# CONCEPTUALIZING THE AUTOMATION MANUFACTURING TECHNOLOGY ADOPTION AMONG SMEs

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**Abstract:**

Small and Medium-sized Enterprises (SMEs) are essential to the growth of the world economy, particularly when it comes to gross domestic product (GDP) contributions, exports and employment. However, with the rapid development of the Fourth Industrial Revolution (IR 4.0), many SMEs face challenges in adopting Automation Manufacturing Technology (AMT) because of perceived complexity, insufficient technical expertise and financial limitations. AMT is still not widely used by SMEs, despite its potential advantages, which include higher efficiency, better product quality and lower costs. Using the Technology-Organization-Environment (TOE) framework, this study attempts to conceptualize the main factors driving AMT adoption and its effect on SME performance in Malaysia. Applying a quantitative approach, data will be collected through a structured questionnaire distributed to managerial-level staff in manufacturing SMEs located in Selangor. This study investigates technological (relative advantage, compatibility and cost), organizational (top management support), and environmental (competitive pressure and government support and policies) variables. Data analysis will be conducted using SPSS and SmartPLS to perform descriptive statistics, hypothesis testing and structural correlations analyses. The proposed conceptual model includes seven hypotheses linking TOE elements to AMT adoption and the relationship between AMT adoption and SME performance. The findings of this research are expected to offer valuable insights for academics, SME and policy makers by providing both a theoretical foundation and practical recommendations to

AMT adoption. This study adds to the limited body of literature on AMT adoption in SMEs and calls for further empirical validation using quantitative and qualitative methods to expand knowledge and encourage technical development in the SME industry.

## Introduction

Small and medium-sized enterprises (SMEs) are crucial in sustaining and expanding various economies throughout the world. According to Abdalla et al. (2024), SMEs make up more than 90% of all firms in developed countries, contributing 55-70% to both employment and gross domestic product (GDP), and representing the majority of businesses in most economies. Conversely, SMEs have an important role in fostering economic growth, job creation and technological development in emerging countries (Das et al., 2020). By reducing unemployment, fostering international trade through exports, raising tax revenue, and improving investment rates, SMEs play a vital role in economic development at the regional and national levels (Abdalla et al., 2024). In Malaysia, SMEs have been the core of the country's economy, playing a key role in financial development and employment (Muhamad et al., 2021a).

As the world enters the Fourth Industrial Revolution (IR 4.0) era, which prioritizes rapid innovation and technological transformation, SMEs are facing mounting pressure to innovate and adapt (Abdalla et al., 2024). According to Jerin et al. (2024), IR 4.0 introduces a cutting-edge business model with the potential to significantly impact SMEs, enabling them to grow on par with larger industries. However, many SMEs in Malaysia remain slow and lagging in the adoption of automation manufacturing technology (AMT) (Thong et al., 2020). This is mostly due to inadequate capital (Jerin et al., 2024), the complexity and perceived burden of technology (Thong et al., 2020) and knowledge and financial limits (Adam et al., 2021).

Despite these obstacles, AMT provides SMEs with a variety of benefits, such as enhanced productivity (Bharge & Arunoday, 2020), increased quality of the product (Carvajal Soto et al., 2019) and reduced operating costs (Kusiak, 2018). Still, the majority of SMEs are hesitant to embrace and invest in AMT (Thong et al., 2020). According to Abdalla et al. (2024), it is essential to comprehend the variables that affect SMEs' decisions to implement the AMT.

This study is critical because it aims to determine and analyze the elements influencing the adoption of AMT and how it affects the performance of SMEs. These valuable insights could be useful to policymakers, SMEs, and government agencies. The purpose of this is to gain a better understanding of the factors that influence SMEs to adopt AMT. Additionally, previous research has mostly concentrated on the adoption of technology in large companies or broad corporate settings (Faiz et al., 2024). Furthermore, there is still a limited number of studies exploring the adoption of technology by SMEs in developing economies (Kumar et al., 2022). Based on these gaps, this research aims to answer the following research questions:

1. What are the significant factors influencing the adoption of automation manufacturing technology (AMT) in small and medium-sized enterprises (SMEs)?
2. How does automation manufacturing technology adoption (AMT) affect small and medium-sized enterprises (SMEs)?

To better understand the factors impacting the adoption of AMT among Malaysian SMEs, a theoretical framework that provides a structured approach is necessary. In order to analyze AMT adoption in SMEs, this study employs the technology–organization–environment (TOE) framework.

## Literature Review

### *Automation Manufacturing Technology (AMT)*

In recent times, automation manufacturing technology (AMT) has come out as a growing trend, as companies seek to increase productivity, reduce costs and improve efficiency. According to Atkinson (2019), the term "automation" was first introduced in 1945 by the Ford Motor Company's engineering department to describe the operations of their new transfer machines, which mechanically removed stamping from body presses and positioned it in front of machine tools. Furthermore, Atkinson (2019) noted that today, automation broadly refers to any manufacturing process that is managed by machines and requires minimal or no human input, thus evolving into a highly automated method.

Automation in manufacturing has become a revolutionary force, transforming both the industrial environment and traditional production procedures (Berawi, 2020). According to Berawi (2020) and Camiña et al. (2020), modern technologies such as robotics, artificial intelligence (AI), machine learning, the Internet of Things (IoT), big data and cloud computing or 3D printing are fundamental components of automation. These technologies are integrated into production processes to develop intelligent and autonomous systems capable of performing tasks reliably, precisely, and efficiently.

The adoption of AMT can bring numerous benefits to organizations such as improved productivity (Bharge & Arunoday, 2020), increased product quality (Carvajal Soto et al., 2019) and cost reduction (Kusiak, 2018). For instance, Pérez et al. (2020) emphasized that productivity can be significantly improved through the use of modern robotics, as automated systems are capable of carrying out repetitive tasks precisely and consistently. This facilitates continuous operations and results in substantial productivity gains.

Moreover, automation enhanced product quality by forecasting and detecting defect patterns at an early stage. It also assists in identifying the specific causes of poor quality, whether they stem from human, machines or environmental factors (Carvajal Soto et al., 2019). In addition, Syafrudin et al. (2018) stated that automation technologies help mitigate production losses caused by unforeseen problems. According to Doh & Kim (2014) and Kusiak (2018), cost reduction is another major benefit derived from implementing automation technologies. Organizations aim to eliminate unnecessary costs to increase their overall profitability. Although initial investments in automation technology may be substantial, it ultimately helps reduce continuing operational costs (Azemi et al., 2019).

Regardless of the benefits above, small and medium-sized enterprises (SMEs) frequently face significant challenges in adopting AMT. Key limitations consist of financial restrictions (Adam et al., 2021) and high initial investment cost (Reis & Camargo Júnior, 2024). These barriers emphasize the importance of understanding the contextual factors that influence SMEs' decision-making processes regarding AMT adoption.

### Factors Affecting Automation Manufacturing Technology (AMT) Adoption

The Technology-Organization-Environment (TOE) framework was established and proposed by Tornatzky and Fleischer (1990). This model outlines three key contexts which are technology, organization and environment, that influence a company's decision to adopt new technologies. The technological factors include both internal and external technologies that are relevant to the company as well as those accessible for potential adoption (Correia Simões et al., 2020). The organizational factors refer to the internal features and the availability of resources of the company that facilitate technology adoption. These include factors such as organizational size, previous experience in the use of technology, managerial structure, and the quality and capacity of human resources (Al Hadwer et al., 2021). Meanwhile, environmental factors surround the external environment in which a company operates and interacts. For instance, the regulatory environment, competitors, and market elements (Correia Simões et al., 2020).

### Technology Factors

#### Relative Advantage

Relative advantage refers to the degree to which a technological innovation is recognized to provide greater advantages than the existing technology within an organization (Muhamad et al., 2021b). Several studies have highlighted the significance of relative advantage in influencing technology adoption decisions (Chong & Olesen, 2017; Priyadarshinee et al., 2017). Previous research indicates that AMT adoption can boost sales, reduce costs and offer chances to make use of common resources (Khayer et al., 2021). According to Aligarh et al (2023), AMT adoption can enhance the efficiency of operational tasks. A study in Indonesia found a positive and significant relationship between the relative advantage of AMT and its adoption (Aligarh et al., 2023) whereas a study in Iran reported a negative relationship (Maroufkhani, Tseng, et al., 2020). These contradictory findings imply that the relative advantages of AMT can vary depending on the situation, impacted by elements like organizational preparation, implementation difficulties and market conditions. Based on these findings, the current study proposes the following hypothesis regarding relative advantage:

> *P1: Relative advantage positively affects AMT adoption*

#### Compatibility

According to Oliveira et al. (2014), compatibility refers to the extent to which users consider that a new technology fits with their existing values, experience and adopters or potential needs. It is also defined as the degree to which an innovation aligns with existing systems within an organizational environment (Effendi et al., 2020). SMEs are more likely to adopt new technology when they perceive it as compatible, as this allows them to assess whether the technology is suitable for their organizational setting. Innovation or new technology is easier to implement and integrate when it is recognized as being compatible with existing systems, processes and the organization's values and beliefs (Harfoushi et al., 2016). When an organization feels that a technology is compatible, the likelihood of continued use increases, as it is expected to offer greater benefits to organizational performance (Mahakittikun et al., 2021). In Malaysia, Shahzad et al. (2023), found a significant and positive relationship between the compatibility and AMT adoption. Based on these findings, the current study proposes the following hypothesis regarding compatibility:

> *P2: Compatibility positively affects AMT adoption*

### Cost

According to Effendi et al. (2020), cost is a significant factor hindering SMEs from adopting new technology, as high-technology solutions usually need an expensive investment. Similarly, Ling et al. (2020) found that limited financial resources and capital are the main obstacles for SMEs, causing many owners to delay adoption because of concerns over financial risk and potential losses. This will make the SME owners slow down adopting technology since they are worried about their finances and do not want to take a risk to bear the loss. The relative cost of innovation is particularly crucial for SMEs compared to larger companies, given their limited access to resources such as financing, materials and labor (Gunawardana, 2020). A study in Iran found a negative and insignificant relationship between cost and AMT adoption (Ghobakhloo & Ching, 2019). Based on these findings, the current study proposes the following hypothesis regarding cost:

*P3: Cost positively affects AMT adoption*

## Organization Factor

### Top Management Support

Top management refers to individuals who play an important role in initiating, implementing and adopting technology in SMEs. Typically, the chief executive officer (CEO) or equivalent makes key decisions regarding the organization's technology strategy and investment (Maroufkhani, Tseng, et al., 2020). According to Harfoushi et al. (2016), top management support can be demonstrated through their active participation in the adoption of new technology within the company. Such support is important as top managers are regarded as experts in identifying the most suitable technological solutions for their organization. According to Shahzad et al. (2023), top management's support is vital to the success of AMT adoption. A study in Iran found a significant and positive relationship between top management support and AMT adoption (Maroufkhani, Tseng, et al., 2020) and similar findings were reported in Malaysia (Shahzad et al., 2023). Based on these insights, the current study proposes the following hypothesis regarding top management support:

*P4: Top management support positively affects AMT adoption*

## Environment Factors

### Competitive Pressure

According Awa et al. (2017), competitive pressure refers to the pressure felt by organizations from competitors or other industry players operating within the same industry. Similarly, Hoti (2015) defined competitive pressure as the increased likelihood of adopting technology and innovation due to heightened competition and rivalry, aimed at gaining a competitive advantage. When competitors adopt new technologies that influence the competitive dynamics of an industry, other companies may be compelled to follow suit to remain competitive and avoid being left behind. Harfoushi et al., (2016), stated that AMT adoption can assist organizations in reshaping the competitive environment in a variety of ways, including industry structures and enabling companies to outperform their competitors. According to Shahzad et al. (2023), a study in Malaysia found a positive and significant relationship between competitive pressure and AMT adoption, while Aligarh et al. (2023) reported similar findings in Indonesia. Based on these insights, the current study proposes the following hypothesis regarding competitive pressure:

*P5: Competitive pressure positively affects AMT adoption*

### Government Support And Policies

According to Hoti (2015), government policies and support refer to initiatives undertaken by the government to encourage SMEs to adopt new technologies. Such policies may include both promotional and restrictive measures, as they can either motivate or discourage organizations from adopting technological innovations (Effendi et al., 2020; Maroufkhani, Wan Ismail, et al., 2020). Governments can facilitate technology adoption by offering incentives such as favorable tax regulations, supportive business development policies and financial assistance. However, empirical evidence on the impact of government support and policies is mixed. For instance, a study in Iran found a negative and insignificant relationship between government support and policies and AMT adoption (Maroufkhani, Tseng, et al., 2020) while a similar finding was reported in Malaysia by Shahzad et al. (2023). Based on these findings, the current study proposes the following hypothesis regarding government support and policies:

> *P6: Government support and policies positively affect AMT adoption*

### Automation Manufacturing Technology (AMT) Adoption And SMEs' Performance

According to Weck & Afanassieva (2023), technology adoption is not a single event but rather a process that starts with the discovery of a technology and concludes with its full utilization in business processes. However, this adoption process is rarely uniform, frequently depending on the perspectives of individual decision-makers, who may be impacted by contextual limitations, risk aversion or a lack of technology expertise. According to Mosbah (2024), SMEs can scale their operations, manage economic instability and increase their competitiveness in the future by implementing AMT. But such positive outcomes are not guaranteed, as the advantages of AMT adoption often rely on the degree of external support and the organization's readiness. Moreover, technology adoption plays a significant role in improving SMEs' market performance and financial performance. Previous studies found that AMT adoption positively affects the financial performance, particularly when it enhances customer satisfaction and drives growth in profitability and sales (Maroufkhani, Tseng, et al., 2020). Notably, AMT adoption also tends to strengthen an organization's financial performance more than its market performance (Yasmin et al., 2020). Based on these insights, the current study proposes the following hypothesis regarding AMT adoption and SME performance:

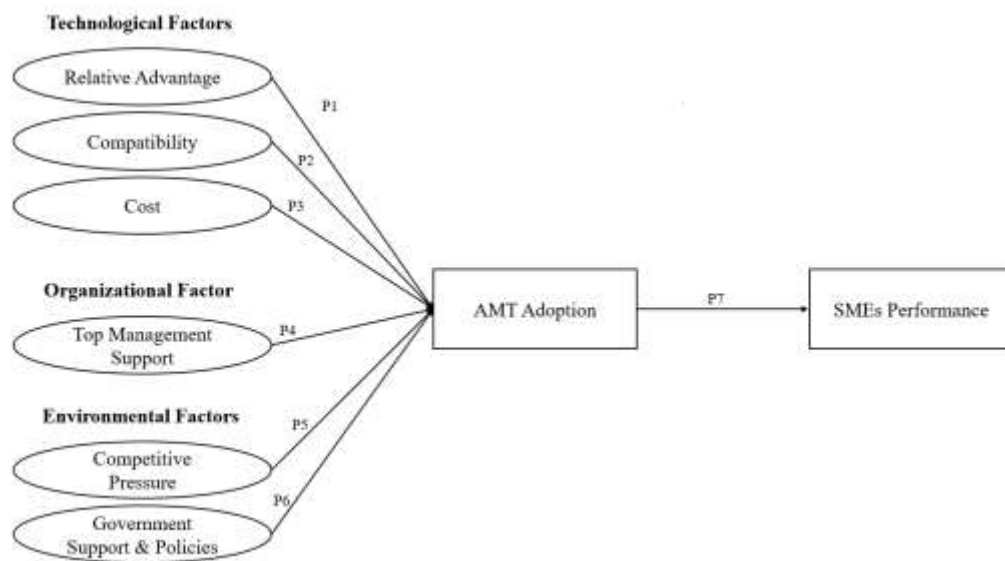> *P7: AMT adoption positively affects SMEs' performance*

### Theoretical Framework and Proposition

To identify the factors that motivate the SMEs to adopt the AMT, this research employs the Technology-Organisation-Environment Theory (TOE) framework to provide a comprehensive theoretical foundation and guide the development of research propositions. This study uses the TOE theory to gain a better and deeper understanding of what factors influence AMT adoption and how AMT adoption influences SME performance. In the previous studies, the TOE framework has been widely applied to examine technology adoption and innovation processes within organizations (Kim et al., 2015).

According to Nikmah et al. (2021), the TOE theory is a classical model initially proposed by Tornatzky and Fleischer (1990). It categorizes the influencing factors into three main contexts, which are technology, organisation and environment. The technological factor encompasses both internal and external technologies relevant to the company including those available for potential adoption (Correia Simões et al., 2020). In this context, relative advantage, compatibility and cost are common factors.

The organizational factor refers to internal characteristics and the availability of resources within the company that support technology adoption. These factors include top management support, size of the organisation, previous experience in the use of technology, managerial structure, and degree of its human resources (Al Hadwer et al., 2021). This study focuses on the top management support.

Lastly, the environmental factor refers to the external environment in which the company operates and engages. This includes the regulatory environment, competitive pressures, and market elements (Correia Simões et al., 2020). The focuses of this study are competitive pressure and government support and policies. Together, these three aspects provide a comprehensive perspective for analyzing the factors that influence SMEs' adoption of AMT.



**Figure 1: Proposed Theoretical Framework**
Source: Author's Own

**Table 1: Summary Of Propositions**

| *Propositions* | |
| --- | --- |
| P1 | Relative advantage positively affects AMT adoption. |
| P2 | Compatibility positively affects AMT adoption. |
| P3 | Cost positively affects AMT adoption. |
| P4 | Top management support positively affects AMT adoption. |
| P5 | Competitive pressure positively affects AMT adoption |
| P6 | Government support and policies positively affect AMT adoption |
| P7 | AMT adoption positively affects the SME performance |

Source: Author's Own

**Research Methodology**
This part outlines the research methodology employed in this study. It provides a detailed explanation of the research design, purpose of the research, the unit of analysis, time horizon, population, sample size, sampling methods, data collection techniques, measurement scales and the data analysis tools used.

## Research Strategy

This study uses a quantitative research strategy. According to Basias and Pollalis (2018), quantitative research involves the structured and empirical investigation of phenomena through the application of mathematical and statistical techniques, as well as the analysis of numerical data. This approach is well-suited for determining relationships, testing hypotheses and examining patterns, which coordinate with the objectives of this research.

## Purpose Of The Study

This study uses a combination of exploratory and hypothesis-testing approaches. An exploratory approach is conducted when limited previous research exists on a particular issue, especially when in-depth studies are scarce or the problem is not clearly defined. In this context, the exploratory stage seeks to gain a better understanding of AMT adoption, as previous studies on this topic are relatively limited. In parallel, a hypothesis-testing approach is conducted to examine the cause-and-effect relationship between variables, specifically, the positive or negative impact of certain factors on AMT adoption, as well as the impact of AMT adoption on SME performance. By using this method, this study examines the relationship between variables and determines whether specific factors significantly influence AMT adoption and whether AMT adoption, in turn, affects SME performance.

## Unit Of Analysis

The unit of analysis for this research is the individual, specifically the managerial-level employees working in manufacturing SMEs in Selangor. This focus is relevant because the study intends to comprehend how AMT adoption influences SME performance from the viewpoint of decision-makers or those directly involved in the operational and strategic activities.

## Target Population

Manufacturing SMEs located in the Selangor area are the target population for this study, as Selangor has the highest number of SME establishments in Malaysia. There are 9,530 SMEs in this region overall, according to the 2016 Economic Census (DOSM, 2017). Based on the sample size determination table by Krejcie and Morgan (1970), a minimum of 368 respondents is required to represent this population. However, if this target cannot be achieved, the G*Power method will be applied, with a minimum sample size of 146 respondents to ensure sufficient statistical accuracy and power for the analysis.

## Data Collection Method And Measurement Scale

This study uses a structured survey questionnaire as the primary data collection method, as it is efficient, simple and capable of producing reliable data. The questionnaire will be distributed through email and the drop-and-collect method, relying on the respondents' convenience and availability. To create the questionnaire, this study uses an adopt and adapt method, whereby items are taken from and modified from previously validated research instruments. To measure respondents' degree of agreement with each statement, a 5-point Likert scale will be used. The scale ranges from 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree) and 5 (Strongly Agree).

## Statistical Tools And Data Analysis Approach

Two statistical tools will be used to analyze the data: SPSS (version 31) and SmartPLS (version 4). SPSS will be used for data coding and entry, identifying missing values and examining any invalid or unengaged responses. Descriptive statistics, including frequencies, means, standard

deviations, skewness and kurtosis, will be employed to explain the characteristics of the data and to assess normality. Meanwhile, SmartPLS will be used to analyze the hypothesis testing and assess causal relationships between variables. This tool is particularly suitable for the current study because it supports structural equation modelling (SEM) and multiple regression analysis, making it effective for exploring complex relationships between constructs.

## Conclusion

The findings from this study have important implications. For SMEs, it provides a tool for strategic decision-making and assessing automation readiness. It also emphasises the need of leadership commitment, policy knowledge and integration adaptability. With the appropriate support, AMT adoption can help SMEs improve their performance, global competitiveness and sustainability. For policymakers, it offers insight into developing specific support programs and incentives. This study was designed to create a framework for determining the theoretical framework of AMT adoption. This study focuses on AMT adoption towards SMEs since less and limited studied on it in previous studies. This paper extends the knowledge on AMT adoption and SMEs performance. Other than that, it also contributes to the existing technology, SMEs and TOE theory body of literature. This study can also be used in future studies and can attract more academician arguments related to this topic to expand and explore more on the suggested proposition. Moreover, in the future, the research needs to focus on both quantitative and qualitative research designs that examine the relationship between the SMEs and factors of AMT adoption.

## Acknowledgements

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