statistical techniques to identify trends, barriers, and the most significant factors affecting IoT adoption. This process aligns with the methodology adopted in prior studies that employed multivariate analyses to evaluate the interplay of organizational and environmental factors in IoT implementation [18]. The analysis also included a comparative evaluation to determine the relative importance of each dimension, leveraging frameworks such as the Technology-Organization-Environment (TOE) model [19].

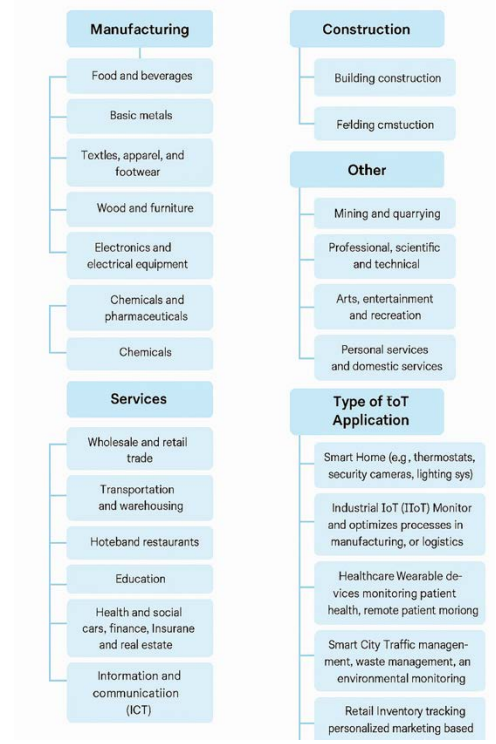


Figure 1. Main industrial sectors and potential IoT applications.

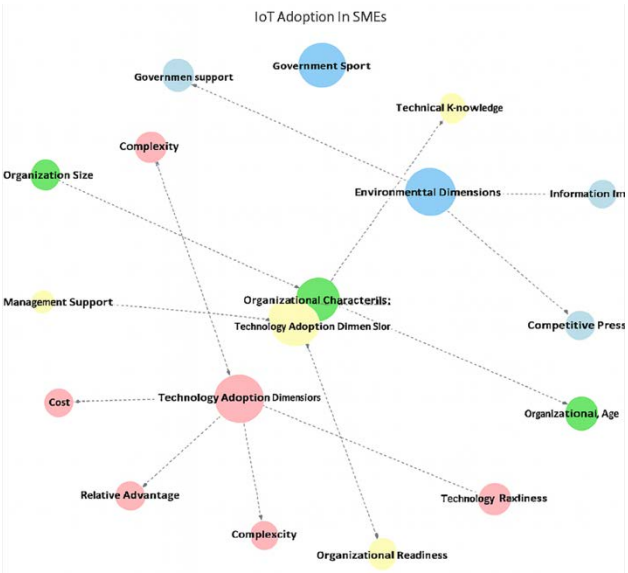


Figure 2. Factors in IoT Adoption in SMEs

To enhance the study's rigor, the research model (see, Figure 3) was developed to outline the key dimensions involved in the survey. This methodological structure aligns with best practices in the field, evident from systematic reviews and empirical studies focusing on IoT adoption frameworks [20], [21].

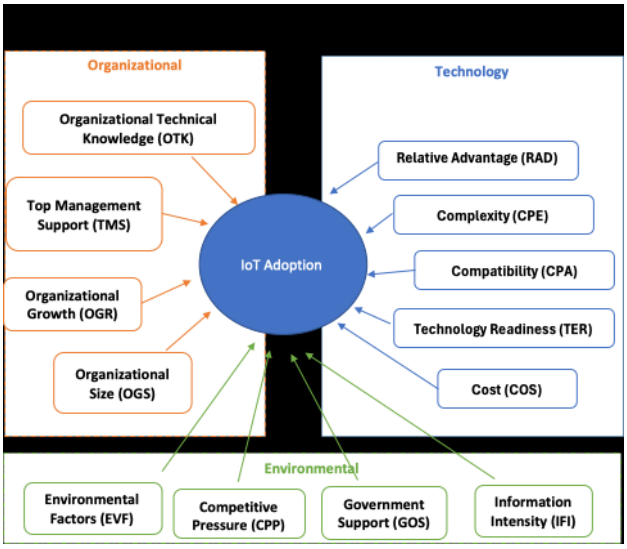


Figure 3. Research model of IoT Implementation in Malaysia SMEs

III. RESULTS AND DISCUSSION

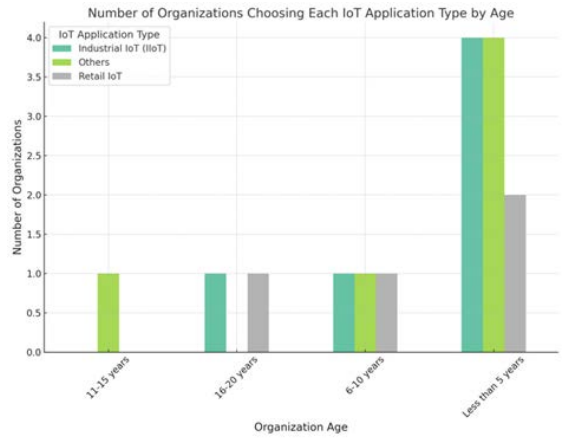
This section discusses the results derived from questionnaires completed by Malaysian SMEs.

A. IoT Adoption Factors

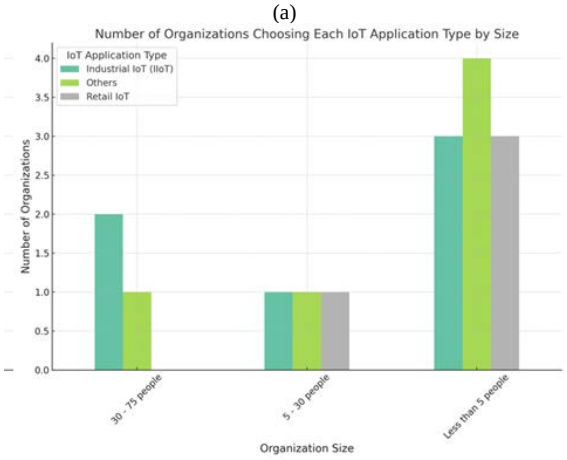
The research highlights how organizations of varying ages and sizes adopt different IoT applications. Figure 3 reveals that younger organizations, particularly those less than five years old, are more inclined to adopting Industrial IoT (IoT), Retail IoT, and similar technologies. These companies appear to be more technology-driven, aiming to modernize operations at an early stage. Conversely, older organizations (6-20 years old) show less engagement, potentially due to well-established workflows or a more cautious approach toward adopting new technologies.

Smaller organizations (fewer than five employees) tend to actively adopt IoT and Retail IoT, likely as a strategy to enhance efficiency given their limited resources. Larger organizations (30-75 employees) also show strong adoption rates, leveraging their greater capacity to manage the complexities and costs associated with IoT implementation. However, medium-sized organizations (5-30 employees) demonstrate lower adoption rates, likely due to constraints such as limited budgets and resource limitations, which may hinder their ability to effectively integrate IoT solutions.

Middle management forms the majority of the respondent pool, highlighting their critical role in executing IoT strategies and serving as a bridge between senior leadership and operational staff. While senior decision-makers are actively involved, the limited engagement of lower-level staff points to potential gaps in knowledge or communication. Implementing inclusive training programs can address these gaps, fostering better alignment across all organizational levels. This approach ensures that IoT strategies are not only effectively implemented but also sustained by a workforce that is well-informed and equipped to adapt to technological advancements.



(a)



(b)

Figure 3. IoT Adoption Dimensions a) Based on Organizational Age and b) Based on Organizational Size

B. Key Technology Dimensions

Figure 4 highlights key dimensions influencing IoT adoption, providing insights into organizational perceptions and challenges. Among these, Relative Advantage receives the highest rating, underscoring respondents' recognition of IoT's potential to enhance efficiency and reduce costs compared to existing solutions. This finding aligns with research demonstrating IoT's role in optimizing processes and improving operational performance. Complexity has a moderate rating, reflecting mixed views on the ease of implementation. While some organizations manage IoT effectively, others face technical and resource-related challenges, particularly smaller organizations with limited expertise. Compatibility**,** which evaluates integration with existing systems, scores slightly lower, highlighting persistent challenges in achieving seamless adoption. Addressing these issues with standardized solutions could enhance interoperability. Technology Adoption, representing organizational readiness, receives a low rating, indicating a need for improved skill development and change management. Finally, Cost**,** while the lowest-rated dimension, appears less critical compared to challenges like complexity and compatibility, suggesting that readiness and integration efforts should be prioritized to drive successful IoT adoption.

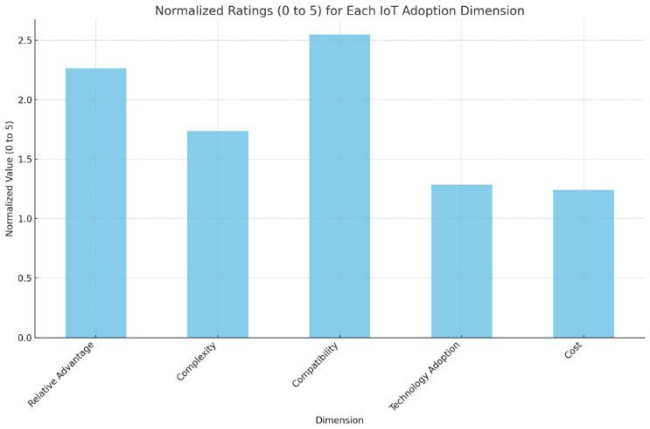


Figure 4. Key Technology Dimensions for IoT Adoption

The perception of IoT adoption from companies' point of view depends primarily on their core business activities. Figure 5 shows how organizational involvement in technology usage connects with the benefits of IoT, such as improving efficiency or cutting costs compared to existing solutions. Organizations actively engaged in Technology Innovation and Software Development achieve the highest scores across all IoT benefits. This reflects IoT's ability to improve workflows, enhance quality, and increase productivity. It demonstrates how effective integration can lead to reduced operational costs. Conversely, organizations with No Involvement exhibit significantly lower scores, suggesting a lack of realized benefits due to minimal or no adoption of IoT-enabled solutions. This reinforces the importance of proactive participation in technology adoption to capitalize on IoT's ability to deliver cost-saving measures and operational efficiencies. The Other category, while showing moderate scores, indicates variability in how IoT benefits are realized based on specific organizational activities. This variability underscores the need for tailored IoT implementations that align with organizational goals.

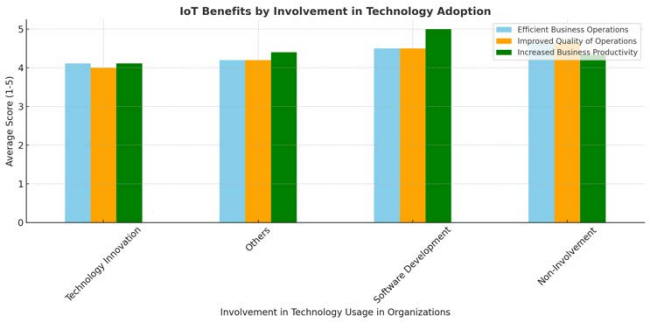


Figure 5: Perceptions of IoT Adoption from Organizational Perspectives

Figure 6 shows how different levels of involvement in technology usage shape organizational views on three important aspects of IoT implementation. First, 'IoT Implementation Requires Custom Adjustments' highlights how much customization organizations feel is needed for successful IoT integration. Second, 'Physical IoT Integration Will Not Cause Problems' examines how easily IoT systems can be incorporated into current physical infrastructure. Lastly, 'IoT Software Integration Is Easy' focuses on how organizations view the process of integrating IoT-related software.

Organizations engaged in Technology Innovation, Automation, Robotics, and Digital Marketing demonstrate high confidence in the ease of IoT software integration,

though there is variability in their perception of physical integration challenges, suggesting potential complexities in infrastructure readiness. Those focusing on Software Development and Big Data Analysis perceive IoT implementation as requiring fewer custom adjustments and display balanced views across all dimensions of adoption. In contrast, organizations with No Involvement consistently report the lowest scores, reflecting a lack of readiness, awareness, or confidence in adopting IoT solutions. Meanwhile, the Other category shows moderate scores, with variability likely influenced by the diversity of activities within this group.

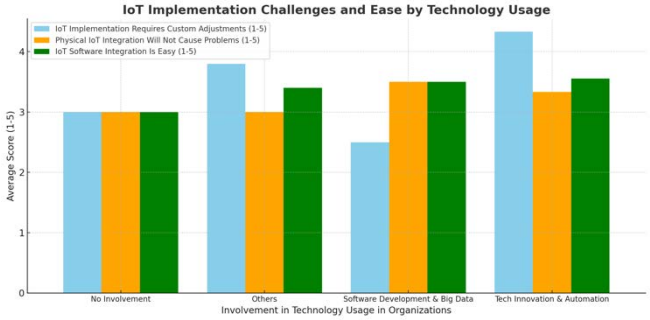


Figure 6: IoT Implementation Perspectives Based on Organizational Involvement

C. *Organizational IoT Knowledge*

The bar chart in Figure 7 shows the average IoT knowledge metrics across different organizational age groups. The x-axis represents four key IoT knowledge metrics: Sector Knowledge of Relevant IoT Skills**,** Professional Staff Trained in IoT**,** Technical Skills for IoT Adoption, and Broad Technical Knowledge**,** while the y-axis shows the average scores for these metrics across different organizational age categories. The results reveal that older organizations, such as those aged 11-15 years and 16-20 years, generally score higher across all metrics, reflecting more established technical expertise and professional capabilities in IoT. In contrast, younger organizations, particularly those aged less than 5 years, exhibit lower average scores, indicating gaps in IoT knowledge and adoption skills. This analysis underscores the impact of organizational maturity on IoT readiness, with older organizations demonstrating stronger preparedness for IoT implementation.

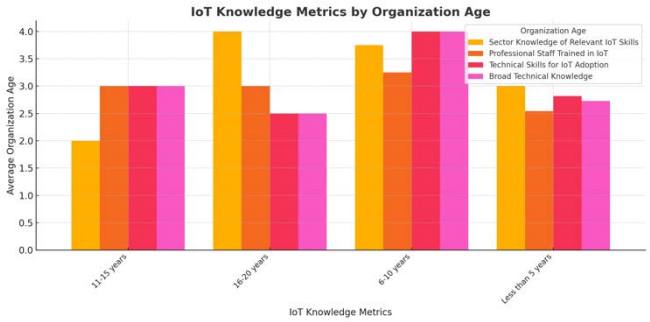


Figure 7: IoT Knowledge Metrics by Organizational Age

Figure 8 illustrates the relationship between IoT knowledge metrics and organization size. It compares four IoT knowledge metrics: Sector Knowledge of Relevant IoT Skills**,** Professional Staff Trained in IoT**,** Technical Skills for IoT Adoption, and Broad Technical Knowledge across three organization size categories: 30-75 people**,** 5-30 people, and Less than 5 people**.** Larger organizations, such as those with 30-75 people**,** consistently score higher across all IoT knowledge metrics, demonstrating stronger preparedness and better resource allocation for IoT adoption. In contrast, smaller organizations, particularly those with Less than 5 people, show lower scores, especially in Professional Staff Trained in IoT, highlighting challenges in workforce readiness for IoT adoption. Medium-sized organizations **(**5-30 people**)** exhibit mixed results, indicating variability in their IoT knowledge and capabilities. This analysis emphasizes how organizational size significantly impacts IoT readiness, with larger organizations displaying a clear advantage in technical expertise and adoption skills.

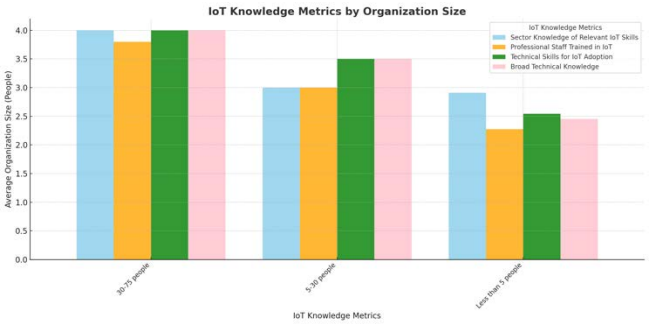


Figure 8: IoT Knowledge Metrics by Organizational Size

D. *Sectoral IoT Adoption*

Figure 9 illustrates the average scores for three key IoT aspects—IoT Fits Well with the Company**,** IoT Compatible with Existing Hardware and Software**,** and IoT Increases Hardware Costs-across five sectors: Manufacturing**,** Service**,** Farming**,** Construction**,** and Other**.** The Service sector consistently scores the highest across all aspects, indicating seamless integration of IoT solutions, robust infrastructure readiness, and manageable cost implications. The Manufacturing sector shows balanced scores, reflecting moderate compatibility with existing systems and a measured impact on costs. In contrast, the Farming and Construction sectors exhibit lower scores, highlighting significant challenges in IoT implementation, particularly regarding hardware compatibility and higher perceived costs for infrastructure upgrades. The Other sector displays variability, achieving high scores for compatibility but facing moderate concerns about increased hardware costs. This analysis highlights the varying levels of IoT readiness across sectors, with the Service Sector leading in adoption potential and the Farming and Construction Sectors requiring targeted strategies to overcome their unique challenges.

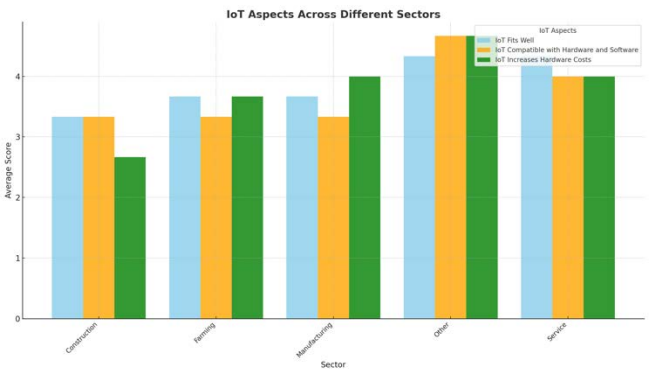


Figure 9: IoT Readiness and Challenges Across Key Industry Sectors

E. Adoption Enablers and Barriers

Analysis of organizational dimensions reveals key factors influencing IoT adoption among Malaysian SMEs, as shown in Figure 10. Technical knowledge and top management support emerge as the strongest enablers, with leadership commitment being particularly crucial for successful implementation [22]. While organizational readiness shows moderate importance, company size proves less significant, indicating that expertise and leadership outweigh organizational scale in driving IoT adoption. The findings demonstrate higher adoption rates among SMEs with 30-75 employees, reflecting their balance of operational agility and resource capability. This suggests the need for targeted support mechanisms, including technical training and financial incentives, particularly for smaller enterprises [23].

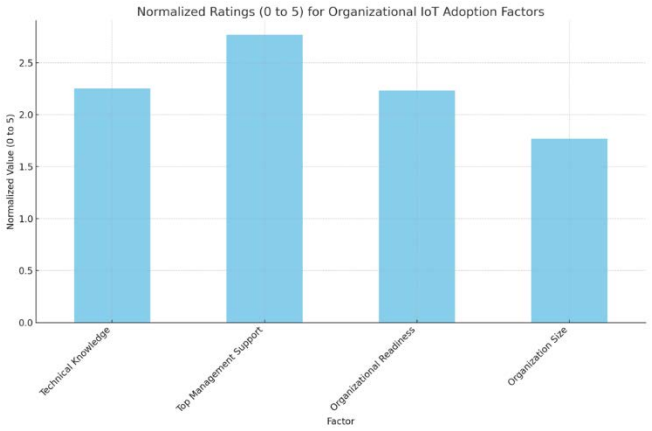


Figure 10: Organizational Dimensions for IoT adoption

External factors significantly influence IoT adoption among Malaysian SMEs, as illustrated in Figure 11. Competitive pressure emerges as the dominant driver, reflecting organizations' urgency to leverage IoT for market differentiation and operational efficiency. Government support ranks as the second most influential factor, highlighting the crucial role of public policies and incentives in facilitating adoption, particularly for resource-constrained enterprises. Information intensity shows relatively less impact, suggesting that market competition and policy support are more critical in driving IoT implementation decisions than information availability. These findings emphasize how external market forces and regulatory support mechanisms shape organizations' IoT adoption strategies.

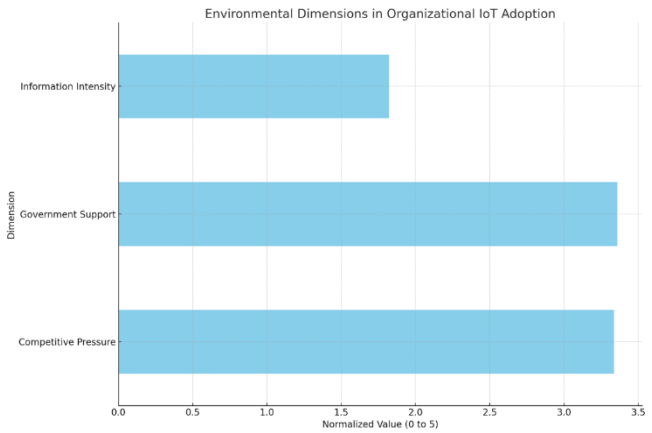


Figure 11: Environmental Dimensions in organizational IoT Adoption

F. Perceptions of Government Support

Figure 12 depicts respondents' perceptions of government support for IoT initiatives, revealing a moderate-to-positive sentiment, with most ratings ranging between 3 and 4. This suggests that organizations acknowledge the government's efforts in advancing IoT through initiatives such as case studies, training programs, and pilot projects. However, the absence of extreme ratings reflects varied opinions on the overall effectiveness of these measures.

For SMEs, government programs may lack the specificity or accessibility needed to address challenges such as high implementation costs, limited technical expertise, and integration difficulties. Research highlights that tailored support is essential for SMEs to overcome these obstacles and fully realize the potential of IoT technologies [16].

Meanwhile, larger organizations might perceive these initiatives as insufficiently aligned with their advanced requirements, further underscoring the need for more targeted approaches. Enhancing government support through sector-specific training, financial incentives, and integration assistance could significantly improve satisfaction and drive wider adoption of IoT across all organizational levels [17].

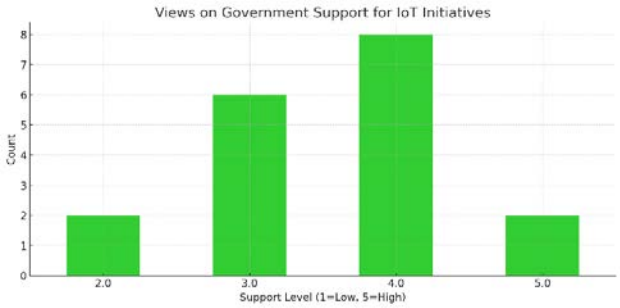


Figure 12: Government Support for IoT

G. Reliability of the Survey

This study evaluated the reliability of the survey using standardized loading estimates and Cronbach's Alpha (CA). Standardized loading estimates, which should exceed 0.6 [18], confirmed the reliability of the constructs, with almost all observed values surpassing this threshold. Internal consistency was further supported by CA values, all of which exceeded the recommended level of 0.7. To evaluate convergent validity, composite reliability (CR) and average variance extracted (AVE) were also analyzed. Both CR and AVE exceeded the recommended cut-off values of 0.7 and 0.5, respectively [18].

As presented in Table 1, all construct groups met or exceeded the required benchmarks for reliability and validity. CR values ranged from 0.726 to 0.966, AVE values were between 0.726 and 0.966, and CA values fell between 0.811 and 0.982—all above acceptable standards. These findings confirm that the constructs demonstrate strong internal consistency and convergent validity, supporting their appropriateness for use in analyzing IoT adoption among SMEs in Malaysia.

Table 1
Cronbach's Alpha and Convergent Validity

Technology adoption	TER	IoT compatible with existing systems	0.622			
Technology Adoption	COS	IoT increases operational costs	0.486	0.78	0.78	0.859
Technology Adoption	COS	IoT causes financial difficulty	0.405			
Organizational	OTK	Sector has trained IoT staff	0.27			
Organizational	OTK	Personal IoT technical knowledge	0.432			
Organizational	TMS	Management interested in competitive advantage	0.73			
Organizational	TMS	Management support is crucial	1			
Organizational	OGR	Organization culture important	0.838			
Organizational	OGS	High company capital	0.243	0.765	0.765	0.898
Organizational	OGS	High employee count	0			
Environmental	EVF	IoT strategic necessity	0.73	0.752	0.752	0.835
Environmental	EVF	Competitiveness requires IoT	0.595			
Environmental	CPP	Understand IoT competitive advantage	0.865			
Environmental	GOS	Government supports IT projects	0.703			
Environmental	GOS	Government supports IoT projects	0.73			
Environmental	IFI	Products require extensive information	0.622	0.788	0.788	0.866
Environmental	IFI	Product ordering process complex	0.459			

IV. CONCLUSION

A new customized TOE (Technology-Organization-Environment) research model tailored for Malaysian SMEs was developed to clearly outline the key dimensions examined in the survey. The results confirm that the constructs exhibit strong internal consistency and robust convergent validity, reinforcing their suitability and reliability for analyzing IoT adoption among SMEs in Malaysia. This refined framework provides a solid foundation for understanding the critical factors driving successful IoT implementation in this context. This study examines IoT adoption among Malaysian SMEs, focusing on the influence of organizational age, size, and sector. Younger and smaller organizations exhibit a strong inclination to IoT adoption to enhance efficiency and competitiveness but face challenges such as cost, complexity, and limited technical expertise. Larger organizations benefit from greater resources and expertise, adopting IoT primarily to streamline operations. Medium-sized and older companies are more cautious, often hindered by resource limitations and organizational barriers. Key enablers for successful IoT adoption include Relative Advantage, Technical Knowledge, and Top Management Support, while Complexity, Compatibility, and Organizational Readiness remain significant obstacles. Sectoral analysis highlights the Service sector as a leader in adoption, whereas the Farming and Construction sectors struggle with hardware compatibility and costs. External drivers such as Government Support and Competitive Pressure further influence adoption, with Information Intensity playing a supplementary role. To overcome these challenges, targeted strategies are essential, focusing on enhancing readiness, technical expertise, and sector-specific solutions. Inclusive training programs, standardized IoT frameworks, and government-backed support can empower SMEs to fully leverage IoT, driving efficiency, cost savings, and sustainable growth across industries.

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CONFLICT OF INTEREST

Authors declare that there is no conflict of interests regarding the publication of the paper.

AUTHOR CONTRIBUTION

The authors confirm contribution to the paper as follows: study conception and design: S. Saat, A. A. M. Isa, M. A. Othman; data collection: M. S. M. Saad, A. F. Othman, Z. H. Zaini, M. Othman[3], Z. Salakin; analysis and interpretation of findings: Y. C. Wong, S. Saat, M. Tamilselvan; draft manuscript preparation: Y. C. Wong, M. A. Othman. All authors had reviewed the findings and approved the final manuscript.

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