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The Future Scenarios of Automation and Robot Implementation in the Manufacturing Industry

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Abstract: Since 1983, manufacturing industry in Malaysia has embraced automation and robotics under the leadership of former Prime Minister, Tun Dr Mahathir Mohamad. Manufacturing companies in Malaysia have been encouraged to embrace automation and robotics as it offers many benefits to the country. However, the radical fluctuations in the dynamic manufacturing environment impose challenges for industries to keep up with the changes. Thus, this study was conducted to identify the STEEPV factors of social, technological, economic, environmental, politics and values that influence the adoption of full automation and robotics in the manufacturing industry. In addition, possible future scenarios for the implementation of full automation and robots were proposed as well. The research was conducted using STEEPV analysis where 50 managers from manufacturing companies responded to the distributed questionnaire. The result showed that economic sector had the greatest influence towards full automation and robots' implementation in the manufacturing industry. In addition, the four scenarios predicted to occur for the next ten to fifteen years were 'the dawn of smart manufacturing', 'inefficacious industry', 'ebb and flow' and 'obstreperous technological development'. The deliberate incorporation of automation and robots, aligned with strategic planning and a flexible policy framework, will not only boost productivity but also bolster the nation's economic growth and global competitiveness. The manufacturing industry, in collaboration with the government, plays a pivotal role in realising the complete potential of these future scenarios, ensuring a prosperous and sustainable future for Malaysia.

Keywords: Automation, robots, STEEPV, future scenario, manufacturing industry

1. Introduction

The term 'robot' was first introduced to the global manufacturing market in 1920, followed by the term 'robotics' coined in 1942 (Suhansa, 2022). Robots are referred to as automated devices or machinery that are programmed to perform work independently or with little supervision from humans, while robotics are defined as a programme that focuses on operation and utilisation based on giving robots intelligence (Sadiku et al., 2021). Robotics works as a tool to perform specific tasks that require high accuracy and speed and is typically used in many automation processes (Norris & Petterson, 2019). Automation, on the other hand, is a measure that determines the extent of the technology used to automate manufacturing tasks (Shekhar, 2019). It can be classified into two categories, referred to as fully automated and semi-automated systems. A fully automated system is identified as the full execution of tasks by robots in transforming raw materials into finished goods that take place in an entire manufacturing cycle (Invotec Engineering, 2018). This approach requires the involvement of human experts to monitor the operation of the high-speed robots. On the other hand, robots assist with half of the work process but the need for human labour, commonly known as operators at each station of the convention line, is enormous in semi-automation systems (Norris & Petterson, 2019). So, it turns out that robots and automation are fundamentally different, but the concept between the two is closely linked.

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Policymakers believe that robots and automation are critical in driving economic expansion and strengthening value-added growth within the manufacturing industry (Bessen et al., 2020). This is due to automation and robotics offering assistance to maintain operation control and viability enhancement in the manufacturing industry, where the result from the implementation emerges in the form of high-end product quality and process efficiency. Undoubtedly, the implementation contributes towards profit enhancement and reduces the costs of direct labour (Bataev & Davydov, 2020). Despite the benefits rendered by automation and robots, they pose drawbacks such as the potential job replacement that may lead to a significant increase in the unemployment rate (Masriadi et al., 2023). In particular, their ability to execute routine tasks and activities that demand abstract skills and operate in an unstructured environment has wiped out a massive number of jobs. To exemplify, Holden (2017) demonstrated that a single robot could accomplish the tasks of three to five employees, in exchange for their position, also indicating the colossal impacts of manufacturing technology on the labour market. These are the collateral damage that may occur if manufacturers invest their money in automated robotics systems. For example, Yong et al. (2020) expected that job security in most manufacturing companies would be potentially under threat of losing to automated systems in 20 years.

The environment in the manufacturing industry will undergo significant changes, leading to a different way of functioning. Accordingly, employees need to venture into new skills to cope with the rapid advance of automation and robotics in order for their companies to stay competitive (Schwabe & Castellacci, 2020). Considering that the rise of smart manufacturing is full of uncertainties, the lack of readiness and awareness to embrace the importance of automation and robotics and the incapability to augment manufacturing competitiveness will jeopardise the survival of the industry (Masriadi et al., 2023). In addition, advanced technologies require the ability to identify and tackle the appropriate condition for installing new equipment and skills to optimise the utilisation of technology (Frank et al., 2019). Given that, it is crucial to discover the factors that influence the implementation of full automation and robots using STEEPV techniques and examine the future scenarios in the manufacturing industry. STEEPV techniques are employed due to their comprehensive analysis that examines the complexities associated with potential risks and opportunities (UNDP, 2022). As a result, the findings of the current study would assist the industry in being better prepared and informatively equipped to face the impending challenges.

1.1 Background of Study

Automation and robotics represent the evolution of technological advancement that has been extensively utilised since the 19th century. The rapid advancement of technologies has been providing impacts on various industries, but the impact on the manufacturing industry has been profound. This is because the industry commonly involves a massive number of machineries and is comprised of repetitive tasks which befitting the implementation of automation and robotics (Soumyashree et al., 2023). The high quality, high precision, and fast speed of work offered by automation and robots increase the acceptance of investment in the industry (Papulova et al., 2022). To illustrate, the introduction rate of robots in the manufacturing industry is recorded as one of the highest compared to the other industries, with countries in Asia showing a strong ascending number and recording the highest robot sales every year (Thirusanku & Ki, 2022). In accordance with that, Malaysia, a part of the Asian countries, is employing automation and robots which has resulted in changes in the country's manufacturing environment (Gen et al., 2022). Since introduced by Tun Dr Mahathir Mohamad, the installation of automation and robotics has been substantially increasing according to the rapid industrialisation of the nation (Abd Rashid et al., 2019).

The importance of employing full automation and robotics is widely accepted because the machines ensure improved and maximised productivity, efficiency, and output quality (Javaid et al., 2021). In addition, automation, robotics, and smart manufacturing are predicted to enhance a country's competitiveness and attractiveness in global investment platforms. Nonetheless, drastic changes in the manufacturing industry necessitate new skills and new competencies to operate in the sophisticated machine environment (Javaid et al., 2021). Also, the human touch is still involved in certain parts of the production process, either in fully or semi-automated systems, although skilled and talented employees who could handle high-level technologies are scarce (Soumyashree et al., 2023). The scarcity of skilled employees is a major concern since it could hinder transformation and investment in automated production systems (Javaid et al., 2021). In contrast, hiring low-skilled employees in risky and repetitive work is less favourable because of the limiting low-skilled tasks. These situations lead to a decline in the overall employment rate (Lu et al., 2020). Moreover, both employers and employees are triggered since robots and automation will eventually fill most positions in the manufacturing industry. In lieu of safeguarding employment, some manufacturers may be hesitant to invest in automation and robotics. This will result in a cautious, stagnant, and uncompetitive industry which will impact economic growth. Therefore, it is crucial for manufacturers to be well prepared and ready to face the upcoming automation and robotics technology evolution.

1.2 Problem Statement

Robotics and automation are the future forms of the workforce due to their huge potential for advancement in productivity volume, quality improvement, income, and national competitiveness uplift. It is a vital trend in the industry's modernisation. However, robotics and automation require workers with higher skills to operate the machines (Moniz & Krings, 2016). Less skilled workers will be terminated and the employment rate will decline. The impacts of robotics and automation on replacing human-oriented jobs have gained a surge in public interest (International Federation of Robotics, 2017). Companies that have workers who are equipped with skilled and related education have a better competitive advantage because the workers can fit themselves in the new technologies. Demands for skilled workers will be high but the supply is limited. As such, educating personnel through the essential process of reskilling and upskilling will allow them to proficiently adjust to the evolving requirements posed by forthcoming technologies (Khan et al., 2021).

Sorgner (2017) emphasises that the advancement of Artificial Intelligence (AI) allows future machines to perform human tasks even better and faster. Repetitive, delicate, and simple tasks can be accomplished in a shorter time to increase production efficiency. Nevertheless, keeping up with drastic changes in the environment of manufacturing due to technological advancement is challenging (Moniz & Krings, 2016). For example, less than 20 percent of manufacturing companies in Malaysia have implemented automation, indicating the country's low automation rate (Eurocham, 2020) and that the majority of companies have either remained semi-automated or entirely dependent on manual processes. However, studies on robotics and automation in the manufacturing industry in Malaysia are scarce. Hence, the current study explored the social, technological, economic, environmental, political, and values (STEEPV) factors that influence the implementation of full automation and robotics in the manufacturing industry in Malaysia.

2. Methodology

This study was conducted on manufacturing companies in Johor, Malaysia. Companies operating with either full or semi-automation systems were randomly selected to be part of this study, specifically using simple random sampling. The type of sampling was employed due to the large pool of elements and the highly homogenous population of the respondents under study (Noor et al., 2022). Additionally, this method provides a fair opportunity for every individual to participate in the study. The data collection was subsequently carried out by distributing a survey questionnaire to managerial personnel of the manufacturing companies.

Federal of Malaysian Manufacturers Malaysia recorded a total of 420 manufacturing companies in Johor in 2017 (Federation of Malaysian Manufacturers Johor Branch, 2017). Industries of various manufacturing companies were selected randomly. Based on Krejcie & Morgan's (1970) sample size tabulation, the sample size for this research was 201 responses. However, only 50 usable responses could be analysed. This was in accordance with Pallant (2013) who recommends a sample size to be between five to ten times the independent variables for an analysis to be conducted. Given there were five (5) variables in this study, the recommended sample size was 50 respondents. This offered precise measurement and a larger range of values (Memon et al., 2020). Even though the current study's response rate was only 25 percent, which was lower than the typical acceptable response rate of 30 percent for surveys (Hair et al., 2010; Sekaran & Bougie, 2016), due to time and financial constraints, previous successful studies on the manufacturing industry of small, medium, and large companies in Malaysia collected a response rate between 10 percent to 29 percent (Chong et al., 2011; Ng & Jee, 2012; Thrulogachantar & Zailani, 2011; Islam & Karim, 2011). In addition, the current study covered a descriptive analysis, requiring comparing the current response rate with past studies and complying with the recommended suggestions, the available 50 responses (25 percent) qualified the required sample size for further analysis. The summary of the respondents' profiles is presented in Table 1.

This study applied the foresight method. The foresight method involves the consideration of various situations that pertain to strategies whether it is challenging or demanding procedures and failure to achieve success. The production of the outcomes is the focus of a foresight process, which may include roadmaps, visions, and scenarios (Dufva, 2016). It is a systematic process with five (5) complementariness and interconnected phases (Popper, 2011), namely scoping, mobilising, anticipating, recommending, and transforming. There are three additional steps and procedures involved. The first step explains scoping as an exercise's objectives and activities. The second step clarifies mobilising as the mobilisation and key players' involvement. The third step explains anticipating, recommending, and transforming that shape and form the future through strategic planning (Malaysia's National Foresight Magazine, 2011).

Scoping the future is in the first phase of the strategic process where the decision is made. It is also known as pre-foresight (Paliokaitė, 2010). The early process decision included the objective of the research, which was to identify the STEEPV factors that influenced the current and future implementation of full automation and robots in the Malaysian manufacturing industry. This research was conducted due to the scarcity of past foresight studies on full automation and robots' implementation in the manufacturing industry in the country. Furthermore, the field of the study analysed the perspective of future trends, issues, and factors on the implementation, thus was set to identify the specific years that full automation and robots would be fully adopted in the Malaysian manufacturing industry. Manufacturing companies in Johor listed in FMM were identified as scoping areas and the tenure of research was within one year.

Table 1 - Demographic profiles of respondents

Demography	Item	Frequency (n=50)	Percentage (%)
Age	21–30 years old	26	52
	31–40 years old	21	42
	41 years old and above	3	6
Gender	Male	31	62
	Female	19	38
Race	Malay	27	54
	Chinese	18	36
	Indian	5	10
Education Level	Diploma	12	24
	Degree	36	72
	Others	2	4
Manufacturing experiences	5 years and less	18	36
	6–10 years	20	40
	11 years and above	12	24
Industry	Computer, electronic, and optical products	16	32
	Chemicals and chemical products	4	8
	Food and beverages products	16	32
	Rubber and plastic products	6	12
	Others	8	16

The second phase is the mobilisation process which requires the interaction and engagement between individuals and the stakeholders (Malaysia's National Foresight Magazine, 2011). The stakeholders involved were the University Tun Hussein Onn Malaysia (UTHM), the Malaysian Industry Government Group for High Technology (MIGHT), and managers in the manufacturing industry. Anticipating the future is the third phase and it involves three elements which are anticipating, recommending, and transforming to produce the 'formal outputs' of the foresight studies. It explains the prospective approaches that are being used. Recommending elements explain planning and decision-making approaches while the transforming element is briefly about the evaluation approaches that are being used (Malaysia's National Foresight Magazine, 2011). In this part, the researcher employed an immediate output of foresight and horizon scanning (FHS) to identify the key drivers of the factors that influenced the full automation and robot implementation in the manufacturing industry.

The key drivers were based on the STEEPV approach, in which S stands for social, T for technological, E for economic and environmental, P for political, and V for value, to identify the forces of change and to define future direction. The five factors were used as a commencing point for future strategic discussion in future which is known as a brainstorming tool (Minhas et al., 2011). Questionnaires were used as research tools in collecting data. The survey questionnaire was divided into four sections: A = demographic background, B = Importance, C = Impact and D = Uncertainty. In section A, multiple-choice questions were administered. In sections B to D, a 5-point Likert scale was employed. The data were analysed using Statistical Package for Social Science (SPSS). During the scanning and brainstorming of STEEPV drivers, recent literature consisting of journal articles, government websites, online newspaper websites, personal blogs, and company blogs were studied. The study later classified each concerned issue according to its related driver, as shown in Table 2.

Results on past literature discussions on automation and robot implementation revealed concerns on technological, economic, and social matters with 30, 28, and 16 issues respectively. Whereas only 8, 7, and 3 were related to value, politics, and environment, respectively. In addition, previous discussions on the technological aspects of automation and robot technology highlighted advanced, assistive, and integrative systems which reduced complex manufacturing tasks and improved the production and operation of manufacturing in these smart factories. The second concern revolved around the economic implications. The implementation modified future employment ecosystems, demand for highly skilled workers, investment involved, operational benefits, and positive economic growth. In terms of the social factor, stakeholders were more concerned with human-robot interactions. The value factor emphasised the competitive advantages, unemployment crisis, and technological development resulting from the implementation of automation and robots into the production line. Moreover, governmental roles and support were highlighted under the political factor. Support from the government played a major role in influencing the implementation of automation and robots at the micro level. Lastly, for the environmental factor, discussions focused on the energy consumption of heavily automated machines and systems, revealing their demanding energy-efficient production by the production floor. The results from the STEEPV analysis were summarised into 13 major issues. Subsequently, the study's questionnaire was developed.

Table 2 - Summary of STEEPV brainstorming

Social	Technological	Economic	Environmental	Political	Values
1. Sharing knowledge between robots and human. 2. Interaction between human and robots 3. The acceptance of industrial robots 4. Workers risk in manufacturing industry 5. Rise of robots at work 6. Human and robots interaction 7. Human and robot collaboration 8. Worker perceptions towards robot 9. Human automation collaboration 10. Maximize the effective implementation 11. Reduce the cost of development for future projects 12. Human robot collaboration 13. Human robot collaboration implementation 14. Enhance productivity and product quality 15. Emergence of new concepts 16. Automation in the	1. Productivity and flexibility. 2. Complexity of programming 3. Rapid paradigm shift 4. Smart factories 5. Robots application's idea 6. Mundane and repetitive task 7. Robotic process automation (RPA) implementation 8. Intelligent system 9. Reduce production times 10. Computer integrated system implementation 11. Industry rapid advancement 12. The manufacturing system 13. Multi-layered framework 14. Manufacturing concepts 15. Scientific and technological barrier 16. Capacity to predict and prevent downtime 17. Optimize equipment effectiveness and maintenance 18. Increase productivity 19. Lack of planning capabilities 20. Tasks limitation 21. Robot planning implementation 22. System integration 23. Reduce the complex manufacturing tasks 24. New robot concept 25. Closing the gap between manual and fully automatic assembly 26. Robust method 27. Flexibility 28. New technologies 29. Technology advances 30. Support tools to find the suitable automation's level	1. Demand for industrial robots. 2. Lack of employees in manufacturing industry. 3. Demand for new talent 4. Demand for high-skilled manufacturing talent 5. Demand for a new type of technology-intensive manufacturing workforce 6. Limited availability of the workforce 7. The numbers of person employed increased 8. Supply chain pressure 9. Investment in automation 10. Global macroeconomic pressure 11. Employment opportunities 12. Rise of the robots 13. Job opportunities 14. Economy shift 15. Demand for skills 16. The need to increase in productivity 17. Human substitution by the robots 18. Applicability of robots in certain jobs 19. Displacement effect on future jobs and wages 20. High implementation cost for SMEs 21. Robots' demand increase 22. Awareness for a higher share in manufacturing 23. Generate and retain the quality of employment 24. High-cost skilled workers 25. Cost effective 26. Long-run of economic growth 27. Sustainability 28. Demand for high skill workers	1. Industrial robots' energy consumption. 2. Reduce environmental impacts 3. Operating conditions	1. Policy enforcement 2. Government support program 3. Government restriction 4. Legal gap between reality and original framework 5. Government roles in policy enforcement 6. Certification of skills by the government 7. Government support	1. Perception toward automation 2. Challenge in manufacturing 3. Significant impact of technology change. 4. Unemployment crisis 5. High level of competitiveness in market 6. Maintain the factory competitiveness in the global marketplace 7. Maintain a competitive edge in the global manufacturing market 8. Manufacturing technologies and processes developments

working environment

3. Empirical Analysis

In the questionnaire, a total of 13 items were repeated according to the different perspectives of importance, impact, and uncertainty. Table 3 shows Cronbach's alpha values derived from the variables, 0.881, 0.872 and 0.882 for importance, impact, and uncertainty, respectively. The obtained values, ranging from 0.8 to 0.9, showed that the variables used in this study were reliable and had high internal consistency.

Table 3 - Reliability analysis

Category	N of items	Cronbach's Alpha
Importance	13	0.881
Impact	13	0.872
Uncertainty	13	0.882

Table 4 shows the overall mean values for 13 items. These items were arranged in descending order. The six (6) most important items were the need for highly skilled labour, operational benefits, human-robot interaction, economic growth, government support and complex manufacturing tasks. The least important among the 13 items were global competitive advantage, smart factories, unemployment, automation and robot use, high costs, technological development, and energy-efficient production. For the graphical representation, these six (6) most important mean values were coded with the new codes Q1, Q2, Q3, Q4, Q5 and Q6, respectively.

Table 4 - Mean score for importance of drivers

Drivers	Mean
1. Demand for high skilled workers	4.36
2. Operational benefits	4.36
3. Human and robot interactions	4.30
4. Economic growth	4.22
5. Government support	4.18
6. Complex manufacturing tasks	4.06
7. Global competitive advantage	3.90
8. Smart factories	3.90
9. Unemployment issues	3.84
10. Automation and robot implementation	3.82
11. High cost	3.78
12. Technological development	3.76
13. Energy-efficient production	3.60

The analysis of the mean values experienced impact and uncertainty variables. The mean values for the impact and uncertainty variable of the six (6) most important items are shown in Table 5. The x-axis represents the impact scores, while the y-axis represents the uncertainty scores. Q1 to Q6 was arranged in descending order from the most important to the least important. To illustrate, Q1: Demand for highly skilled workers had the highest mean of 4.36 for Importance, which was similar to Q2: Operational benefits. Even though both Q1 and Q2 had the same level of Importance, they were different in terms of their Impact and Uncertainty. Q2 had the highest Impact with a mean of 4.42 as compared to Q1 with only 4.28. Whereas for Uncertainty, Q1 and Q2 had slightly low means, with Q1 scoring 3.30 and Q2 with 2.98. On top of that, Q3: Human and robots' interaction recorded a high mean for Importance of 4.30. Additionally, Q3 also had a high tendency in its Impact and Uncertainty, in which Q3 recorded a mean of 4.40 for Impact and 3.16 for Uncertainty. It was followed by Q4: Economic growth, in which Q4 had a high level of Importance with a mean of 4.22. However, Q4 only had an average tendency for its Impact and Uncertainty, where the mean for both did not exceed 4.00. The Impact for Q4 had a mean of 3.84 and the mean for Uncertainty was 3.24. Compared to the others, Q5: Government support scored the second lowest for Importance. Q5 had a high tendency for both Importance and Uncertainty but had only an average tendency in its impact. Q5 had a mean of 4.18 for Importance, 3.78 for Impact, and 4.12 for Uncertainty. Q6: Complex manufacturing tasks showed the least importance compared to Q1, Q2, Q3, Q4, and Q5. Although Q6 had a high tendency in its Importance with a mean of 4.06, it had only an average tendency for its Impact and Uncertainty with a mean of 3.98 and 3.50, respectively.

Table 5 - Impact-uncertainty scores

Code	Drivers	Item	Mean value		
			Importance	Uncertainty (y-axis)	Impact (x-axis)
Q1	Demand for high skilled workers	Rises of robots and automation in work increase the demand of higher skilled worker in operating the machines.	4.36	3.30	4.28
Q2	Operational benefits	The collabouration between human and robots in work are needed in order to improve the company productivity and flexibility in future.	4.36	2.98	4.42
Q3	Human and robot interactions	The interaction between human and robots can lead to the reduction of production time in manufacturing company	4.30	3.16	4.40
Q4	Economic growth	Maximising the effective implementation of automation and robots in manufacturing industry can encourage the future economic growth.	4.22	3.24	3.84
Q5	Government support	Support from the government can cultivate the worker perception towards the acceptance of robots and automation in manufacturing industry.	4.18	4.12	3.78
Q6	Complex manufacturing tasks	Human robots collaboration (HRC) implementation in operation can overtake the complex manufacturing tasks.	4.06	3.50	3.98

All six codes are plotted into a graph as depicted in Figure 1 using the coordinates from Table 5. Based on Figure 1, two coordinates with higher Impact and Uncertainty were chosen. The chosen coordinates were Q2 and Q5. Q2: Operational benefits had a coordinate of (2.98, 4.42) which explained that it had the highest Impact score compared to the other items. As for Q5: Government support with the coordinate of (4.12, 3.78) explained that it had higher Uncertainty compared to the other items. These two chosen codes were used to develop future scenarios.

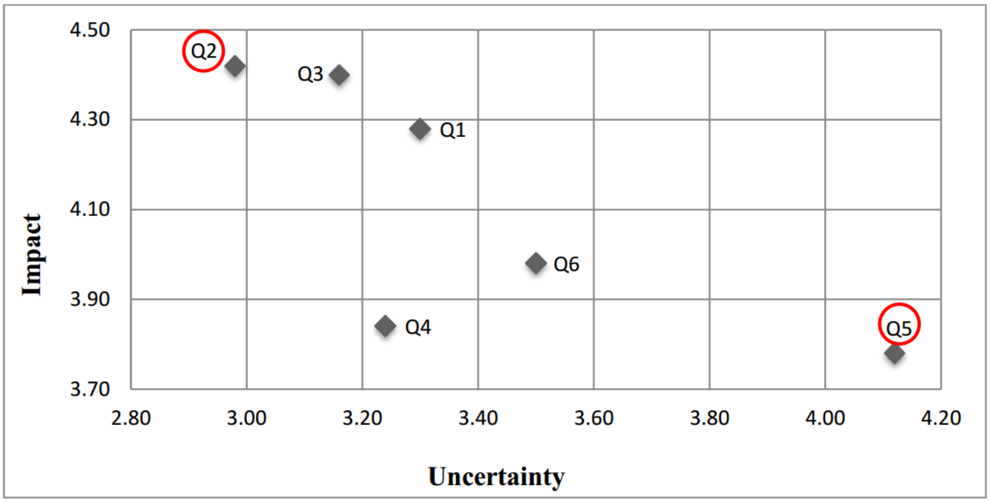

Fig. 1 - Impact-uncertainty analysis

4. Discussion

This research consisted of two objectives. The first objective was to identify the factors that influenced the implementation of full automation and robots in the manufacturing industry using STEEPV techniques and the second objective was to study the future scenarios in implementing full automation and robots for manufacturing companies in Malaysia.

The first objective was administered based on six STEEPV factors which are social, technological, economic, environmental, political, and values. Technological and economic factors are found the main contributors to influencing full automation and robots in the manufacturing industry. In creating future scenarios as the second objective, two main drivers were chosen to measure the level of impact and uncertainty using the impact-uncertainty analysis. The selected drivers from six major drivers were based on the highest impact and highest uncertainty in juxtaposition. The driver with the highest impact indicates that it has a great jurisdiction towards the future of full automation and robotics implementation in Malaysia and the driver with the highest uncertainty depicts the uncertainty perception level on how the implementation would affect the industry.

Q2: Operational benefit recorded the highest impact as compared to the other issues and drivers. It was chosen by the respondents to be the most impactful driver and was recommended to seize the operational benefits of full automation and robots in the future manufacturing industry. The future will be a human collaboration alongside with robotics and full automation (International Federation of Robotics, 2017). From this collaboration, the rate of error in the manufacturing industry is believed could be reduced by as much as 40 percent (Wee & Baur, 2015). From economic insight, automation and robots assist the manufacturing company in producing finer voluminous products and services to boost the company's productivity which in turn will benefit the growth of the economy (Masriadi et al., 2023).

Q5: Government support is one out of the six drivers with the highest mean. However, government support recorded a fifth of importance with only 4.18 mean and the last place with only 3.78 in terms of impact out of the total score of 5. These figures mean that government support has a small or little influence on the implementation of full automation and robotics in the manufacturing industry. With the coordinate of (4.12, 3.78), it is obvious that government support has the highest uncertainty as compared to the others. This explains that the respondents chose the driver of government support as the most unforeseeable and unsure driver that will affect the prospect of full automation and robots in the manufacturing industry in Malaysia. Public interest in robotics and automation is enhanced due to the advancement of technology. One of the concerns is that although full automation and robotics in the manufacturing industry can boost a company's productivity, it is costly and threatens the employment rate. Automation and robotics need a smart factory system with less humanoid interaction. High unemployment rates will affect the economic growth of a country. Given this, the government has a significant role in laying out the plans, policies, funds, and support towards technological advancement for its people (Hernandez, 2016). This can be done by information dissemination, education, funds, and support because new automation technology requires funds, knowledge, and skills.

The second objective was to study the future scenarios in implementing full automation and robots for manufacturing companies in Malaysia. The objective was to discover the trend that will dominate the future of full automation and robots. This objective was achieved through the selection of two drivers with the highest impact and highest uncertainty. From the top two drivers, four future scenario analyses were generated. Those four generated scenarios were the possibilities of the situation that may occur within 10 to 15 years in the future. The future scenarios are illustrated in Figure 2, with the vertical line explaining two extremes of operational benefit and the horizontal line explaining two situations on government support. Each of the quadrants had been relevantly identified with forecasted future scenarios. They were the dawn of smart manufacturing, inefficient industry, ebb and flow, and obstreperous technological development.

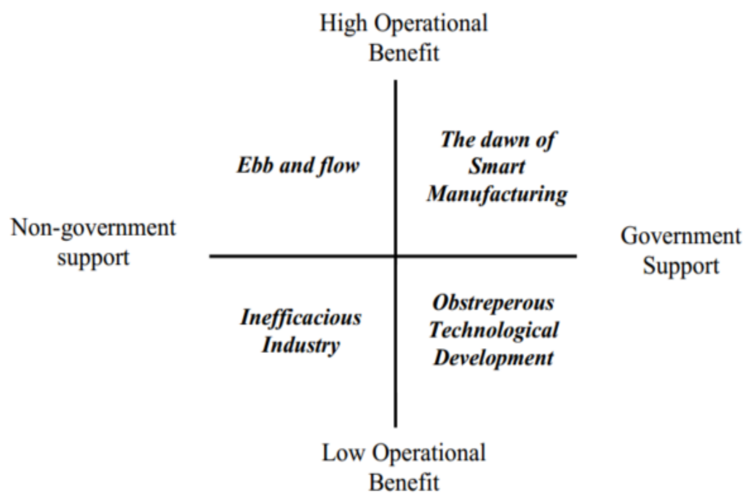

Fig. 2 - Future scenarios for two key drivers

4.1 Scenario 1: The Dawn of Smart Manufacturing

The first scenario referred to the dawn of smart manufacturing when the industry realised the importance of optimising production operations by employing advanced technology through the support of government policies. As the world is moving towards digitalisation in the Industrial Revolution 4.0, smart manufacturing has been the centre of attention and will be a game changer in the future of operations (UK Business, 2015). Despite the drawbacks such as rising operational costs endured by the entrepreneurs and the government, manufacturers are increasingly becoming bolder in adopting more advanced technologies such as robotics and pursuing new automated production lines. The end results showed better operational benefits such as higher flexibility, availability, and productivity will intensify global competitiveness. This will lead to the growth of the economy. As such, the government should consider providing the industry its full support and encouragement towards the revolution of full automation and robotics in the manufacturing industry (Thoben et al., 2017).

In the context of the Malaysian manufacturing industry, the key players were fully aware of the drive and motivation to incorporate full automation and robots in manufacturing activities to obtain greater flexibility and productivity. However, the government and industry were anxious that the implementation would have detrimental effects on demands for human labour that would lead to a surge in the unemployment rate (Masriadi et al., 2023). The public should be wisely informed that the adoption of full automation and robots in the industry will not only benefit the manufacturers in terms of lessening wastage, decreasing the reworks, reducing the defects, and many more but it also will continuously create new jobs with new set of skills. As such, the implementation of full automation and robots has a way of providing opportunities for high-quality employment for the public. Especially in the operation line, where mundane and repetitive work, complex and dangerous manufacturing tasks can be done smoothly with a new level of speed and accuracy by the machine without any errors and danger to the workers (Hinds et al., 2004). The dawn of smart manufacturing scenario is the most ideal scenario as it represents the manufacturing industry of the future. Compared to the traditional manufacturing industry, smart manufacturing with advanced and new levels of accuracy, speed, exactitude, agility, productivity, and flexibility generates higher profitability and greater competitiveness. Thus, through support from the government in implementing full automation and robots in the manufacturing industry, the scenario of the dawn of smart manufacturing can be realised.

4.2 Scenario 2: Inefficacious Industry

The second scenario represented an inefficacious industry. This scenario will occur when the government does not offer support in making changes towards technological advancement in the manufacturing industry and when the industry stays in its comfort zone without motivation to achieve high operational benefits. This scenario will worsen if both government and industry do not intend to move forward due to unforeseen barriers and obstacles. The manufacturing industry is continuously facing major changes and transformation. Instead of targeting high operational benefits, the industry is incapable of making the best use of its resources. One of the reasons might be because of the digital instability and inefficiency that causes software breakdown and leakages of information in the industry (Wee et al., 2015). This insecurity reason impedes the industry from being open and changing to new practices. Moreover, an inadequate level of awareness and skill enhancement among manufacturers in Malaysia regarding the impact and demand for advanced technologies could affect business opportunities and model disruption, thereby hindering the industry's progress towards automation (Yong et al., 2020). Consequently, it will produce an ineffective industry, particularly in terms of security.

The continuously changing and unstable political situations inseminate an inefficacious industry scenario. The government and policymakers have huge roles in influencing the manufacturing industry to move towards full automation and robots through favourable policies and support. As a preliminary, the Malaysian government has introduced the Malaysia National Policy on Industry 4.0 (Industry4WRD) which provides a collaborative and extensive transformation agenda in the manufacturing industry and related services (Ministry of International Trade and Industry, 2018). This indicates that the government is very conscious of the expeditious technological revolution and the threats it poses to manufacturers. However, these efforts may not be highly evident to the public as they primarily involve technocrats and have not yet reached a wider audience (Ling et al., 2020). Consequently, the industry will remain the same and the inefficacious industry scenario will be observed in the future (Khin & Hung, 2022).

4.3 Scenario 3: Ebb and flow

The 'ebb and flow' scenario was the third scenario that could occur in the future. Ebb and flow is defined as the situation, circumstances, opportunities, and surroundings that keep changing from time to time corresponding to the changes in political events. Furthermore, it describes the intention of moving in a specific direction but due to some circumstances, it is compelled to move in the other direction (Giunchigliani, 2016). This scenario occurs when the industry is seeking to move for high operational benefit but the intended changes are not in line with the government support principles and are stuck to the position that the government has assigned them to. As a result, the manufacturing industry is amid major digitalisation and automation transformation to grow substantially.

Despite the benefits gained by the industry in moving forward with technological advancement in the manufacturing industry, it attracts attention towards political and economic issues. For example, a government would create a robot tax that affects the manufacturer's basic income (Arntz et al., 2017). On the other hand, the abolishment of certain taxes, better regulation flexibility, and the eradication of certain rigid procedures will promote better prospects for all. Therefore, the government and the industry must create a middle ground to nurture mutual understanding between the two because the industry will keep on striving with or without support from the government and the government is obliged to make progress for the country. In short, incessant unpopular taxes, inconsistent labour, trade, and other policies are making the industry hard to keep up with, causing the industry to resist and hesitant to transform towards a better future.

4.4 Scenario 4: Obstreperous Technological Development

The final scenario was obstreperous technological development. It occurs due to the force of one party wanting to change while the other party is not ready to change. The term ‘obstreperous’ is defined as something or someone that is challenging, complex, difficult to manage, and disruptive. In the manufacturing context, this term is metaphorically used to describe a party or organisation that obstructs the manufacturing plan and process. It indicates challenges as manufacturers are hesitant to change or their lack of readiness to embrace automation (Tay, 2020). Even though the government gives its full support towards the implementation of full automation and robots in the manufacturing industry, the industry resists the opportunity and does not put an effort towards the advancement transformation. This leads to the obstreperous technological development scenario to happen.

Government support is offered due to the forecasted benefits that can be achieved at the macro level by a country towards a better economic future of a nation. Although technological advancement causes some employment to be obsolete, it produces and creates new jobs, inflates the market, and boosts global competitiveness (Chang & Bureau, 2016). Nonetheless, the Malaysian manufacturing industry is unprepared to encounter significant hurdles posed by emerging technologies without realising that overlooking the issue could set a huge threat to the industry (OpenGov Asia, 2019). Although there is awareness about this advancement, the hesitancy to embrace has driven them towards neglection of the potential advantages (SME Bank, 2017). Due to a lack of awareness that the industry is moving towards manufacturing digitisation, some manufacturing companies remain in conventional operations (Wee & Baur, 2015). Another reason for industries to maintain the status quo is also due to the long period of execution process for achievement evaluation (Ministry of International Trade and Industry (MITI), 2018). However, this scenario might change towards a better scenario once the industry becomes aware and conscious of the benefits gained when implementing full automation and robots throughout the production line.

5. Conclusion

Automation and robots are widely used in many industries, with both being widely introduced and urged to be implemented, specifically in the manufacturing industry. Among the six factors categorised as social (S), technological (T), economic (E), environmental (E), political (P) and value (V), the most influential factor impacting the implementation of full automation and robots was technological. Technology and automation share a common relationship. In addition, the current study expected four (4) future scenarios namely: the dawn of smart manufacturing, inefficacious industry, ebb and flow, and obstreperous technological development. The research findings underscore the pivotal role of technology in shaping the future landscape of the manufacturing industry through the implementation of automation and robots. As the manufacturing sector embraces the dawn of smart manufacturing, industry leaders must recognise the transformative power of technological advancements. For example, the integration of smart technologies into manufacturing processes not only enhances efficiency and precision but also opens doors to new possibilities in product development and customisation.

However, amid the optimism surrounding automation, there exists a potential scenario labelled as an ‘inefficacious industry’. This highlights the need for a cautious approach to deploying automation technologies. Manufacturers must strike a balance between embracing automation to increase productivity and address potential challenges such as workforce displacement and the need for reskilling. The ebb and flow scenario introduces a dynamic element to the future of manufacturing, emphasising the need for adaptability. The industry must be prepared for fluctuations in technological trends and market demands. Flexibility in adopting new technologies and agile business models will be essential for manufacturers to thrive in this ever-evolving landscape.

Furthermore, the obstreperous technological development scenario emphasises the rapid pace at which technology evolves. Manufacturers must stay vigilant and invest in continuous research and development to stay ahead of the curve. Collaboration between industry players, research institutions, and government bodies becomes crucial in fostering an environment that encourages innovation and keeps the manufacturing sector globally competitive. Moreover, this study also found the implementation of full automation and robots in the manufacturing industry where machines are thought to be more consistent, highly precise, and more flexible in performing various tasks in a short time can have advantages and drawbacks for the nation and industry. As the manufacturing industry navigates these future scenarios, policymakers play a crucial role in laying the foundation for a supportive ecosystem. Disseminating information and policies that address not only the technological aspects but also the social and economic implications of automation is vital. Likewise, government funding and support can also attract manufacturers towards embracing the new digitisation era. It serves as a catalyst for industry-wide transformation, incentivising manufacturers to invest in cutting-edge technologies and adapt their operations to stay globally competitive. In addition, the findings are useful to all stakeholders and the knowledge is valuable to assist the enhancement of Malaysia’s productivity and economic growth. From the perspective of the manufacturing industry, the government must view automation not merely as a cost-saving measure but as an investment in long-term sustainability and growth. Nonetheless, embracing automation should be accompanied by strategic workforce planning, focusing on upskilling and reskilling initiatives to ensure that the workforce remains a valuable asset in the age of automation. As a result, collaboration between industry stakeholders, educational institutions, and government bodies becomes imperative to create a skilled workforce that aligns with the demands of an increasingly automated manufacturing environment.

In conclusion, the synergy between technological advancements, government support, and industry collaboration positions the Malaysian manufacturing sector on the cusp of significant transformation. The proactive integration of automation and robots, coupled with strategic planning and a responsive policy framework, will not only enhance productivity but also contribute to the nation's economic growth and competitiveness on the global stage. In short, the manufacturing industry, in partnership with the government, holds the key to unlocking the full potential of these future scenarios and ensuring a prosperous and sustainable future for Malaysia.

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Authors' Contribution

Azman, NA – conceptualization, data curation, methodology, project administration, validation; **Ahmad, N** – supervision, formal analysis, writing – review & editing.

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