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An Overview of Robotic Technologies Towards Effectiveness of Operation in Manufacturing Company

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ABSTRACT

This research provides an overview of robotic technologies and their effectiveness in Malaysian manufacturing companies. In the current industrial landscape, the shift from mass production to customized production is evident. Robotics technology plays a pivotal role in the context of Industry 4.0, offering extensive capabilities within the manufacturing sector. Industrial robots are key players in the realm of "Industry 4.0," enabling automation systems to enhance precision in executing repetitive tasks while maintaining cost efficiency. Robotic technology is currently leading the way in producing high-quality products and ensuring operational efficiency. In this era, robotics technology proves invaluable for performing complex and hazardous tasks, sustaining high-temperature environments, running continuously, and operating for extended durations on assembly lines. Many robots in smart factories employ artificial intelligence to execute high-level tasks, adapt, and learn from various ongoing situations. The primary contribution of this paper lies in providing a deeper understanding of the elements of robotics that enhance productivity effectiveness and exploring the potential applications of robotic technologies in Malaysian manufacturing firms. This analysis was conducted using bibliometric and text mapping tools, specifically NVivo. The findings indicate that Malaysians can gain insights into the overview of robotic technologies in the context of Industrial Revolution 4.0 and analyse their potential applications in Malaysia's manufacturing systems, offering significant advantages.

Keywords:
Industry 4.0; industrial revolution, robotics; manufacturing

1. Introduction

Industries stand as secondary activity as every country's economy relies on the industrial sector, which is a key driver of growth and employment. Industry sector mainly focuses on manufacturing that converts raw material into products. The first industrial revolution was made up in the mid to late 1700s in Germany. Nevertheless, industry 4.0 has become famous once they found it is important to the manufacturing sector as it exhibits the subsequent wave of technology using efficiency across

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the operations. Failing or rejecting to embrace the technology of industrial revolution 4.0 will only be a reason for the organizations to fall behind as their operations will not be computerized enough to competitors [1].

1.1 Research Background

1.1.1 Industrial revolution history

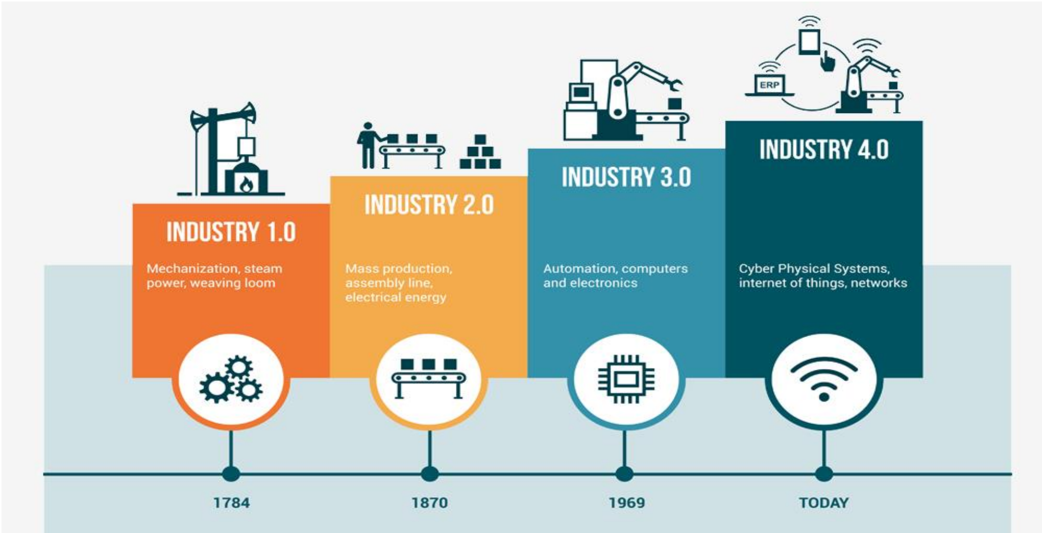


Fig. 1. Industrial revolution phases

Until the present day, the course of industrial revolutions (IR) has unfolded across four distinct stages. The journey began in the 18th century when the First Industrial Revolution, or IR1.0, commenced in Britain. It was marked by the introduction of steam power and the mechanization of production. Moving forward, IR2.0 emerged in the mid-19th century with the advent of electricity production and assembly lines. A significant turning point came in the 20th century when Henry Ford introduced the concept of conveyor belts and mass production. Ford drew inspiration from a Chicago slaughterhouse, where conveyor belts were employed to efficiently process pigs and cows, with each butcher responsible for a specific part of the process. He ingeniously applied these principles to automobile manufacturing, fundamentally transforming the industry. This concept also had a profound influence on other manufacturing sectors, including aerospace, metalworking, and chemical production [2-4]. Subsequently, in the 1970s, IR3.0 commenced with the emergence of partial automation, facilitated by memory-programmable controls and computers. This phase of the industrial revolution saw the automation of production processes without the need for human intervention.

As of 2022, we find ourselves in the era of IR4.0, commonly referred to as Industry 4.0. In this latest revolution, the Internet of Things (IoT) and cyber-physical systems are interconnected in a way that enables the seamless fusion of software, processors, sensors, and communication technologies. These elements play a pivotal role in facilitating the transmission of data from various "things" and ultimately adding value to the operational processes [5,6].

Indeed, IR4.0 represents a logical progression from the developments of IR3.0, where we already witnessed the integration of computer technologies into production lines, now further enhanced by network communication. In essence, IR4.0 signifies the next phase in the automation of production, leading to the creation of "cyber-physical production systems." Consequently, smart factories have emerged, where manufacturing systems, components, and personnel interact seamlessly over a network, and production processes are highly self-reliant [7]. The potential of IR4.0 is truly remarkable, promising significant improvements in production settings. These include the ability to predict machine failures and self-organizing logistics. The overarching concept of IR4.0 emphasizes collaboration, wherein all production units are digitized and interconnected in a standardized manner. Within the economic context, IR4.0 encompasses a wide array of technological fields, including vertical and horizontal system integration, simulation, additive manufacturing, the Internet of Things (IoT), cybersecurity, big data analytics, cloud computing, augmented reality, and robotics, all of which are integral components of this revolution [8,9].

The ultimate goal of IR4.0 is to transform traditional machines into self-aware and self-learning entities, capable of facilitating improved production processes and self-maintenance. Key requirements for IR4.0 implementation include real-time data monitoring, product status and position monitoring, and the ability to store commands for controlling manufacturing processes [10]. Hence, this research consists of 3 main objectives which are: i) To identify type of robotic technologies towards industry 4.0 in manufacturing company, ii) To analyse robotic technologies implementation towards industrial revolution 4.0 in order to increase efficiency and productivity using Nvivo software and iii) To evaluate the robotic technologies potential in Malaysia that gives advantages in manufacturing system. All the objectives are accomplished in this research.

1.1.2 Robot in Industry 4.0

The industrial robots have human like mobility and able to carry out variety of complex tasks. The primary pro of the robot is that it does not get worn out as human do after completing a task. With the help of robots, firms will be able to attain rise in productivity, depletion in production costs and able to increase utilization compared to human labour. Manufacturers in industry sectors have prolonged use robots to handle complex tasks but robots are evolving to be even useful. The robots have become more self-sufficient, adaptable, and cooperative. They will ultimately communicate with one another, work safely alongside humans, and discover from people. The use of robotic arms in manufacturing begins in 1937, with the first robot design by "Bill" Griffith P. Taylor, who created a "crane-like" design as mentioned by [11-14].

As the time goes, with the advancement of microprocessor innovations in the 1980s, the use of robotic arms in welding and mounting became widespread, especially in automotive industry sectors, and the robotic industry grew, with YASKAWA, FANUC, MOTOMAN, ABB, and KUKA leading the way. Currently, the concept of industry 4.0, combines the most significant technological innovations in the fields of automation, control, and information technology, and that is applied to manufacturing processes. Autonomous robots are linked together so that they could collaborate and automatically adjust their actions to accommodate the next incomplete product in line. High-performance sensors and control units allow for joint coordination with humans. Similarly, industrial-robot supplier ABB is introducing ‘YuMi’, a two-armed robot designed specifically to assemble products such as consumer electronics alongside humans. Safe interaction and part recognition are made possible by two padded arms and computer vision [15].

1.2 Problem Statement

Currently, Malaysia finds itself in a situation where the majority of its manufacturing sectors are positioned between the second and third industrial revolutions, straddling the line between Industry 2.0 and 3.0. This reality is particularly prominent in the context of small and medium enterprises (SMEs), which constitute a significant portion of Malaysia's manufacturing landscape compared to larger firms. While awareness of Industry 4.0 exists in Malaysia, the adoption of its principles by manufacturers and companies remains in the preparatory stages. The Ministry of International Trade and Industry has expressed concern that this lack of awareness and adoption, especially among SMEs, could lead to a national crisis, as embracing Industry 4.0 is crucial for improving manufacturing competitiveness in the future. Additionally, there is a low level of digital adoption among SMEs, with less than 20 percent utilizing digital technologies, and a limited use of automation in manufacturing firms, where the majority employ less than 50 percent automation.

One of the major challenges faced by Malaysian manufacturing firms is the high cost associated with adopting Industry 4.0 technologies and processes. This includes the upfront investment cost and the extended payback period. Furthermore, there is a significant shortage of skilled talents, expertise, and knowledge related to Industry 4.0, particularly in fields like the Internet of Things, artificial intelligence, and robotics [8,9]. Additionally, there is a limited of research studies exploring the relationship between robotics and Industry 4.0 on productivity within Malaysian manufacturing firms. This study serves as a foundational resource for future researchers who can use it as a justification for conducting further investigations on Industry 4.0 within the context of Malaysian manufacturing companies [16-18].

The research on the implementation of robotics in the context of the industrial revolution and its impact on production in manufacturing companies was conducted through a comprehensive review of past research in Google Scholar. Key terms such as "Industry 4.0" and "robotics" were utilized when searching for available journal papers in various databases. The study collected current data related to the robotic industrial revolution and its effects on productivity in manufacturing firms [19]. Through the analysis of downloaded journal papers, several pieces of information were extracted, providing a better understanding of various topics, including the elements that contribute to productivity effectiveness and the potential applications of robotics in Malaysian manufacturing firms.

2. Literature Review

2.1 Advance Robotic in Industry 4.0

Sensor technology advancements are important for industry 4.0 factories because data processing, sharing, and collection using this technology. In the last couple of years, few sensors for object recognition, force detecting, collision avoidance, auditory perception and range detecting have been established using a robot for manufacturing jobs by assisting robot's perception in safety handling, automatic picking, and part sensing [20,21].

2.2 Influence of Robotic on Productivity

When it comes to robotics, human comparisons are on the agenda. The quantity and quality of work completed is impressive. Human workers in manufacturing sites overtaken faster in the next decade, lowering manufacturing labour costs. Robots shortly be present in manufacturing plants all over the world [18-21]. Agriculture, defence, electronics, consumer products, medical, mining, automotive and more other industries rely on robots for preciseness, heavy lifting, and lower operating costs. Engineers are developing robots that are more power saving and, eventually, energy independent by using solar or another energy source. Manufacturers are looking for ways to use new, lightweight robots to do jobs that were previously done by larger, heavy weight robots to reduce power consumption. Robots increase the efficiency of industries, businesses, and manufacturers. Robotic automation is a great way to enhance efficiency in any industry to increase productivity and reducing downtime [22-24].

2.3 Benefits of Robotic

A couple of functions may be completed concurrently via business robotics. Facility administrators can successfully leverage industrial floor space and minimize hardware footprint by replacing heavy multi-core computing capabilities with existing programmable logic controllers (%) as mentioned by [25]. Robots have been integrated into the food processing facilities with the aid of primary meals corporations. The robots carry on various tasks in improvement with imaginative and prescient era, cameras, and AI. They're able to be cutting, measuring, packing, and pallets the whole lot. Industries with a wealth of sensors song machinery and production procedures in real-time to avoid aberrant output and services. Machine imaginative and prescient robots can perform complicated optical methods with specific precision. Microscopic structural defects or minor colour variations can be detected and corrected without delay to uphold great performance [13].

3.0 Methodology

3.1 Research Design

This study has applied qualitative research. This research conducted by locating and analysing many related journals and blogs on industry 4.0, its effectiveness on productivity and robotics. The methods used in this study has done by searching all the available online databases with the keywords such as 'industry 4.0', 'productivity', 'robotics' and 'manufacturing' by using platforms such as Google Scholar, Scopus, ResearchGate, Science Direct and Emerald Insight.

The available online databases were analysed by Nvivo software. Nvivo is a software program used for qualitative and mixed method study and produced by QSR International. Usually, it is used for the analysis of unstructured text, audio, video, and photo facts which also includes interviews, recognition organizations, social media, surveys and articles. With the help of Nvivo, interviews that have been transcribed, can be uploaded, and coded in Nvivo earlier than the datasets can be evaluate. Figure 2 and Table 1 shown the procedures and process generated in this research.

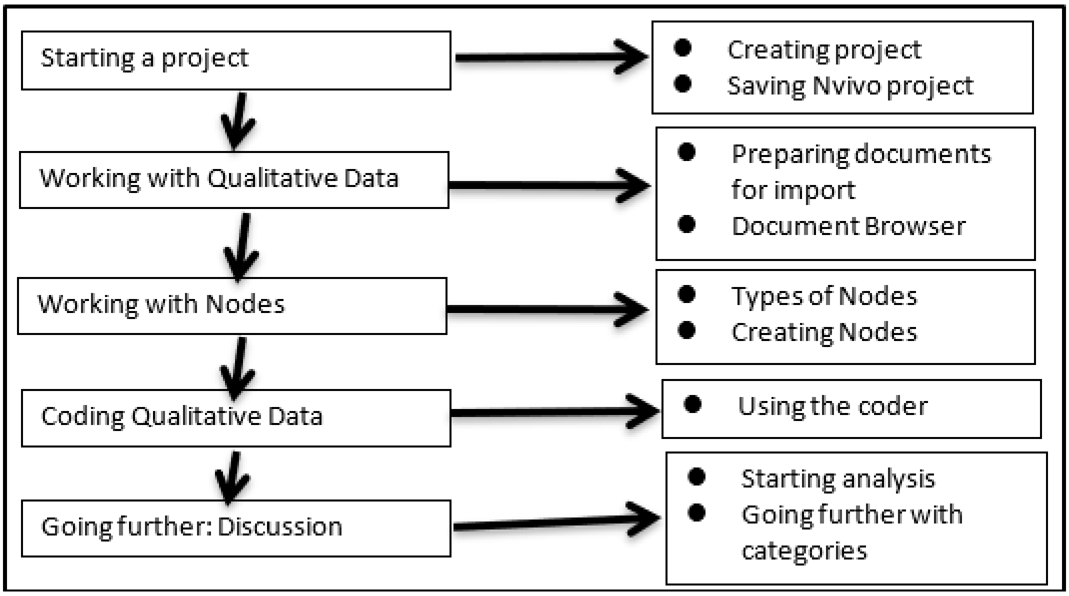


Fig. 2. Procedures and flow chart of the research

Table 1
Process

The Process	Tools to support
Purpose in relation to research	Nvivo map
	Nvivo memo
Searching the literature	EndNote- search online libraries
	Nvivo- search existing literature
Collecting and managing material	Both within EndNote and Nvivo
Reading and interpreting	EndNote- abstract, notes, keywords
	Nvivo- annotate, code PDFs and notes/abstracts.
	Nvivo- Analysis support tools
Reviewing, writing, updating	Nvivo- write up, links to supporting info

3.2 Data Analysis

All the collected data were analysed deeply. The first domain focuses on implementation of robotics in manufacturing, while second domain is to be focus on IR4.0 effectiveness of productivity in manufacturing company. All the collected qualitative data were analysed using Nvivo software. The qualitative data were coded under related nodes by the researcher after analysing the domain topic or themes of each article. The data were coded by applying certain text search and word frequency queries on Nvivo. These helped to identify common in most of the research topics related to industrial revolution 4.0 and robotics as Nvivo compile the words into their frequencies.

The researcher came across several stages in Nvivo analysis. The researcher had to analyse the sources, attributes, values and classify them. Next, after identifying the domain topic that has been master in each source were created into initial nodes. Analytic is the third stage, with the help of Nvivo, all the created nodes were merged into hierarchy charts. The usage of word query and visualization were run using Nvivo toolkit.

Starting a project: The first step in this stage was to create a project as shown in Figure 4, comprised of all the documents, coding data and information that can assist during the project.

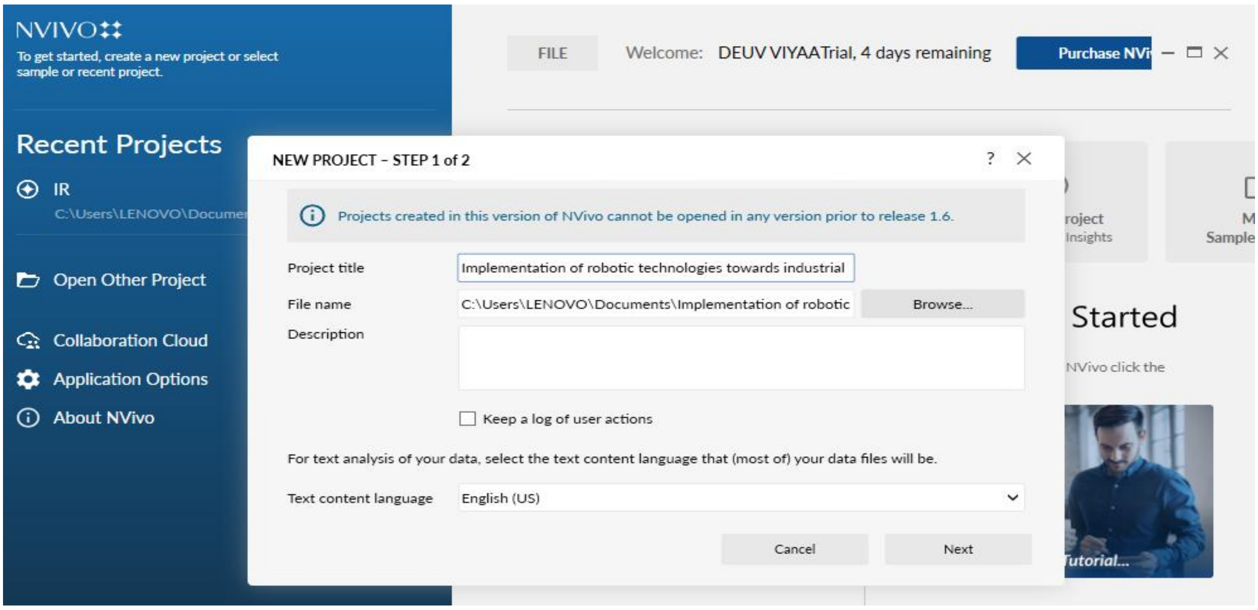


Fig. 4. Nvivo screenshot of study project

Working with qualitative data files: Researcher imports all the relevant articles obtain from online libraries and classified as articles. Researcher search articles with keywords such as 'technologies', 'robotics', implementation', Industrial revolution 4.0' and 'manufacturing industry' and downloaded a total of 73 articles. From the downloaded paper, all the information about the implementation of robotic technologies in manufacturing company used from each paper extracted and gathered in the Nvivo. After that, researcher imports the articles into Nvivo as shown in Figure 5. Downloaded articles> Import> File.

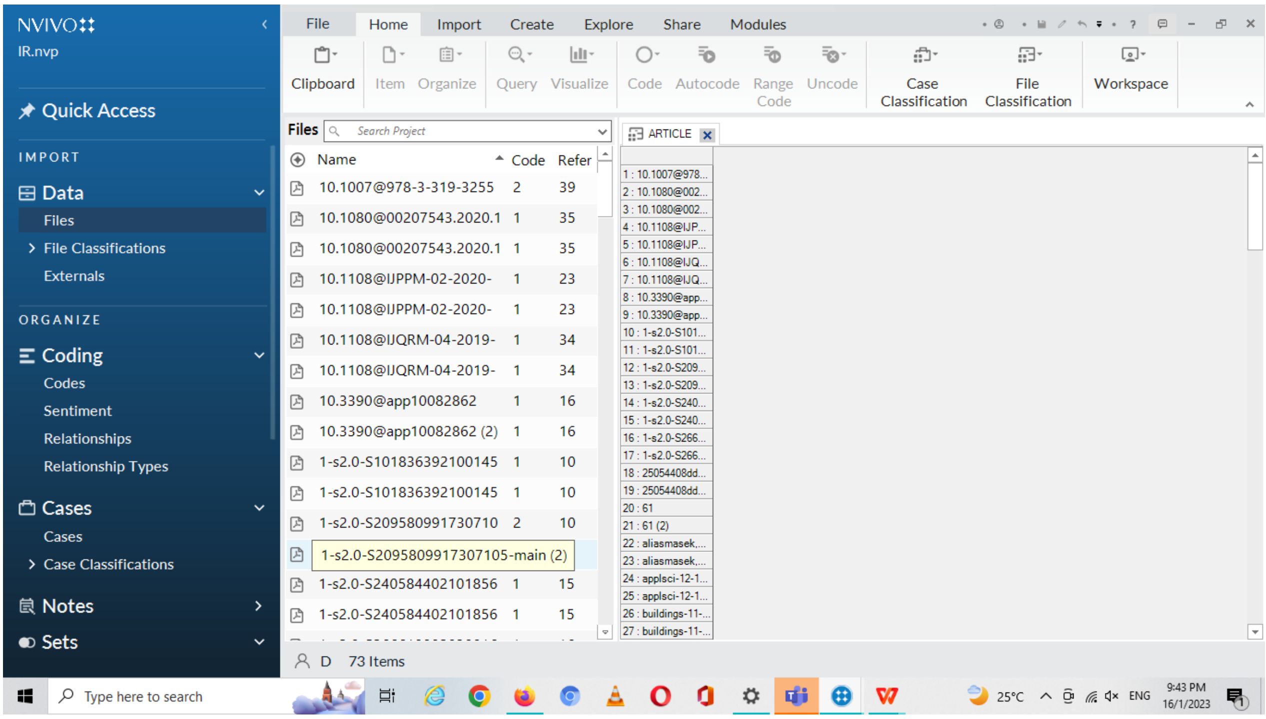


Fig. 5. Screenshot of imported Nvivo files

Working with nodes and coding qualitative data: The researcher created codes both manually and auto code using Nvivo Coder. For manual codes, the researcher created the codes by highlighting important information from the articles and insert them into code selection as shown Figure 6. Article>Highlight>right click>select code selection>Code under the relevant issue. For Nvivo auto coder the researcher highlighted all the relevant files and click the auto code to obtain the codes as shown in Figure 7.

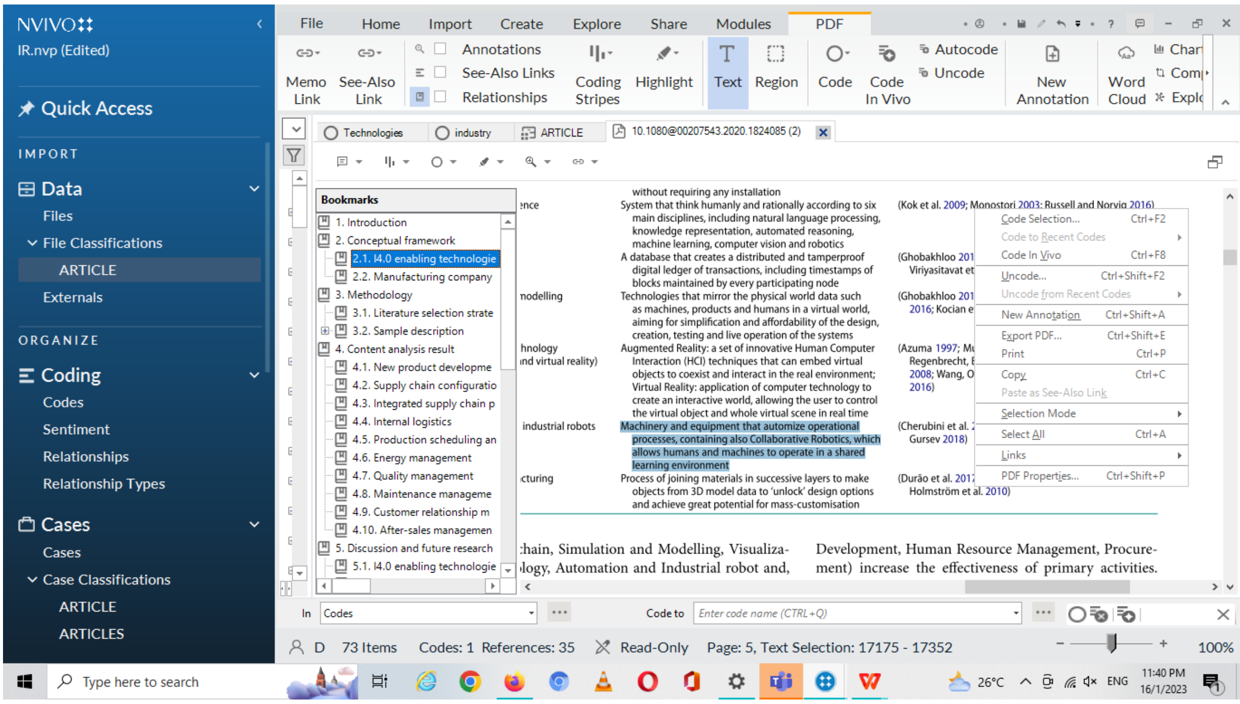


Fig. 6. Screenshot of code selection

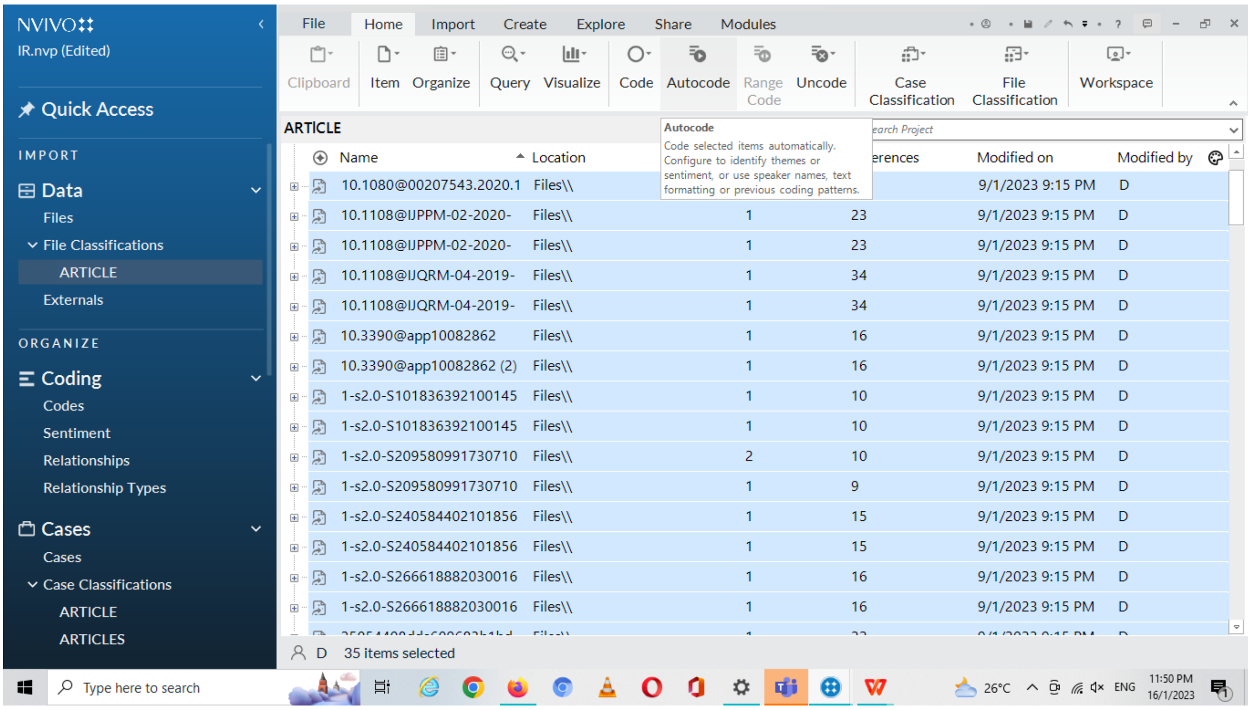


Fig. 7. Screenshot of Nvivo autocoder

4.0 Result and Discussion

Based on the analysis conducted using NVivo software, all the research objectives have been successfully achieved. The findings indicate that the implementation of robotic technologies in the context of Industrial Revolution 4.0 is still in its early stages, as evidenced by a limited number of key indicators.

Based on the methodology employed, a total of 73 articles were included in the study. The first objective, which was to identify the types of robotic technology implementations within Industry 4.0 in manufacturing companies, was successfully accomplished. This was achieved by importing all the relevant databases into NVivo software and subsequently coding them, both manually and through automated processes within NVivo. The researcher then conducted an analysis of the coded data, focusing on codes related to robotic technologies and their implementations. The results of this analysis are presented in Figure 9 and Figure 10, depicting the outcomes of manual and automated coding processes, respectively.

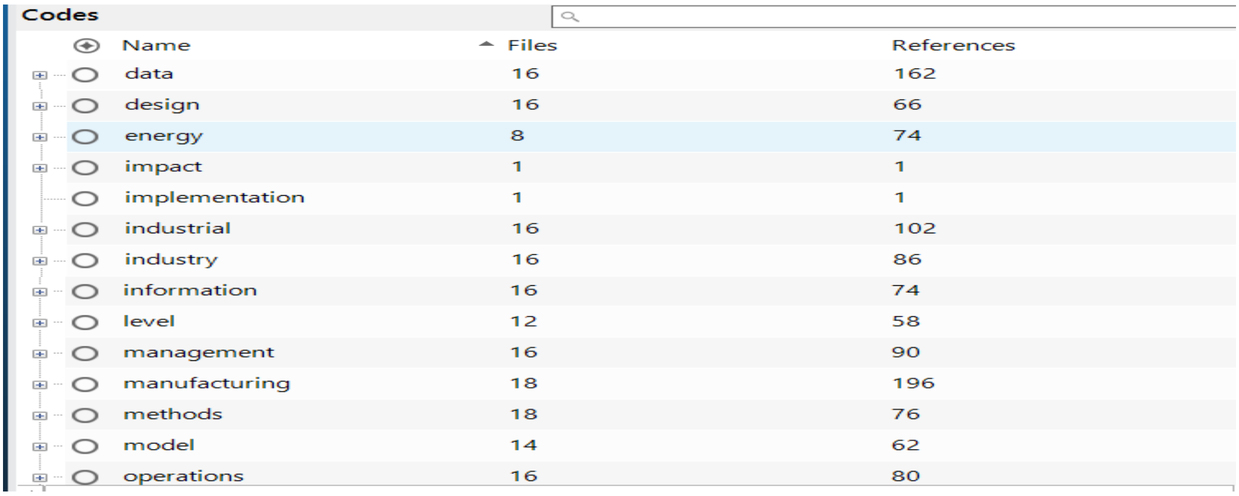


Fig. 9. Screenshot of Nvivo codes

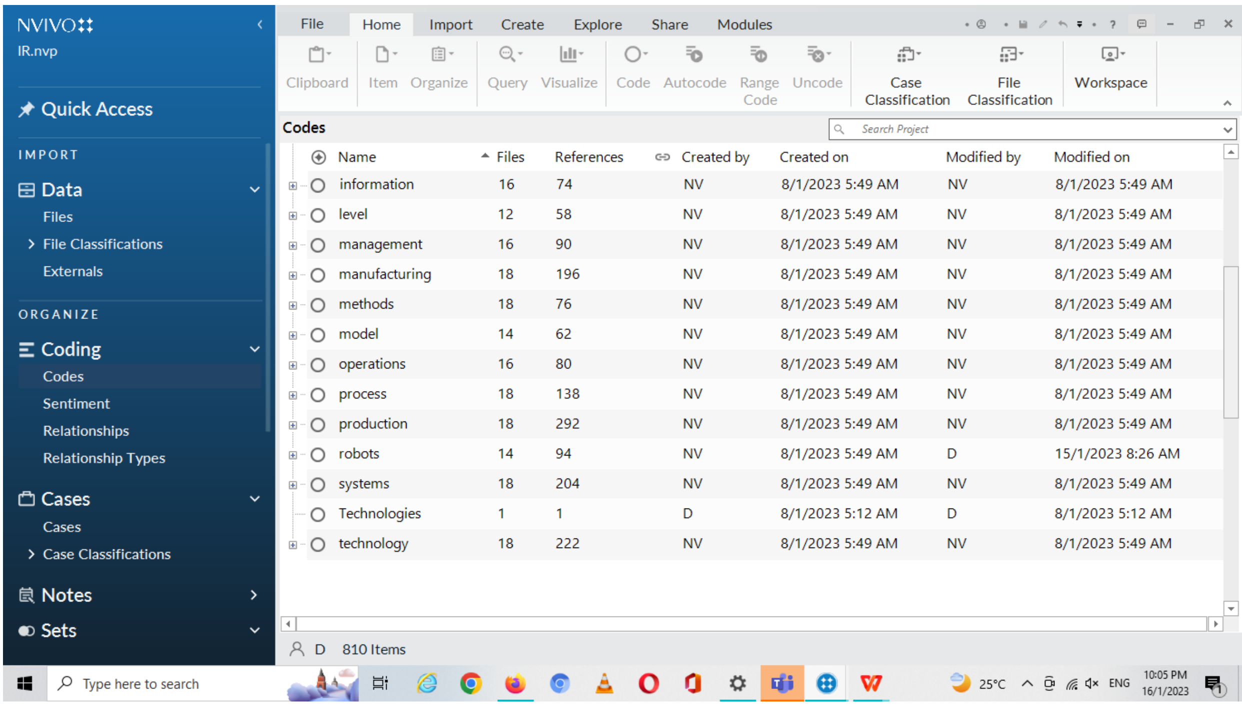


Fig. 10. Screenshot of Nvivo codes

A co-occurrence analysis map was generated using a word cloud analysis of the selected articles to explore the keywords and key topics found within the records related to Industry 4.0 and robotics. This approach was chosen because it offers a comprehensive view of the literature and allows for content analysis. In addition to the co-occurrence map, a record of the selected articles was created to validate the results obtained from the co-occurrence analysis. The content of the articles within each cluster was thoroughly examined, aiding the researcher in visualizing a core set of topics covered by the publications. The size of the text within the word cloud corresponds to the prevalence of that keyword or topic in the literature, providing insights into the depth of knowledge within each area. This word cloud analysis of keywords, coupled with the number of references derived from the code selection process, is illustrated in Figure 11.

Fig. 11. Word cloud analysis of keywords

The researcher obtained word cloud analysis in Table 2 using search query. The search query adjusted to include “words with exact match”. Only the word with more than five characters are displayed in the figure. The results include the number of times that the word occurs within the searched paper. Based on the ‘manufacturing’, ‘technology’ ‘operation’ and ‘robots’ nodes, the researcher has identified a few robotic processing operations that implements robotic technologies. For example, welding, polishing, and loading. Under the node of operation, an article highlighted robotics technologies are used for material handling to handle steadiness and dangerous products that could risk contamination if in contact with humans. The researcher found that most of the manufacturing industry applies robotic technologies in assembly systems commonly. This is because assembly section consists of long and repetitive job.

Table 2
Word frequency result

Words	Length	References
Technology	10	222
Products	6	292
Industry	8	86
Industrial	10	102
System	6	204
Manufacturing	13	196
Robots	6	94

To complete the next objective for this research which is to analyse robotic technologies towards industrial revolution 4.0 to increase efficiency and productivity using NVivo software, there are few more procedures have been completed. To achieve this, data analysis involved a comprehensive examination of all the articles, and the creation of nodes to merge related information in order to identify databases addressing efficiency and productivity. This hierarchical structure was visually represented in Figure 12. The associated level of implementation was determined by analysing the relationships within the data. The study revealed a substantial and positive impact of Industry 4.0 on the productivity of manufacturing firms.

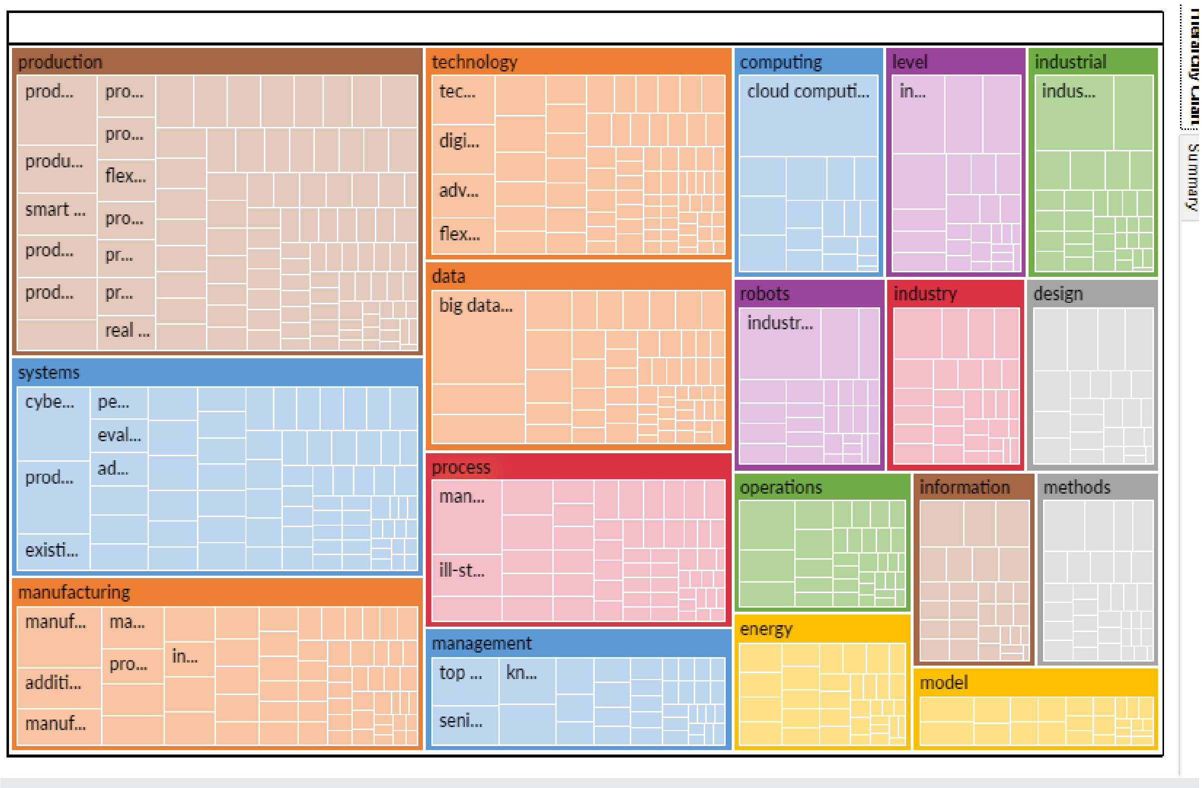
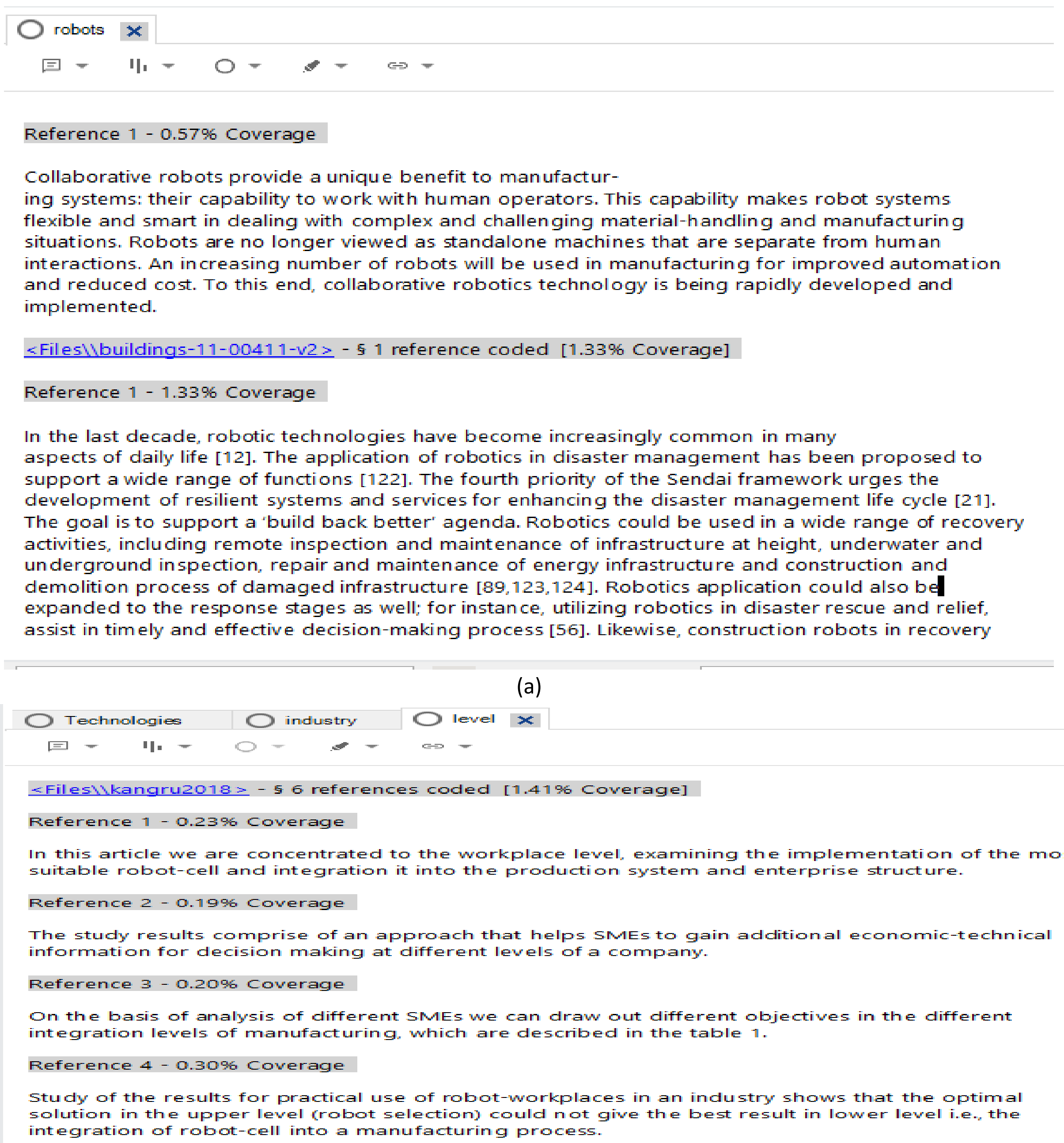


Fig. 12. Hierarchy chart created after merging the nodes

For instance, each node and its references were correlated with reference coverage obtained from selected articles, as depicted in Figure 13(a) and (b). The research underscores the potential of industrial robotics in Malaysia and the various stages of implementation in manufacturing firms, including exploration, installation, initial implementation, and full implementation. The Malaysian industry appears to be positioned between the installation and initial implementation stages.



(b)

Fig. 13. References coverage

To gain a more accurate understanding of the real-world implementation of industrial robots, the researcher supported these findings by analysing statistical data on the implementation of industrial robots provided by the International Federation of Robotics (IFR). This additional evidence suggested that in Asia and Australia, implementation follows an exponential growth pattern, while in Europe and America, it follows a linear trend. According to records from 2018, the top ten countries in the world with descending implementation rates of industrial robots were Spain, Mexico, France, Italy, Taiwan, Germany, Republic of Korea, United States, Japan, and China. To address the final objective of this research, which is to evaluate the potential advantages of robotic technologies in Malaysia's manufacturing systems, the researcher analysed all 73 articles to extract information regarding the benefits of robotic technologies. This information was categorized under nodes such as "technology," "robots," and "advantages."

In Figure 14, the most prominent robotic technologies have been listed. Collaborative robots, often referred to as cobots, are widely utilized in the manufacturing industry. They are specifically designed to work alongside humans, assisting in repetitive tasks and making work more manageable, thereby enabling human workers to focus on other responsibilities. This assertion has been substantiated through analysis under the nodes of "robots" and reference 1, as depicted in Figure 14.

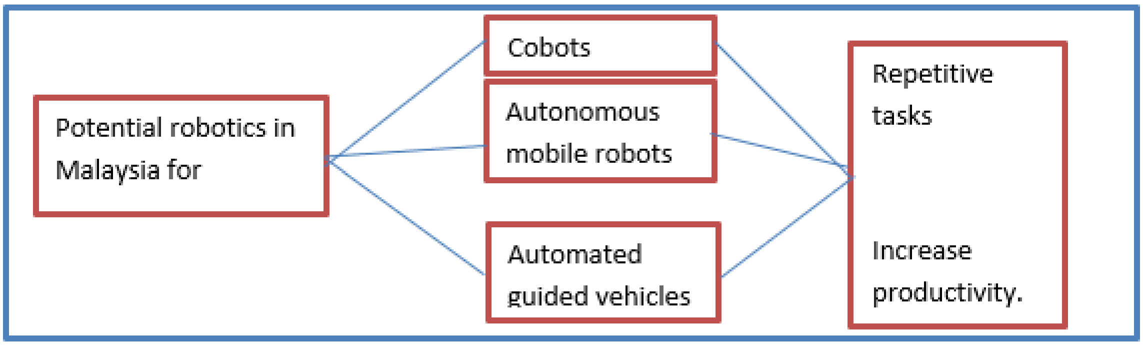


Fig. 14. Potential robotics technologies in Malaysia

Furthermore, the study's results reveal the prevalence of Industry 4.0 technologies currently in use and their most effective implementations. Many manufacturing firms in Malaysia, including those in the glove industry, have adopted autonomous robots. This choice is driven by the need for continuous improvements in productivity efficiency and cost reduction. For instance, KUKA robots are highly favored in the manufacturing sector, particularly within glove manufacturing firms. The study indicates that autonomous robots facilitate enhanced communication within the manufacturing system, leading to increased efficiency and productivity.

5.0 Conclusion and Future Work

In conclusion, this study has delved into the implementation of robotics in the context of the industrial revolution, focusing on its impact on productivity within manufacturing firms. The research has effectively explored the relationship between robotics, Industry 4.0, and productivity in Malaysian manufacturing firms. However, it's important to note that the developed conceptual framework primarily addresses the relationship between Industry 4.0 and productivity in Malaysia's manufacturing sector. To provide actionable insights for business professionals and government decision-makers in Malaysia, further research is recommended. Future studies should specifically investigate Malaysian manufacturing firms and their implementation of robotic technologies, adhering to a well-defined timeline.

Based on the findings and the primary contributions of this paper, it can be concluded that Malaysia's manufacturing sector is prepared for Industry 4.0, with initial-stage implementation evident in certain areas such as assembly and design. The level of implementation within each manufacturing industry in Malaysia varies and is contingent upon the capacities and capabilities of individual firms. The adoption of robotic technologies in manufacturing aims to enhance productivity, reduce costs, and improve product quality. This research suggests that Malaysia is poised to fulfill the objectives advocated by Industry 4.0, with a higher degree of robotic technology implementation, potentially involving the redesign of existing manufacturing processes or the introduction of new ones. The implementation of robotic technologies is pivotal and leads to increased efficiency and flexibility within the production processes of the manufacturing industry. As Industry 4.0 continues to evolve, trends in robotic technologies are expected to witness significant growth, particularly in the realm of collaborative robots and autonomous robots.

This study serves as a foundational resource for future researchers, who can build upon its findings and justifications to conduct further investigations within the context of Industry 4.0 in Malaysian manufacturing companies. Moreover, given the increasing automation of processes, innovative solutions tailored to specific circumstances will be required. The success of Industry 4.0 hinges on the efficient integration of manufacturing and logistics systems, with robotic automation poised to find applications across a wide spectrum of industrial processes.

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