







## What Drives IoT Adoption? Insights from SMEs in Manufacturing

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**Citation:** Ying, C. J., Senathirajah, A. R. B. S., Haque, R., Soliman, K., Ibrahim, S. M. and Lam, N. T. (2025). What Drives IoT Adoption? Insights from SMEs in Manufacturing, *Journal of Cultural Analysis and Social Change*, 10(3), 1012-1026. <https://doi.org/10.64753/jcasc.v10i3.2542>

**Published:** November 29, 2025

### ABSTRACT

This study examines key factors influencing the adoption of Internet of Things (IoT) technology among small and medium-sized enterprises (SMEs) in the Malaysian manufacturing sector. IoT has the potential to transform business operations by enhancing efficiency, productivity, and competitiveness, yet its adoption reported remains low among SMEs. This study examines the factors influencing adoption of IoT within the manufacturing sector grounded in the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB). Through a comprehensive literature review, this research examines key factors influencing IoT adoption, including Attitude and Perceived Behavioral Control derived from the TPB model, Perceived Ease of Use and Perceived Usefulness derived from TAM model. Both frameworks offer understanding on how factors shape the IoT adoption decisions. The insights provided in this study aim to fill a critical gap in IoT adoption literature by focusing on the underexplored context of Malaysian manufacturing SMEs. By understanding the analysis of the frameworks, the findings show how variables of the framework influence IoT adoption decision in SMEs. This study identified key determinants such as Attitude, Perceived Behavioral Control, Perceived Ease of Use, and Perceived Usefulness. This study contributes to theoretical and practical implications and highlights areas where interventions can effectively support IoT implementation.

**Keywords:** IoT Technology, IoT Adoption, IoT in Manufacturing Sector, SMEs Manufacturing, Sustainable Growth, Economic Growth.

### INTRODUCTION

With rising technological development and the implementation of digitalization in this era, Internet of Things (IoT) based technologies has introduced a new perspective on consumer lifestyle and business operations. The most common IoT application in consumer life is “smart homes” where home applications are interconnected to

the network (Elena et al., 2021) and can be controlled remotely. From the perspective of business, the adoption of IoT in SMEs is not just a technological upgrade; it represents a strategic shift towards embracing Industry 4.0 (Soori et al., 2023). As the SMEs manufacturing sector face increasing pressure to innovate and remain competitive, the adoption of IoT technologies will be critical in enabling these enterprises to meet the demands of the modern market. IoT has contributed to various aspects such as operational efficiency and automation in streamlining processes and enabled businesses to collect precise data on patterns, behaviors, and performances through embedded sensors and interconnected devices (Hamed, 2022) which presents more promising opportunities for business growth (Metallo, 2018). IoT does not only provide robust technological infrastructure but also support digital transformation innovations that address information technology and business challenges, efficiency and significantly impact the economy (Ferraris, 2019).

In the manufacturing sector, IoT technology is used to connect various machines and devices. The interconnection in machines and devices enables real-time monitoring, providing real-time information about production status and performance (Mourtzis et al., 2021). The integration of smart sensors increases in productivity by providing predictive data such as maintenance (Dalzochio, 2020) alert users with potential issues, and optimize processes (Mohsen, 2023). For example, IoT allows real-time update and informs businesses about the status of inventory, achieving cost and time saving (Shim et al., 2019).

IoT technology has impacted the economy positively as it increases internal and external communication of businesses and production, resulting in better productivity (Wilson & Paul, 2018). Studies show that data-driven decision-making enabled by IoT leads to significant productivity gains and such productivity improvements are closely linked with economic growth (Kufeoglu, 2022). As businesses become more efficient and productive, they can produce more goods and services at lower costs, driving demand and economic expansion. Besides, IoT growth has increased demand for graduates and professionals with IoT knowledge. Positions such as IoT solution architects, IoT security specialists, data scientists, and IoT developers have become critical in various industries (Hung, 2022).

Given that all devices are interconnected, data such as business operations are more accessible, organizations can access information needed at greater efficiency (Oforji et al., 2021). IoT transforms large organizations and small startups into higher productivity and speed increase in processes. With the integration of IoT, cost of production will be cheaper with the optimization of smart energy and IoT integration of renewable energy, reduced energy waste and cost-efficient maintenance lead to greater cost savings (Oforji et al., 2021). IoT allows businesses to operate and manage processes at global state.

SMEs have made up as much as 98.5% of the total business establishments in the country, serving as the backbone of the nation's economy (Azuar, 2024). The manufacturing sector stands as the second-largest contributor and is a key driver in fostering economic growth and industrial development. Despite the great positive impact of IoT Technology, the adoption of IoT among SMEs in the manufacturing sector remains as low as 10% compared to larger enterprises (Shahzad et al., 2023). According to study, (Abdulaziz et al., 2023) SMEs in Malaysia understand the importance of IoT, but the obstacles faced during implementation of IoT is a lack of knowledge, only 30% of Malaysian firms are familiar with IoT. A particular study among SMEs in Malaysia showed that the digital adoption rate was around 20%, with most manufacturing business implementing less than 50% automation. (Yatid, 2019) A recent report stated that Malaysian SMEs face challenges in implementing digital solutions due to high initial investment costs, lack of knowledge and resistance to change (Azuar, 2024).

This research aims to investigate the key factors that influence the adoption of IoT amongst Malaysian manufacturing SMEs. First variable is attitude, which is the individual's perception an evaluation on a circumstances. Secondly, perceived behavioural control, which reflects the individual's perception of their ability to adopt IoT. Then, perceived ease of use refers to individual's beliefs on how straight-forward integrating IoT into processes is. Lastly, perceived usefulness, is the belief of a person that integrating IoT will enhance the performances or processes.

## Problem Statement

It is said that the IoT influences various fields and transforms how society functions, shaping the path toward the future (Robin, 2023). The adoption of Internet of Things (IoT) technology in SMEs within the manufacturing sector remains a critical challenge, despite its potential to greatly improve operational efficiency, innovation, and boost competitiveness.

According to SME Corp, around 77% of SMEs in Malaysia remain at the basic digitalization stage (SME Corp, 2020). A local study of digital tool adoption conducted amongst SMEs in the manufacturing sector to compare digital tool adoption frequency before COVID-19 and after COVID-19 (Muhamad et al., 2021) found that the adoption rate for web presence, e-payment and e-commerce which are directly related to IoT -based systems is below 10% after the pandemic. This suggests that many SMEs are slow to adopt the basic digital transformation.

While IoT offers transformative capabilities for the manufacturing sector, the adoption amongst SMEs is still limited due to various barriers. These barriers impede the full realization of IoT's benefits, resulting in SMEs falling behind in the rapidly evolving industrial landscape. Understanding and addressing these factors is essential to accelerate IoT adoption and unlock the technological potential that can drive SMEs' growth and sustainability in a competitive market.

### Research Objectives

The primary objective of this research is to explore the relationships between factors influencing intention to adopt IoT in amongst Malaysian SMEs in the manufacturing sector.

**RO1:** To examine the influence of attitude on the intention to adopt IoT amongst SMEs in the manufacturing sector.

**RO2:** To understand the influence of perceived behavioral control on the intention to adopt IoT amongst SMEs in the manufacturing sector.

**RO3:** To investigate the influence of perceived ease of use on the intention to adopt IoT amongst SMEs in the manufacturing sector.

**RO4:** To investigate the influence of perceived usefulness on the intention to adopt IoT amongst SMEs in the manufacturing sector.

## LITERATURE REVIEW

### Global Perspective on Adoption of IOT

Despite the widespread of IoT adoption, some potential application areas in IoT technologies are undiscovered (Sandro et al., 2020). The key impacts include automation in various sectors such as logistics, supply chain and processes, data-driven analytics and increased productivity. In the manufacturing sector, IoT adoption not only promises enhanced operational efficiency but also offers opportunities for innovation and new business models that can help SMEs scale and compete on a global level (Lee et al., 2021).

Studies have shown that IoT is considered as the core carrier of the smart system to contribute to operational efficiency in the business world (Grammatikopoulou, 2022), with a view to reaching a competitive advantage and economic growth. IoT technology has impacted global SMEs positively as it increases internal and external communication of businesses and production, resulting better productivity (Wilson & Paul, 2018). Studies show that data-driven decision-making enabled by IoT leads to significant productivity gains and such productivity improvements are closely linked with economic growth (Kufeoglu, 2022). As businesses become more efficient and productive, they can produce more goods and services at lower costs, driving demand and economic expansion.

Besides, IoT growth has increased demand for graduates and professionals with IoT knowledge. A report by Gartner stated positions such as IoT solution architects, IoT security specialists, data scientists, and IoT developers have become critical in various industries (Chamberlain, 2021). Given that all devices are interconnected, data such as business operations are more accessible resulting in organizations being able to access information needed at greater efficiency (Etim et al., 2021). IoT transforms large organizations and small startups into higher productivity. With the integration of IoT, cost of production will be cheaper with the optimization of smart energy and IoT integration of renewable energy, reduced energy waste and cost-efficient maintenance leads to greater cost savings (Etim et al., 2021). IoT allows businesses to operate and manage processes at a global level. Previous studies have stated that the growth of IoT will affect the economic growth (Edquist, 2019). Doms(2005) also suggested that technological change such as the integration of IoT is the key driver of growth, contributing to overall economic growth.

The adoption of IoT varies significantly across the globe, with some countries rapidly advancing while others lag. Countries like China, the United States, and India are leading the charge, investing heavily in IoT infrastructure and applications into various sectors, including manufacturing, healthcare, and smart cities (Alam, 2018). In contrast, some countries face challenges such as limited technological infrastructure, costs, and lack of skilled professionals to integrate IoT effectively. Many SMEs in countries like Brazil, South Africa, Romania are struggling with barriers adoption of IoT (Alam, 2018). In Romania, the adoption of IoT amongst SMEs remains low due to economic constraints and a lack of digital infrastructure. Many SMEs in Romania struggle with the high costs associated with IoT implementation and maintenance. Additionally, there is a significant knowledge gap, with many business owners unaware of the potential benefits of IoT (Szetensí, 2021). In Turkey, while there is a growing interest in IoT, the adoption rate among SMEs remains low due to economic instability and regulatory challenges (Alenizi & Khamis, 2023). In South Africa, SMEs face significant barriers to IoT adoption, including high costs, limited internet connectivity, and a lack of technical expertise. A study in Sub-Saharan Africa stated the main

challenge SMEs are facing is the sociotechnical challenges which are low digital skills, lack of self-efficacy and perceived usefulness (Achieng & Malatji, 2022). As businesses are increasingly dependent on data analytics, digital tools and automation, these challenges have resulted in a slower adoption of IoT amongst SMEs compared to larger enterprises (Achieng & Malatji, 2022; Ahmetoglu et al., 2022).

By addressing these barriers and providing the necessary support, it is possible to enhance the adoption of IoT among SMEs, enabling them to leverage the benefits of digital technologies for improved efficiency, productivity, and competitiveness.

### **Malaysian Perspective on Adoption of IoT**

The IoT industry in Malaysia has shown significant growth, with a valuation of RM9.7 billion (approximately USD 2.3 billion) in 2019. Research from the Malaysian Communications and Multimedia Commission (MCMC) reveals that this industry will expand to RM37.1 billion (around USD 8.9 billion) by 2025 (Waqar, 2023). This substantial growth reflects the increasing adoption of IoT across various sectors in Malaysia, driven by both government initiatives and market demand.

According to local study, technological advancement and digitization are two important pillars for a competitive economy in Malaysia (Siong et al., 2020). IoT is expanding in Malaysia in various industry sectors. For example, during the Covid-19 pandemic, Malaysia was actively promoting IoT-based industries such as e-commerce, big data analytics, and automation (Muhamad, 2023). Malaysian government introduced plans by enhancing the country's digital connectivity through extensive deployment of mobile, fiber and fixed wireless access across all sectors. The pandemic also significantly transformed the education sector, necessitating a shift from conventional learning methods to digital platforms. In agriculture, IoT technologies, such as traceability systems in the food supply chain, are being adopted to improve food safety and enhance production transparency (Muhamad, 2023). During the pandemic, the Multinational Corporation (MNCs) were quick to adopt IoT to maintain business and operational efficiency, but SMEs faced challenges and slower IoT Adoption (Muhamad, 2023). In today's SMEs environment in Malaysia, innovation is defined as a continuous process that plays a critical role in contributing to the GDP, exports and job creation (Shahzad et al., 2023). According to the Malaysian Investment Performance Report 2022, Malaysia is welcoming investors especially investors in Southeast Asia, particularly in high-technology ICT, IoT systems, and smart logistics which are crucial for advancing Malaysia's industrial capabilities (MIDA, 2022). The Malaysian government is actively encouraging the adoption of IoT into business applications especially among SMEs as part of the country's digital transformation efforts. The government has announced the National IoT Strategic Roadmap as part of the continuous effort to create opportunities for digital transformation and economic growth.

Malaysian companies are aware that the connectivity and computing storage are dominated by huge telecommunications and tech companies. Experts also suggested that Malaysian start-ups should go for applications by using IoT as a solution to customers and create an ecosystem by collaborating with device makers (Tan, 2021). However, with the Malaysian government's continued efforts through initiatives like the National IoT Strategic Roadmap, SMEs have opportunities to overcome these barriers and contribute to the nation's digital transformation. The adoption of IoT is essential for enhancing Malaysia's industrial capabilities and maintaining competitiveness in the global market.

### **Attitude has a Positive and Significant Influence on IoT Adoption.**

Attitude refers to the way in which a person views and evaluates something or someone, a predisposition or a tendency to respond positively or negatively toward a certain idea, object, person, or situation (Alfonso et al., 2016). In this case, attitude refers to the positive or negative feelings of SMEs towards adopting IoT technology. It reflects the degree to which SMEs believe that adopting IoT will be beneficial for their operations. A positive attitude towards IoT adoption can significantly influence the intention to adopt technology. Studies show that SMEs with a favorable attitude towards digital technologies are more likely to integrate them into their business processes (Zamani, 2022).

**H1:** Attitude has a positive and significant influence on IoT Adoption.

### **Perceived Behavioral Control has a Positive and Significant Influence on IoT Adoption.**

Perceived Behavioral Control (PBC) refers to an individual's perception or belief of the ease or difficulty of controlling their performance. In this case, adoption of IoT, influenced by past experiences and anticipated obstacles (Li et al., 2024) assesses the SMEs' perception of the ease or difficulty of adopting IoT. It includes factors such as resources, knowledge, and external support that can facilitate or hinder IoT adoption. SMEs with higher perceived control over the adoption process are more likely to implement IoT solutions. Research indicates that perceived behavioral control can be defined as the confrontation between internal and external reticence when someone wants to execute a certain activity (Santisteban, 2022).

**H2:** Perceived Behavioral Control has a positive and significant influence on IoT Adoption.

**Perceived Ease of Use has a Positive and Significant Influence on IoT Adoption.**

Perceived Ease of Use refers to the person who feels that utilizing a specific system will require little to no effort. In the context of IoT adoption, SMEs perceive the ease of use as how effortless it is in implementing and using IoT technology. It is a key component of the Technology Acceptance Model (TAM) and influences the intention to use IoT. If SMEs believe IoT is easy to use, they are more likely to integrate IoT into existing processes (Kalesamy, 2021). When SMEs believe that IoT technology is user-friendly and straightforward to integrate into their existing processes, they are more inclined to adopt and incorporate it into their operations (Jaspers & Pearson, 2022). This perception not only lowers the barriers to entry but also fosters a more positive attitude toward the technology.

**H3:** Perceived Ease of Use has a positive and significant influence on IoT Adoption.

**Perceived Usefulness has a Positive and Significant Influence on IoT Adoption.**

Perceived Usefulness refers to the degree to which an individual believes that using IoT technology will enhance the performance of their manufacturing operations (Abdullah et al., 2021). Studies have shown that perceived usefulness is a strong predictor of technology adoption among SMEs (Muridzi, 2024) because technologies that are perceived as useful are those that can enhance business performance, efficiency or productivity by streamlining operations, reduce costs and improve decision making processes.

**H4:** Perceived Usefulness has a positive and significant influence on IoT Adoption.

**Conceptual Framework**

Based on the literature review, the independent variables are attitude, perceived behavioral control, perceived ease of use and perceived usefulness. The dependent variable is adoption of IoT among SMEs manufacturing sector. The resulting research model is depicted in Figure 1.

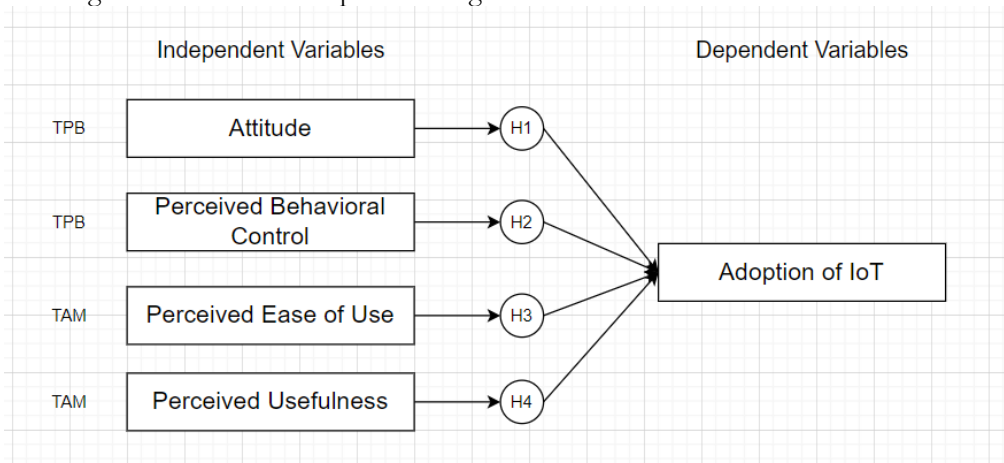


Figure 1. Research Model

**RESEARCH METHODOLOGY**

**Research Design**

This research will use a quantitative approach to examine the factors influencing the adoption of IoT amongst SMEs manufacturing sector. Survey questionnaires will be distributed to targeted respondents within the SMEs manufacturing sector in Penang. The survey will include questions addressing key factors such as attitude, PEOU, PU, PBC, organizational readiness and support associated with IoT adoption.

Literature review will support the data collection for this research, sources of literature are primarily academic journals, conference papers and credible online resources. The review will be analyzed to capture the key factors affecting IT adoption. The findings are summarized and structured corresponding to research objectives, questions, supported with hypotheses.

**Target Population and Location**

Penang’s economy is driven by SMEs with 99.0% of all registered businesses establishments made up of SMEs (Yaacob & Radzi, 2022). The manufacturing sector of SMEs in Penang is the second largest contributor to the sector in the country (Penang Institute, 2020). By referring to Table 1 below, there are 4021 SMEs and 16% of 1016

the people in Penang are engaged in SMEs. Penang is known as the “Silicon Valley of the East” (Seow, 2024) which offers a unique opportunity to study SMEs operating in the region with strong focus on technological advancement, making it an ideal place to understand the underlying factors contributing to low adoption rate of IoT in the manufacturing sector. The concentration this location allows for a comprehensive analysis of the manufacturing sector’s practices, challenges, and opportunities related to IoT. Besides, the targeted respondents are working professionals within the manufacturing industry involved in or knowledgeable about IoT projects, thus ensuring that the findings are relevant and offers valuable perspective.

**Table 1.** Contribution of Penang’s SMEs according to the Economic Sectors, 2015

Sector	Number of Establishments	Value Added (RM million)	Number of Persons Engaged Total	Salaries and Wages Paid (RM million)
	Total	% Total		% Total
Agriculture				
Total	486	100.0%	1,064	100.0%
SMEs	470	96.7%	349	32.8%
Construction				
Total	2,888	100.0%	3,474	100.0%
SMEs	2,804	97.0%	1,823	52.5%
Manufacturing				
Total	4,191	100.0%	34,294	100.0%
SMEs	4,021	95.9%	8,223	24.0%
Services				
Total	59,997	100.0%	24,061	100.0%
SMEs	59,600	99.3%	19,743	82.1%

*Note.* Adapted from Penang Institute. (2020b). Penang economic and development report 2019/2020, George Town: Penang Institute.

### Sampling Size

By referring to Krejcie and Morgan Table (Bukhari, 2021), with a population size of 4021 establishments, the required sample size for a population of 4,021 establishments is approximately 351.

### Sampling Technique

Sampling technique chosen for this research is a non probability sampling which is convenience sampling for a more generalized result (Elfil & Negida, 2017). This method allows a broader population approach, and every individual of the Penang population has an equal rate to be selected for sampling. Questionnaire will be distributed online through business-focused social media platforms such as LinkedIn and relevant community groups. This approach is effective to reach targeted audience of professionals within the manufacturing sector located in Penang.

## RESULTS AND FINDINGS

### Demographic Profile of the Respondents

Online survey has been conducted for this study with a total of 351 respondents’ data collected at the targeted location, Penang. Table 2 below shows the frequency and percentage distribution of each demographic category. The distribution among gender is quite balanced, female respondents are 178 (50.7%) out of 351 respondents and male respondents are 173 (49.3%). The majority of the respondents are from age group 21 – 30 (37.9%) and 31 – 40 (35.9%), followed by age group 41 – 50 (14.2%) and 51 – 60 (12%). Half of the respondents are degree holders (49.9%) or higher Master/ PHD holders (22.8%). This also indicates that the respondents pool is well-educated and are more likely to understand and integrate IoT technologies.

In terms of employment position of the respondents, majority of the respondents are engaged with roles associated with technical and operations: Engineer/ Business Process/ QA (38.5%), Manager from General/ Operations/ Production (30.2%). Respondents engaged with technical, and operations role indicates suitability for this survey as they are more likely to integrate and accessible to IoT technologies at their workplace. Whereas managers (30.2%), executives and business owners (16.8%) are able provide insights that represented the decision-maker of companies. Nearly half of the respondents are working in a medium size enterprise (45.9%), followed by

small enterprise (28.5%) and micro enterprise (25.6%). This survey is focused on the manufacturing sector, 92.9% of the respondents are from the manufacturing industry while 7.1% are from the other industries like agriculture and pharmaceuticals.

**Table 2.** Table of demographic profile of the Respondents

Item	Frequency	Percentage
Gender		
Male	173	49.3
Female	178	50.7
Age Group (Years Old)		
21 – 30	133	37.9
31 – 40	126	35.9
41 – 50	50	14.2
51 - 60	42	12.0
Academic Qualification		
SPM/ STPM	25	7.1
Diploma	71	20.2
Degree	178	49.9
Master/ PHD	80	22.8
Employment Position		
Executive/ Owner/ CEO	59	16.8
Manager (General/ Operations/ Production)	106	30.2
Engineer/ Business Process/ QA	135	38.5
Internship	51	14.5
Size of Organization		
Micro (1 - 4 employees)	90	25.6
Small (5 – 74 employees)	100	28.5
Medium (75 - 200 employees)	161	45.9
Sector of Industry		
Manufacturing	326	92.9
Other	25	7.1

### Pilot Test Results

Pilot test was conducted with 30 respondents to examine the validity and reliability of the questionnaire. This is to ensure that the questions are clear with minimal typographical errors and respondents are able to understand, interpret and answer the questions accordingly.

Table 3 below shows the Cronbach's Alpha reading of each variable which are above 0.75 which indicates that the reliability of the variables is considered high. Results show that the questionnaire is reliable and consistently measuring the variables.

**Table 3.** Cronbach's Alpha of Each Variable from the Pilot Test

Variable	Cronbach's Alpha
Adoption of IoT	0.882
Attitude	0.797
Perceived Behavior Control	0.878
Perceived Ease of Use	0.823
Perceived Usefulness	0.921

### Reliability Analysis

Cronbach's Alpha is used to determine the reliability of the variables as tabulated in Table 4. Adoption of IoT as the dependent variable has a Cronbach's Alpha reading of 0.880 indicating that this survey has strong reliability in capturing the perspectives of respondents in adoption of IoT.

The 4 independent variables are all having similar Cronbach's Alpha reading: Attitude (0.859), PBC (0.836), PEOU (0.782) and PU (0.886) indicates good reliability. This also confirms that the questionnaire has been reliable in effectively capturing the data for analyzing the factors influencing adoption of IoT technology amongst MEs.

**Table 4** Reliability Analysis

Variable	Cronbach's Alpha
Adoption of IoT	0.880
Attitude	0.859
Perceived Behavioral Control	0.836
Perceived Ease of Use	0.782
Perceived Usefulness	0.886

### Multiple Regression Analysis

This section provides statistics such as R (Correlation Coefficient) value, R Square (Coefficient of Determination), Adjusted R Square and Standard Error of the Estimate to evaluate the influence between Dependent Variable: Adoption of IoT and the four Independent Variables: Attitude, Perceived Behavioral Control, Perceived Ease of Use, and Perceived Usefulness. It provides insights into which independent variables are the most influential.

**Table 5** Table of Multiple Regression Analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.776	0.603	0.598	0.493

From the resulting data in Table 5 above, the reading of Correlation Coefficient is  $R = 0.776$ . This suggests that the independent variables have strong positive relationship with the dependent variable, Adoption of IoT. With an R square reading of 0.603, indicates that the independent variables account for 60.3% of the variance in the dependent variable. The remaining variance of 39.7% represents the portion that is not explained or variables that are not included. Adjusted R Square provides a higher accuracy measurement. With value of 0.598, slighter lower than R Square shows that this slight reduction is reliable and not inflated by any redundant independent variables.

**Table 6** Coefficients of Multiple Regression

Model		Unstandardized B	Coefficients Std. Error	Standardized Coefficients Beta	t	Sig. (p value)
1	(Constant)	0.330	0.166		1.989	0.047
	Attitude	0.331	0.051	0.334	6.473	<0.001
	Perceived Behavioral Control	0.387	0.055	0.336	7.058	<0.001
	Perceived Ease of Use	0.259	0.053	0.229	4.840	<0.001
	Perceived Usefulness	-0.027	0.027	-0.036	-0.989	0.323

From the regression analysis results above shows that Attitude, Perceived Behavioral Control and Perceived Ease of Use influences the dependent variable, Adoption of IoT significantly as their p values are all less than 0.05. Greater t-value indicates greater evidence against the null hypothesis (Majumder, 2023). Attitude results ( $\beta = 0.334$ ,  $t = 6.473$ ,  $p < 0.001$ ) show a moderate positive effect of Attitude on Adoption of IoT. Similarly, Perceived Behavioral Control ( $\beta = 0.336$ ,  $t = 7.058$ ,  $p < 0.001$ ), shows that respondents are more likely to adopt IoT when they feel more in control of the technology. Perceived ease of use ( $\beta = 0.229$ ,  $t = 4.840$ ,  $p < 0.001$ ) is also a significant variable. In contrast, the result of Perceived Usefulness ( $\beta = -0.036$ ,  $t = -0.989$ ,  $p = 0.323$ ) does not show a statistically significant effect on Adoption of IoT. Overall, the analysis shows that Attitude, Perceived Behavioral Control, Perceived Ease of Use are key factors influencing IoT adoption, with Attitude and Perceived Behavioral Control showing particularly strong effects.

### Hypothesis Testing

By referring to the data collected, and analysis conducted above, a summarized table for hypothesis is tabulated below:

**Table 7.** Hypothesis Testing

Hypothesis	Std Beta ( $\beta$ )	t-value	p-value	Decision	R <sup>2</sup>	VIF
H1: Attitude has a positive and significant influence on IoT Adoption.	0.334	6.473	<0.001	Supported	0.603	2.324
H2: Perceived Behavioral Control has a positive and significant influence on IoT Adoption	0.336	7.058	<0.001	Supported		1.974
H3: Perceived Ease of Use has a positive and significant influence on IoT Adoption.	0.229	4.840	<0.001	Supported		1.955
H4: Perceived Usefulness has a positive and significant influence on IoT Adoption.	-0.036	-0.989	0.323	Not Supported		1.156

From Table 7, H1, H2 and H3 shows positive and significant influence of the variables on Adoption of IoT. With similar  $\beta$  reading for H1 = 0.334, H2 = 0.336 and H3 = 0.229, positive result of t-value, H1 = 6.473, H2 = 7.058, H3 = 4.840 and p-value < 0.001 indicates that the hypothesis is supported. H2 with the variable Perceived Behavioral Control has the strongest support of influence on IoT Adoption because this hypothesis has the highest value of standardized beta ( $\beta = 0.334$ ), highest t-value (7.058) with p-value <0.001. A high t-value with p-value <0.001 indicates strong relationship between the variables (Majumder, 2023). Perceived Behavioral Control and Adoption of IoT. Attitude and Perceived Ease of Use both also have high t-value and p-value <0.001 which indicates a positive relationship with Adoption of IoT.

In contrast, H4 with result  $\beta = -0.036$ , t-value = -0.989, p-value = 0.323 shows that the relationship between Perceived Usefulness and Adoption of IoT is not supported.

## CONCLUSION AND RECOMMENDATION

### Research Questions

#### *Research Question 1*

What is the influence of attitude on the intention to adopt IoT amongst SMEs in the manufacturing sector?

#### *(a) Attitude on Adoption of IoT*

**H1:** Attitude has a positive and significant influence on IoT Adoption.

This hypothesis suggests that a positive attitude towards IoT adoption can significantly influence the intention to adopt IoT technology. Coefficient of Multiple Regression result for Attitude on Adoption of IoT ( $\beta = 0.334$ , t = 6.473, p < 0.001) suggests that if the attitude of SME's is towards positive, the more likelihood of IoT adoption will occur.

Attitude is derived from the Theory of Planned Behavior model. Findings suggest that attitude contributes significantly to the intention to perform certain behavior, in this case, adoption of IoT. Supported hypothesis also indicates that this framework is well-supported and relevant towards intention to adopt IoT.

Result findings are also aligned with studies. Research show that attitude is positive influence on behavioral intention for adoption of IoT among SMEs in developing countries (Sajid et al., 2024). Some positive attitudes are such as openness to innovation, teamwork assist in smooth adoption of IoT, and willingness of participation. Another study also discovered that attitude is derived as a person's belief and intention that can affect the intention to adopt IoT in the logistics industry (Zhang & Lee, 2023). Attitude significantly influences the adoption of IoT because it plays a crucial role in adoption decisions (Narakorn & Seesupan, 2019). When employees or decision-makers in SMEs have positive attitude towards adoption of IoT, the more likely that the intention to adopt IoT is positive. SMEs with IoT implementation in production are striving towards efficiency and improved operations (Abdulaziz et al., 2023). The study also emphasized that positive attitude reflects the readiness to adopt new technology into operations. Readiness is crucial for SMEs in the manufacturing sector as it shows how open is a company to integrate new technology and solutions into their daily operations. When SMEs are have a postive and open attitude and prepared to invest in new technology, they are more likely to achieve industry advancements. In conclusion, this hypothesis is supported and confirms that attitude is a key factor that influences the adoption of IoT among SMEs in the Malaysian manufacturing sector.

#### *Research Question 2*

What is the influence of perceived behavioral control on the intention to adopt IoT amongst SMEs in the manufacturing sector?

**(a) Perceived Behavioral Control on Adoption of IoT**

**H2:** *Perceived Behavioral Control has a positive and significant influence on IoT Adoption*

This hypothesis suggests that Perceived Behavioral Control has a significant impact on the intention to adopt IoT technology among SMEs in the manufacturing sector. This hypothesis is supported with a strong R Square value of 0.603, indicating that 60.3% of the variance in IoT Adoption is explained with Perceived Behavioral Control being a critical contributor. The Cronbach's Alpha for Perceived Behavioral Control is 0.836, which indicates high reliability of this measure. The Coefficient of Multiple Regression for Perceived Behavioral Control on IoT Adoption ( $\beta = 0.336$ ,  $t = 7.058$ ,  $p < 0.001$ ) strongly supports the hypothesis. This variable shows the strongest influential factor in Adoption of IoT with the highest beta value and, and  $p < 0.001$ . This suggests that when SMEs perceive they have control over IoT adoption, such as having access to resources, knowledge, or technical support, the likelihood of adoption increases.

This variable, Perceived Behavioral Control (PBC) is derived from the Theory of Planned Behavior (TPB). The results are also aligned with study that stated hypothesis with PBC has a positive effect that impacts the intention to adopt Industry 4.0 ICT technologies (Saeedi et al., 2022), which IoT is considered a part of Industry 4.0 technology. Past studies also expect that attitude facilitates alongside with PBC to impact the intention to adopt IoT (Saghafi et al., 2017).

In summary, this hypothesis is supported. Perceived Behavioral Control influences the Adoption of IoT amongst SMEs manufacturing sector significantly.

**Research Question 3**

What is the influence of perceived ease of use on the intention to adopt IoT amongst SMEs in the manufacturing sector?

**(a) Perceived Ease of Use on Adoption of IoT**

**H3:** *Perceived Ease of Use has a positive and significant influence on IoT Adoption.*

This hypothesis suggests that Perceived Ease of Use positively influences the intention to adopt IoT technology among SMEs in the manufacturing sector. The results of the survey analysis support this hypothesis, with a standardized beta ( $\beta$ ) value of 0.229, a t-value of 4.840, and a significant p-value ( $< 0.001$ ). The Cronbach's Alpha is 0.782 for Perceived Ease of Use, indicating high reliability and the perceptions are captured effectively. The VIF of 1.955 also indicates minimal multicollinearity, suggesting the result is reliable and contributes positively to the model. By comparing Attitude and Perceived Behavioral Control, Perceived Ease of Use has a positive but moderate impact on Adoption of IoT due to the lower standardized beta. The results are aligned with studies conducted in Suzhou China (Lu, 2021) which stated that the result of the findings for PEOU's influence on adoption of IoT is significant but small. Similar findings are from research conducted in India (Mital et al., 2018).

Perceived Ease of Use is derived from the Technology Acceptance Model (TAM). This model suggests that if the technology, in this case, IoT, the more its interface is user-friendly or easy to use, the more likely the person is going to adopt it. By referring to the TAM, PEOU can be influenced by external variables that shape users' perceptions on the simplicity of technology. One of these influential external factors could be Attitude. This concept is aligned with a local study stated that a positive attitude toward a technology can enhance an individual's readiness to adopt it, which can positively affect their perception of ease of use (Subramaniam & Mat-Jizat, 2023). Another local study also found that the organization's positive attitude towards Adoption of IoT influences the PEOU of the employees positively and have higher intention to adopt IoT (Jamalut et al., 2022).

In summary, with the hypothesis being supported, suggesting that IoT are highly potential to be adopted by SMEs manufacturing sector when employees see IoT technologies are easy to handle and operate. Studies also suggested that organizations with positive attitude fosters higher technical readiness, resulting in more likely to have perceived ease of use towards IoT and more likely to adopt IoT. (Howard-Grenville, 2021)

**Research Question 4**

What is the influence of perceived usefulness on the intention to adopt IoT amongst SMEs in the manufacturing sector?

**(a) Perceived Usefulness on Adoption of IoT**

**H4:** *Perceived Usefulness has a positive and significant influence on IoT Adoption.*

The results indicate this hypothesis is not supported. Perceived Usefulness does not have a significant positive influence on the intention to adopt IoT among SMEs in the manufacturing sector. PU is derived from TAM,

similar with PEOU. PU and PEOU both significantly influences the intention to adopt IoT (Lu, 2021;Narakorn & Seesupan, 2019). However, the result of this study suggests that PU does not influence the adoption of IoT. A study stated that perceived usefulness may have limited impact on IoT adoption due to implementation challenge and concerns (Wong et al., 2023). In the manufacturing sector, SMEs might have other priorities such as cost and scalability over general perceptions of usefulness, even though IoT technology provides significant benefits (Alenizi & Khamis, 2023). High initial investment is required for IoT infrastructure. Ongoing maintenance costs, and the need for specialized skills to operate the technology can deter SMEs from adopting IoT, especially when operating on limited budgets (Sajid et al., 2024). If IoT solutions are not adaptable to their specific needs or require extensive restructuring, SMEs may view the technology as incompatible with their current setup.

In summary, the resulting data suggests this hypothesis is not supported. Perceived Usefulness does not significantly impact Adoption of IoT and may be due to external factors such as cost and scalability that are prioritized over IoT benefits among small businesses.

## IMPLICATIONS OF THE STUDY

Considering all four variables: Attitude, Perceived Behavioral Control, Perceived Ease of Use, and Perceived Usefulness and their impact on Adoption of IoT among SMEs manufacturing sector have provided valuable insights for theoretical and managerial implications.

### *Practical Implications*

This study offers strategic implications for SMEs and organizations aiming to integrate IoT among the manufacturing sector by highlighting the strategies and unique challenges. From the findings, attitude impacts the adoption of IoT technology significantly. To foster a positive attitude towards IoT, management could work on cultivating positive mindset within the organization (Radu, 2023) that can be achieved by supportive culture around technology adoption. A previous study also stated that when management has a positive attitude, employees tend to act similarly as well (Asir, 2023). Management could encourage employees by introducing benefits of IoT adoption to foster openness and highlighting successful IoT implementation examples for motivation (Liu et al., 2017).

Perceived Behavioral Control is the strongest influential factors among all the variables for Adoption of IoT. There is a need for employees to feel confident and trust in their ability to use and operate IoT technology. The Malaysian government are encouraging technological adoption especially among SMEs by introducing the National IoT Strategic Roadmap (Abdulaziz et al., 2023). Managers can take the government's initiatives to encourage employees to facilitate IoT adoption by providing resources and support to employees.

Perceived Ease of Use is another factor that impacts the intention to adopt IoT and it can be affected by external variables according to TAM. To foster positive attitude among employees, management can create motivation by associating employees to enjoy using IoT technology (Nawi et al., 2021). This could be achieved by introducing user-friendly technology and awareness to encourage employees to understand IoT.

## LIMITATIONS OF THE STUDY

This study focuses on SMEs in the manufacturing sector in Penang. The results may only be applicable to the manufacturing sector rather than other sectors or larger organizations. Different sectors may face different influencing factors such as regulatory requirements, geographical location and technology accessibility. The results may also not be applicable to other regions as this study is focused on Penang. Some factors such as government support, cultural attitudes and knowledge familiarity towards IoT may affect the outcome of the findings.

Potential bias like non-response bias may be introduced due to survey being distributed online. Some individuals may differ from sample respondents and difficult to identify due to limited sources of information and understanding (Sedgwick, 2013). Different groups drawn from different populations could differ in their perceptions and intentions toward IoT adoption compared to the sample respondents, potentially impacting the generalizability of the findings.

Besides, this survey questionnaire is designed using the rating in Likert scale. Likert scale is effective in capturing perceptions of respondents, but the depth of the study may be limited in opinions from the respondents. Likert scale can also lead to central tendency bias which is common to be found in Likert scale rating questionnaire (Douven, 2017).

## FURTHER RECOMMENDATIONS

This study focuses on the state of Penang geographically. For future studies, it is recommended to obtain a larger sample size in other locations to capture broader variations. Other than that, expanding the study to other locations can reveal location-specific trends and understand the unique barriers in adoption of IoT. To conduct in-depth studies, it is recommended to conduct the research internationally to gain insights into global IoT adoption.

From the limitations of the study, it is stated that Likert scale may be limited in depth analysis of the opinions from survey respondents. It is recommended to conduct interviews with respondents to gain insights into the potential challenges and external variables that influence the adoption of IoT that are not captured in the Likert scale survey questionnaire. By combining surveys with interviews, future studies can gain more indepth insights.

Findings found that the hypothesis for Perceived Usefulness is not supported by the data and by referring to certain studies, Perceived Usefulness can be affected by external variables especially when organization prioritize other concerns over usefulness (Wong et al., 2023). It is recommended to include factors such as cost, scalability and organization fit into the study to understand why Perceived Usefulness itself is not sufficient to drive the decisions in IoT adoption into processes (Ahmetogulu et al., 2022).

## CONCLUSION

In conclusion, this study provides a comprehensive analysis of the factors influencing IoT adoption among SMEs in the manufacturing sector with the variables Attitude, Perceived Behavioral Control, Perceived Ease of Use and Perceived Usefulness. The findings support the relevance of TPB and TAM frameworks proposed earlier. The hypothesis developed for Attitude, Perceived Behavioral Control and Perceived Ease of Use are supported, with strongest influential variable being Perceived Behavioral Control, followed by Attitude from TPB framework. Perceived Ease of Use shows positive moderate impact on Adoption of IoT from TAM framework. The hypothesis for Perceived Usefulness is found not supported and this may be due to external factors affecting the variables like cost and scalability that SMEs prioritize over usefulness.

This study also offers both theoretical and practical contributions. Theoretically, the findings contribute to TPB framework by affirming that Attitude and Perceived Behavioral Control show strong impact on adoption of IoT. This study also suggested areas where TAM could be improved in further studies to examine external variables that could impact the variables from TAM on adoption of IoT. The limitations and further recommendations are also identified. By integrating these recommendations, future studies can examine in-depth findings based on this context.

**Author Contributions:** Conceptualization, Cheah Jui Ying; methodology, Abdul Rahman Bin S Senathirajah, Rasheedul Haque; validation: Karim Soliman and Nguyen Thanh Lam; formal analysis: Sumaila Mohammed Ibrahim; data curation: Abdul Rahman Bin S Senathirajah; writing—original draft preparation: Cheah Jui Ying; writing—review and editing: Nguyen Thanh Lam, Rasheedul Haque, Karim Soliman; visualization: Nguyen Thanh Lam; supervision: Abdul Rahman Bin S Senathirajah; project administration: Rasheedul Haque; funding acquisition: Abdul Rahman Bin S Senathirajah. All authors have read and agreed to the published version of the manuscript.

**Conflict of Interest:** The authors declare no conflict of interest.

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