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IoT Implementation Framework to Support Industry 4.0 in the Malaysian Manufacturing Industries: A Systematic Review

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Abstract: The manufacturing industry is adopting new technologies such as IoT to improve its manufacturing processes. However, the understanding of IoT implementation in Industry 4.0 is limited, especially in Malaysia. To fill this gap, this study aims to identify the IoT implementation framework in Industry 4.0 manufacturing and the associated challenges. The study employed a systematic review of 42 articles published between 2011 and 2022. The results indicate that Industry 4.0 has revolutionized the manufacturing industry, and Malaysian companies need to embrace this digital transition to remain competitive. The study recommends that Malaysian manufacturing companies should invest in IoT development and employee training to optimize IoT usage. Furthermore, the government needs to create awareness about IoT implementation to boost Malaysia's economy. This study contributes to the development of guidelines and standards for companies that want to implement IoT.

Keywords: Industry 4.0, IoT, Implementation framework, Challenges, Malaysian Manufacturing Industries

1. INTRODUCTION

The international industrial landscape has shifted dramatically in recent years due to numerous technological advances, innovations, and developments [1]. The "4th industrial revolution, generally known as Industry 4.0, is one of the most popular topics in today's academic and professional communities" [2, 3]. Processes for manufacturing and planning are being transformed by Industry 4.0. An integral part of this idea is "smart manufacturing" [4]. Manufacturing companies are currently undergoing a period of transformation known as Industry 4.0, during which they are working to achieve full digital incorporation (i.e., linking all of their production systems and business functions) using data collected throughout the lifecycle of the product [5]. The smart industrial age of Industry 4.0 is replacing the traditional manufacturing period as a result of advances in machine learning. As a result of digital transformation, "Industry 4.0" is gaining prominence as both a term and a trend influencing technical shifts in the sector and the economy. It is typically viewed through the lens of consolidated modern technologies that provide convergence among business and industrial elements, production methods, and the internal processes of firms [6].

Industry 4.0 depends on implementing digital technology to gather data in real-time and analyze it, giving the industrial system essential data [7]. The use of digital technology and a shift in the business's strategy assume the potential of "cost-effective personalized manufacturing" in response to each customer's unique needs [8]. The idea of "Industry 4.0," which relies on the integration of "cyber-physical systems," became feasible due to "advancements in cloud computing," the "Internet of Things (IoT), big data analytics, and related technologies" [9]. Automation of processes, integration of systems, cyber-physical system (CPS) creation, the "IoT, and the Internet of Services (IoS)" all contribute to 4.0's unique characteristics [8, 10]. These interconnected technologies fill the gap between the virtual and physical worlds by enabling the simultaneous transmission of information among participants in the value chain [10, 11].

One of the main challenges faced in the Industry 4.0 era is the highly intricate technological structure of modern manufacturing systems [7]. Therefore, research is still needed to study how to integrate Industry 4.0 technology effectively [7, 12]. Previous studies have assessed how these affect organizational performance and manufactured output [12] and provided implementation models of these technologies (e.g., [7, 9, 13]). The adoption of these technologies in manufacturing companies is not well documented, which raises essential questions like what is the current IoT implementation framework for industry 4.0 in manufacturing companies? What are the problems involved, and what are the challenges that management is encountering in the process? To address these questions, this research will be divided into six main sections: the introduction provides a general understanding of the topic, the literature provides

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the previous studies on the topic, the methodology gives the process of the study, the results, reviews the previous studies; in the discussion, overall results are discussed; in the conclusion section, all points are summarized, and suggestions are provided in light of the study results.

2. LITERATURE REVIEW

A. Industry 4.0

The term "Industry 4.0" was developed as an initiative of the federal government of Germany alongside universities and commercial businesses in 2011. It was a strategic initiative to develop "cutting-edge manufacturing systems" to raise the national industry's productivity and efficiency [4]. Industry 4.0, which stands for autonomous manufacturing procedures facilitated by devices and machines that digitally communicate with one another, is currently being implemented globally; the German government immediately recognized its potential [14, 15]. This concept represents the manufacturing system's new industrial phase by bringing together several convergents and emerging technologies that improve manufacturing operations as a whole [12].

A socio-technical transition in the function of humans in manufacturing systems is necessary to support this new industrial phase, with all working activities along the value chain carried out using smart methods (Smart Working) based on "information and communication technologies (ICTs)" [16]. At the heart of "Industry 4.0" is the idea of advanced manufacturing, commonly referred to as "smart manufacturing." This is a system in which adaptable lines autonomously alter manufacturing processes to accommodate a wide variety of goods and dynamic market demands [17].

By boosting quality, efficiency, and adaptability, Industry 4.0 can pave the road for mass production of sustainably made, individually crafted items with minimal impact on the environment [18]. The capabilities of manufacturing technology for data transfer and automation are referred to as "industry 4.0" [19]. Unparalleled levels of interconnectedness are brought about by the fourth technological revolution, and significant cultural shifts have been seen over the past decade, even in the manufacturing industry. The on-demand economy, made possible by technology that can quickly fulfill demand, maybe one example [20].

B. IoT and Industry 4.0 Manufacturing

IoT is a technology that is rapidly expanding and has played an important role in the implementation of "Industry 4.0." IoT is defined as a worldwide, dynamic network of accessible, embedded computing devices that may automatically configure themselves using open standards for networking and data exchange. It's a cutting-edge technology that's expanding quickly, with useful services and functions in many aspects of life. The IoT seeks to permeate our daily activities and its objects by joining the digital and physical spheres and enabling "people and devices to be linked anytime, anywhere, with anything, and with anybody" [21]. In addition to the automation and digitization of industrial production, the IoT is often credited with igniting Industry 4.0. Traditional industrial and manufacturing methods are integrated with cutting-edge technology like the "IoT, CPS, and large-scale machine-to-machine (M2M) communications." Incorporating features like "self-maintenance, optimization, cognition, and customization" into existing industries is another major goal [22].

Industry 4.0 has been seen as the direction of production and an active study subject for almost a decade. "Industry 4.0" technologies like the IoT are already in use. The IoT has helped businesses embrace digital revolutions in many different areas, including customer service, manufacturing, automation, and comparative advantage [23, 24]. The rapid expansion of industrial processes has gained attention due to the development of cost-effective electronic circuits, high-performance data processing methods, and innovative advancements in manufacturing technology [25]. Similarly, both the prevalence of sensor systems and the variety of tasks they perform are growing rapidly. Improved by modern technology, sensors, and gadgets may now coordinate their efforts online for management and monitoring [26].

Miniaturization is the most significant of the distinctive qualities that the sensors must exhibit to meet the criteria of IoT devices, which include compact size and narrow bandwidth [15, 27]. Production systems have become more resilient due to the extensive use of "computer numerical control(CNC) and manufacturing robots" [28, 29]. On the contrary, computer-integrated beneficial production has emerged as a result of "computer-aided design (CAD) and computer-aided process planning (CAPP)" [30]. Such M2M or human-machine connections yield massive quantities of data that may be put to good use by companies [31]. For IoT networks to function properly, it is necessary to analyze and make use of this massive amount of data. The networks generate useless data; therefore, businesses must rely on analytical technologies [32].

A maintenance schedule based on the IoT is used by many companies to keep an eye on the quality of spindles to reduce the likelihood of failure and expensive repairs [33]. To prevent premature failure of critical components, some companies are turning to IoT-based maintenance management solutions [34]. A study [35] proposed an IoT framework aimed at facilitating the integration of IoT in practical settings, particularly for Malaysian SMEs. The framework comprises three phases: "IoT preparation, planning and implementation, and evaluation and improvement." The study's [35] results demonstrate that the adoption of the IoT framework effectively addresses challenges related to time and location, enabling remote monitoring and control within the industry. As companies collect and analyze data in real-time, they become more adaptive and predictive, better able to anticipate and prevent operational disruptions like system failures. Smart factories are examples of such high-tech production facilities [36]. With IoT, manufacturers may gain useful information from the data they collect about their manufacturing processes, maintenance plans, and surroundings [37].

In no uncertain terms, the IoT's use of a modern and dynamic network of linked devices can provide a plethora of cutting-edge services and applications that can improve not only people's quality of life but also their professional prospects, income, and overall financial well-being [7]. The IoT in industries generates game-changing advancements in the production sector. It finds widespread use in industrial contexts as a tool for tracking production processes. Because it allows for greater performance, this technology also creates opportunities for innovation in manufacturing [38]. Despite being in the "early stages of development, acceptance, and implementation," Industry 4.0 and the IoT have the potential to provide a diverse array of new solutions, applications, and services. Therefore, they have the potential to enhance life quality and offer advantages and future possibilities on a variety of scales, including personal, intellectual, and financial [1].

Malaysian manufacturers compete with other Southeast Asian nations, including Thailand, the Philippines, Vietnam, and even India and China. In contrast to Malaysia's relatively high labor wages, those of its Southeast Asian and Indian counterparts are far lower; nevertheless, China's greater adoption of Industry 4.0 technology more than makes up for this disparity [38]. By adopting Industry 4.0, Malaysia can boost its competitiveness in this sector. Industry 4.0 is likely to provide substantial and far-reaching improvements to manufacturers' productivity. The labor productivity in Malaysia is growing slowly, in contrast to the expected productivity improvements through technology [40].

The government of Malaysia has acknowledged the importance of Industry 4.0. In October 2018, the "Malaysian Ministry of International Trade and Industry (MITI)" issued a national approach to Industry 4.0, and the "Malaysian Industry Development Authority (MIDA)" offers tax advantages [41]. The Eleventh Malaysia Plan also incorporates Industry 4.0 as a macro approach to stimulate economic development [42]. Not much is known about the IoT or Industry 4.0 in Malaysia. There is a lack of research on Malaysia's governmental, industrial, and educational levels. An additional study was needed to guarantee that direction is given to Malaysian industry practitioners and decision-makers. Therefore, this research was conducted on the IoT implementation framework and Industry 4.0 in Malaysian manufacturing companies.

3. METHODOLOGY

Through a PRISMA-style systematic review, this study explores the "IoT implementation framework to support Industry 4.0 in the manufacturing industry." A "systematic review (SR)" is a rigorous research method that involves a structured search for articles related to a specific topic using library databases and other sources. The articles are then screened for relevance and evaluated in detail to determine their eligibility for inclusion in the review. The review encompasses both quantitative and qualitative analyses of the chosen studies, employing explicit and systematic approaches to identify, select, and critically evaluate relevant research. This approach aims to be comprehensive and reproducible, in contrast to the more subjective narrative review process [43]. Figure 1 presents the steps of SR.

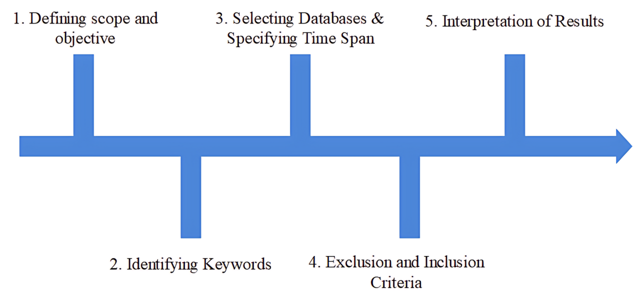

Figure 1. Steps of Systematic Analysis

The first step of an SR was to define the aim and scope of the study. In the second step, keywords related to the aim, scope, and questions of the study were identified. After undertaking extensive, multifaceted brainstorming sessions, the keywords were found. To improve credibility, the keywords were fixed using Boolean logic and combined into a search series, for example, "IoT implementation framework" AND ("implementation" OR "Internet of Things") AND "industry 4.0" OR "manufacturing industry" OR "Malaysian manufacturing industry." The OR "Boolean operator" was used to combine search phrases inside each element to retrieve as many publications as feasible. The outcomes were then filtered using the Boolean operator AND to gather the most appropriate studies for the research. The future scope, challenges, and limitations of an IoT implementation framework to support Industry 4.0 in Malaysian manufacturing companies were highlighted. Ten appropriate search series were identified using TITLE-ABSTRACT-KEYWORDS and finalized after continual refinement (Table I).

The third stage included the selection of the most relevant databases as well as the stipulation of a time frame. Six databases—Web of Science, Research Gate, Google Scholar, Science Direct, Eric, and Scopus—were used in the study. These databases provided full-length abstracts from reputable journals to assist researchers in identifying high-quality publications that are manageable and analyzable. Initial research on these databases indicated that academics and practitioners have been increasingly interested in publishing about IoT applications and the usage of IoT in Industry 4.0 manufacturing since 2011. Therefore, the research period was set for 10 years, from 2012 to 2022, a period during which there was intense interest in studying the IoT and Industry 4.0 in the manufacturing sector.

TABLE I. Keywords and Search Query

Sr.	Search Query
1.	"Industry 4.0 AND IoT"
2.	"Industry AND Manufacturing"
3.	"IoT AND Manufacturing AND Industry"
4.	"IoT AND Implementation Framework"
5.	"Industry 4.0 ANDIoT implementation framework"
6.	"Industry AND Manufacturing AND IoT implementation framework"
7.	"IoT AND Implementation AND IoT implementation framework AND Industry 4.0"
8.	"Industry AND Manufacturing AND Industry 4.0 AND Malaysian manufacturing industry"
9.	"Challenges AND IoT implementation framework AND Industry AND Industry 4.0 AND Manufacturing"
10.	"Opportunities AND IoT implementation framework AND industry AND Manufacturing AND industry 4.0"

The fourth stage was concerned with inclusion and exclusion criteria. Non-peer-reviewed publications, dissertations, textbooks, abstracts, and newspaper stories were eliminated from the search. Also, articles with incomplete evidence were excluded, as this might limit research. As was done during the selection process, four researchers checked the extracted data to ensure its reliability. The following limitations were then imposed.

- Full-text articles,
- Peer-reviewed,
- English Language,
- and papers published over the previous 10 years (2012–2022).

4. RESULTS

Interesting insights regarding publication trends were identified through the quantitative analysis of the article meta-data. Figure 2 shows the total number of yearly publications. Since 2011, researchers have paid more attention to IoT and Industry 4.0, with a corresponding rise in papers. It turns out that most of the research was done in 2018, while 2019 showed a hike in industry 4.0 publishing rates. This demonstrates an interest among academics in studying the fields associated with IoT and Industry 4.0.

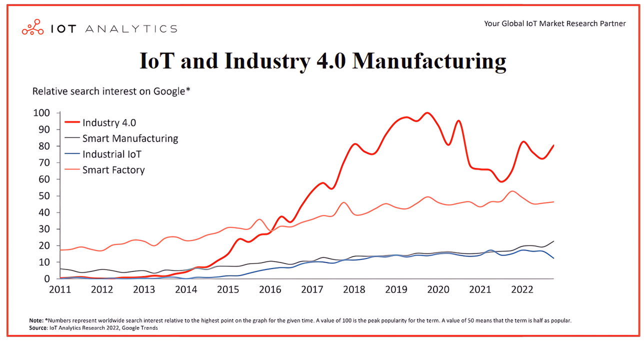

Figure 2. An annual volume of articles published on IoT and Industry 4.0 in manufacturing

The initial electronic search found 100 articles from six databases using keywords developed during the brainstorming process. After deleting 30 duplicates, a total of 70 papers were obtained. The relevance of the abstracts was then assessed, and 8 articles were deleted. Then 62 papers were retrieved in full form to determine their eligibility. Furthermore, 22 papers were deleted; leaving 40 papers for further consideration. Using the snowball method, references within selected articles were examined to uncover 2 more publications that were not included in the study. A total of 42 articles were selected for analysis. The search strategy and inclusion/exclusion criteria used to choose the most related publications for this study are highlighted in Figure 3. It was found that 42 out of 100 papers met the requirement that a keyword present in the papers is analyzed. As a result, these 42 papers were used for the analysis (see Figure 3).

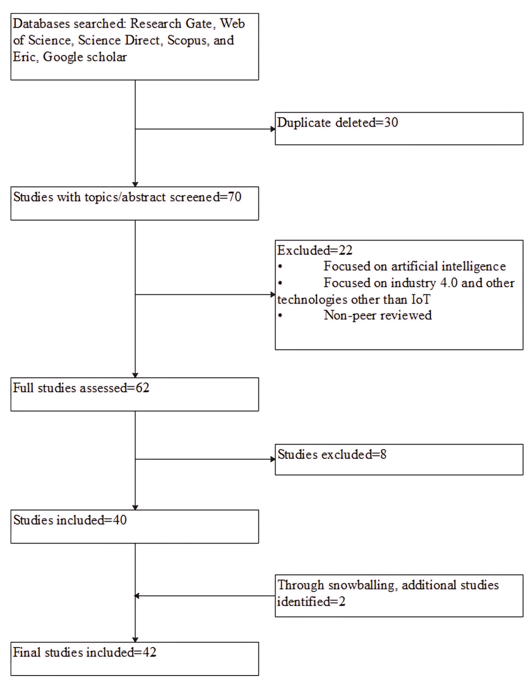

Figure 3. Shortlisting of papers

The articles were coded based on the type of application discussed in each of them. The top four categories were i) IoT in Industry 4.0, ii) Industry 4.0 and Smart Manufacturing, iii) Industry 4.0, IoT, and the Malaysian Manufacturing Industry, and iv) Challenges of IoT Implementation in Industry 4.0 Manufacturing.

A. IoT in Industry 4.0

The rapid advancement of micro-integrated devices and the increasing importance of cloud computing have paved the way for the adoption of low-power networked devices to monitor and control operations, leading to the emergence of next-generation industrial settings [44]. Modern electronics and wireless data transmission networks rely heavily on these systems for their operation [45]. The complexity of industrial systems makes them conducive to a wide variety of IoT applications [46].

There have been three primary areas of IoT use described in previous studies. First, several factors such as "human-machine interaction, monitoring, planning, asset management, advanced manufacturing, performance optimization, and end-to-end accountability in processes" are incorporated into manufacturing operations [40, 47]. Second, elements like manufacturing resource monitoring and tracking are part of the repair and manufacturing resource development in the manufacturing base (from the location of the resources to the confirmation of issues like quality, competence, and any damage or catastrophes) [48, 49].Third, field service consists of things like setting up and fixing industrial machinery [48, 50].

Businesses must adapt their management styles to keep up with the ever-evolving digital technologies, which are expanding in both breadth and depth as they move the globe toward more interconnected operations. Manufacturers may now share information about their production cycles, maintenance schedules, and surroundings due to the IoT [51]. IoT integration raises the level of intelligence and adaptability in the production process, fostering an atmosphere in which automated and self-optimized gear and equipment may improve output quality [52].

With the use of IoT connections and devices, manufacturing facilities may collect actionable, real-time data insights about the factory's and the delivery chain's physical assets. When paired with data analytics, cutting-edge technology, and faster networks, these data allow businesses to improve asset maintenance and productivity. Smart factories are made possible by the IoT because it helps manufacturers increase efficiency and production and generates massive data to aid in procedural and strategic decision-making. The researchers have shown that understanding, training, and investment in sustainability ideas are crucial preconditions for introducing sustainable methods in manufacturing companies. Technology adoption can improve industrial processes' effectiveness and capacity for energy conservation [53].

The services of IoT, which include computer processing, transportation systems, apps, detectors, applications, software, and storage technologies, enable increased capability and the ability to manage and monitor companies' assets and processes. Applications and services offered by the Internet of Things are indispensable for streamlining production planning, scheduling, and regulation [54, 55]. Furthermore, IoT allows real-time responses and actions by decentralizing analytics and decision-making via the various connected computers that may communicate and collaborate with more "centralized controllers" [56].

There is immense potential for extraordinary levels of economic development and economic output efficiency as a result of decreased unplanned downtime for businesses, increased manufacturing efficiency, and decreased product time-to-market [54, 55]. For Chinese manufacturers, the phrase "Industry 4.0" is not utilized. China has been emphasizing "Made-in-China 2025" rather than "Industry 4.0." In both cases, the intended result is a rise in production, and the enabling technologies are the same. In this context, IoT, IoS, CPSs, and the Internet of Media (IoM) refer to cooperative robotic systems. The IoT and Industry 4.0 in Malaysia will boost output by allowing manufacturers to better adapt their facilities to changing demands. Human productivity is predicted to rise as a result of the combination of the smart grid with Industry 4.0 technology [57].

During 2017, primary data was gathered in Malaysia through cloud computing in manufacturing companies for various outcomes, including productivity. A total of 188 respondents felt that using cloud computing helped them improve their workplace performance and increase their productivity [58].

B. Industry 4.0 and Smart Manufacturing

An integral part of the industrial sector that has a significant effect on people's quality of life and a country's economy is the manufacturing sector. Moreover, it is among the largest and most interconnected IoT markets, offering a diverse range of distinct practices, processes, services, products, and more. IoT offers services and applications, including improved monitoring and tracking, human-machine interaction, and performance and maintainability optimization, to improve manufacturing, profitability, and quality of product management (QPM) across the product life cycle [59].

This suggests that the manufacturing industry, which is unique in its complexities, range of operations, diversity of CPSs, and manufacturing operation management (MOM) techniques, may benefit from a wide range of solutions provided by the IoT. Smart manufacturing (also referred to as "intelligent production") is a new production paradigm that, as part of Industry 4.0, makes extensive use of contemporary data and manufacturing processes and methods and advances using "service-oriented architecture" (SOA) [59]. It aims to transform traditional companies into innovative ones that can thrive on demand-driven economics, which key on "customers, partners, and the public;

enterprise performance and variability management; real-time integrated computational materials engineering and rapid qualification; demand-driven supply chain services; and broad-based workforce involvement" [60].

The study [1] highlights the immense potential of IoT and Industry 4.0 to revolutionize traditional industries by incorporating advanced technologies. This integration of digital processes with physical assets results in the creation of smart manufacturing environments and smart factories. Despite being in their early stages of development, Industry 4.0 and IoT can offer numerous modern solutions, services, and applications that can enhance the "quality of life and provide significant professional, economic, and personal advantages."

To maximize output, quality of products, and operational efficiency, smart manufacturing integrates the intelligence of humans with that of machines. It provides smart solutions for the monitoring and detection of prospective problems due to breakdowns, malfunctions, and potential damage. Further, it optimizes resource administration and sharing, increases supportability and reliability, and boosts control and management. Furthermore, it incorporates "cutting-edge technologies" into a wide range of various traditional systems, products, and services [59].

Therefore, it is evident that smart manufacturing has a significant impact on how businesses operate and how profitable they are, and that it will open the door for the growth of modern industries. The goal of smart manufacturing is to create systems that can make decisions in the absence of human input and in real time. Machine learning, artificial intelligence, hereditary processing, and other cutting-edge technologies, methods, and approaches are used to achieve this goal. This is a key distinction between intelligence and conventional production methods. Both types of production, however, have the same overarching objective: to meet the demands of their respective markets while also maximizing profit and cutting waste to a minimum [1, 61].

C. Industry 4.0, IoT, and the Malaysian Manufacturing Industry

The Malaysian manufacturing industry is growing at a high speed. In the "Global Competitiveness Report 2012–2013 of the World Economic Forum," Malaysia was ranked 25th out of 144 nations. The ranking was based on the complexity of the production process [62]. With IoT adoption, the industry is expected to employ about 14,000 [63]. Again, the ASEAN action plan for manufacturers revealed that the Malaysian manufacturing industry is expected to generate about 30 billion dollars from the industry of 4.0 IoT [64]. Even with this high potential, Malaysian manufacturers across the "Association of Southeast Asian Nations (ASEAN)" are still in the early stages of their digital journey. Manufacturers in the region still use outdated and traditional models. This slows the IoT adoption and other industry 4.0 components [59].

The adoption of IoT is growing exponentially. As many as "75.44 billion" IoT devices will be in use by 2025 [65]. Many research advances show the importance of uncovering and leveraging the IoT. The IoT is transforming the way Malaysian manufacturing companies are operating. It has vast potential, which will take the manufacturing industry to a whole new level. IoT has shown evidence of improving businesses' productivity in the manufacturing industry [66].

The Malaysian manufacturing industry plays a vital part in the development of the economy. Many Malaysian-based businesses are willing to adopt IoT in the next few years [67, 78]. A study conducted by [68] to investigate the Malaysian manufacturing industry's readiness for IoT adoption revealed that there is a strong interest in IoT adoption in the country. The main factor in Malaysia's shift from a "middle-income to a high-income" economy will be the adoption and integration of IoT in its industrial systems. The manufacturing value chain might reach a completely new and more substantial level due to IoT.

The study of [69] explores IoT adoption in the manufacturing industry of Malaysia. They stated that industries must be willing to invest in IoT if they indeed want to adopt it and stop the term IoT from just being a concept. The authors added that IoT is still not properly integrated into Malaysian manufacturing industries, including the gas and oil sectors. The lack of integration is a result of factors such as insufficient knowledge in terms of research, especially in the oil and gas sector.

Compared to other neighboring nations like Vietnam and Singapore, Malaysia is currently behind in utilizing digital transformation to its fullest potential [70]. Even though IoT has become the new trend in manufacturing industries around the globe, the industry still faces challenges with this new advancement, such as security and privacy issues. The risk associated with IoT security is very critical; this is because of the nature of IoT (highly dynamic, heterogeneous, global connectivity, and accessibility). Research on IoT privacy and security challenges suggests using provenance approaches in IoT systems to help manufacturing industries deal with privacy and security issues [71].

The adoption of IoT will bring about a transformation in the Malaysian manufacturing industry by adding new dimensions such as testing facilities to meet global operations standards, software development to facilitate niche applications and services, and system integration for interaction between stakeholders and the ecosystem [72], because of the potential of IoT adoption in Malaysia's manufacturing industries for the economic growth of the country. The Malaysian government established the Industry4WRD intervention to encourage businesses in the manufacturing industries to adopt and implement IoT [73].

The IoT adoption in Malaysia's manufacturing industry is still in its infancy [74] to achieve its goal of becoming the leading technology hub nation in the world. The industry's stakeholders need to provide adequate training to employees to strengthen Malaysia's position in IoT adoption [75]. The study of [76] recommended that organizations in the manufacturing industry organize workshops and training sessions regularly on IoT related to their field to eliminate operational issues that can arise as a result of a lack of technical knowledge on IoT.

The study of [67] shows some of the challenges that Malaysia's manufacturing industries face in adopting IoT to improve process efficiency. Some of the challenges include high investment costs, which is one of the factors slowing the growth of IoT implementation in the manufacturing industry of Malaysia. Malaysia is still lagging behind neighboring countries like Singapore and Vietnam in fully embracing digital transformation. The industry faces some challenges with this new advancement, such as security and privacy issues. The risk associated with IoT security is very critical; this is because of the nature of IoT (highly dynamic, heterogeneous, global connectivity, and accessibility). To address IoT's security and privacy issues, it is recommended to use provenance approaches in systems of IoT to help mitigate problems of privacy and security faced by manufacturing industries [71].

D. Challenges of IoT Implementation in Industry 4.0 Manufacturing

The term "Industry 4.0" refers to an emerging construct in which mechanical, social, and organizational advancements are mutually integrated. Instead of being a clearly defined, homogenous development, the challenges of Industry 4.0 appear to be a collection of many developments [77]. The authors argue that while planning for sustained expansion, businesses should include issues of social responsibility, protecting the environment, ethical conduct, and the protection of human rights. Visibility in operations is the biggest barrier to providing ethical and environmentally responsible services [78]. The manufacturing sector lacks information on how Industry 4.0 may promote moral behavior and sustainable output. It is more difficult in developing nations to maintain the accessibility of processes due to an insufficient information-technology infrastructure, a poor organizational culture, regulations, and sophisticated technological applications [79].

According to [2] "Industry 4.0" has the potential to revolutionize the way "manufacturing and other industries operate," but its implementation faces several challenges, such as interoperability, security, and privacy. The authors proposed a research agenda to address these challenges and to guide future research on Industry 4.0. The agenda includes topics such as the development of open standards and architectures, the design of privacy-preserving and secure systems, the integration of human factors in the design of "Industry 4.0" systems, and the exploration of new business models and organizational structures that can use the potential of Industry 4.0.

Further, the security issues like privacy and trust, protection, and trust as key areas were highlighted by [79]. Other areas of attention were advances in connection and recognition innovations, decentralized network innovations, and intellect. Management of energy and resources, data privacy and analysis, and product interoperability are all crucial issues. The study of [81] found that reliability and availability, mobility, management and economy, interoperability and globalization, privacy, and security are only some of the important IoT challenges and Quality of Service (QoS) needs.

Key industrial IoT difficulties were identified by [82] as functional security, management of error tolerance, data latencies and adaptability, heterogeneous singularity, and secure and scalable real-time cooperation. According to [83], the most significant obstacles to business IoT technology are data management and mining, security and privacy latencies and adaptability, heterogeneous singularity, and secure and scalable real-time cooperation. The study of [84] concentrated on the difficulties with privacy and security in industrial IoT and their susceptibility to various cyberattacks. Large initial investments, system modeling and analysis, cyber security, management of big data, standardization and interoperability of IoT, and people's intentions to use IoT are all challenges [1]. The study results are summarized below as Table II gives an overview of the main areas of IoT that apply to industrial processes.

TABLE II. Primary areas of IoT use in industrial processes

Primary Areas	**Description**
Human-Machine Interaction	Incorporates factors such as monitoring, planning, asset management, advanced manufacturing, performance optimization, and end-to-end accountability in processes.
Manufacturing Resource Monitoring and Tracking	Involves tracking of manufacturing resources and development in the manufacturing base, from the location of the resources to the confirmation of issues like quality, competence, and any damage or catastrophes.
Field Service	Consists of setting up and fixing industrial machinery.

Table III gives an overview of the benefits of IoT in smart manufacturing.

TABLE III. Benefits of IoT in smart manufacturing

Benefits	**Description**
Improved Monitoring and Tracking	IoT offers services and applications to improve monitoring and tracking, increasing supportability and reliability, and boosting control and management.

Human Machine Interaction	IoT integrates the intelligence of humans with that of machines to maximize output, quality of products, and operational efficiency.
Performance Optimization	IoT integration raises the level of intelligence and adaptability in the production process, self-optimized gear and equipment may improve output quality.
Real-Time Responses and Actions	IoT allows real-time responses and actions by

Table IV presents the challenges in implementing IoT in various industrial processes.

TABLE IV. Challenge of IoT Implementation

Challenge	**Description**
Interoperability	In IoT, there are many different devices and systems that need to communicate with each other, but they may use different communication protocols, making interoperability a significant challenge.
Security	IoT devices can be vulnerable to security threats, such as hacking, malware, and data breaches, which can result in significant financial and reputational damages.
Data Management	The amount of data generated by IoT devices is vast and requires effective management to ensure it is processed, analyzed, and utilized efficiently.
Workforce Training	The integration of IoT in manufacturing requires a new set of skills, knowledge, and training for the workforce, which can be a significant challenge for businesses.
Cost	The cost of IoT implementation and maintenance can be high, which can be a significant barrier for small and medium-sized businesses.
Privacy	IoT devices can collect a vast amount of personal data, raising concerns about privacy and data protection.
Regulation	There is a lack of clear regulations governing IoT devices and systems, which can lead to uncertainty and inconsistency in their implementation and use.
Sustainability	The adoption of "IoT and Industry 4.0" can increase energy consumption and carbon emissions, making sustainability a significant challenge for businesses.
Complexity	The complexity of IoT devices and systems can be a significant challenge, requiring businesses to have a thorough understanding of the technology to effectively implement and manage it.

5. DISCUSSION

As technology continues to advance and daily life becomes increasingly digitized, customer expectations and demands are rapidly evolving. Meanwhile, the level of competition across global markets has increased significantly. Consequently, it has become increasingly important to be able to quickly and flexibly respond to these changes in real-time. Thus, to meet and satisfy these new demands, businesses choose to adopt emerging technological standards, practices, and research approaches. They also look for new creative approaches to boost their productivity, enabling them to outperform competitors while improving product quality and boosting profits. Changes in the manufacturing paradigm, technological advancements, etc. are just a few examples of how innovations may lead to both new possibilities and new challenges.

Companies need to adopt digital transition and virtualization to survive in today's globalized market, generate new values, and drive innovation for increased comparative advantage. In addition, they should innovate their manufacturing method and combine technology and administrative techniques to boost their total competency. In a dynamic and ever-evolving environment, Industry 4.0 is a solution to the recently developed challenges. A new degree of order and control has been introduced throughout all value chains as a result of this smart manufacturing environment's reputation for being highly integrated, digitalized, mechanized, autonomous, and productive.

In particular, it seeks to address the evolving demands of consumers and businesses by fostering the growth of smart manufacturing to turn traditional sectors into data-driven ones. To do this, industry 4.0 integrates the traditional industry's powers into cutting-edge technologies (such as advanced data analytics, big data, cloud computing, CPS, IoT, etc.). Industry 4.0 was successfully implemented due to the IoT. It paves the way for instantaneous, global communication between individuals and "things" via any available network or service.

The IoT is an ambitious plan to link all kinds of devices, large and small, all over the world in a way that is both seamless and safe. Further, the IoT offers a wide range of market and industry opportunities through its many functions, services, and applications. The implementation and adaptation of IoT technologies and Industry 4.0 can enable companies to achieve levels of economic development and production efficiency that were previously unattainable:

- The manufacturing systems development that is open, versatile, adaptable, agile, and proactive
- Engineering, operations, management, and decision-making all benefit from increased efficiency, speed, and quality.
- Improvements in framework and facilities lead to more opportunities and ease of maintenance.
- A shorter time-to-market due to increased efficiency and reduced lead time.
- Making it easier to adjust to specific customer needs and market dynamics.
- Decrease in general costs and wastes
- Competence in robust, enterprise-wide data analytics.

Although the Internet has a well-documented design, the IoT lacks global coherence and is thus seen as a development of the Internet. Consequently, concerns about the privacy and security of information have surfaced, and explicit decisions have been made about how data may and should be shared between industries, apps, and physical objects. Automated production lines and real-time monitoring of control systems are two key components of Industrial 4.0, which is helping the industrial sector achieve operational efficiency by cutting down on job errors. Because of this correlation between integration and demand of customer care and real product usage and performance, consumers may attain higher levels of happiness and satisfaction. Due to the Internet of Things, better, more consistent, and more engaging consumer experiences may be provided in both the online and offline realms [2, 47].

System modeling and analysis, management of big data, standardization and interoperability of IoT, sustainability, cyber security, and energy usage are all examples of technological problems that must be overcome. Non-technical barriers to IoT acceptance have included a lack of skill and strategy, sound decision-forming and negotiating mechanisms, effects on jobs, high initial expenses, and the influence of human behavioral goals. Despite its importance to Industry 4.0, the IoT presents several difficulties, such as those related to its technological implementation, efficient use, and administration [2, 48]. Previous studies indicate that IoT is being used effectively in service management, production asset management, and operations and maintenance. Integration of production facilities is achieved by the successful employment of suitable technical approaches and intelligent manufacturing technologies in these areas [52].

The combination of Industry 4.0 and the IoT has the potential to provide a plethora of advanced solutions, applications, and services, and can create significant opportunities for individuals in terms of personal, professional, and financial growth. Therefore, businesses and industries that are successful in implementing and adapting to IoT and Industry 4.0 will enjoy many profits and benefits and will be capable to remain competitive in the market. However, because the IoT and Industry 4.0 are still in their infancy in terms of development, adoption, and application, many issues and challenges must be overcome.

6. CONCLUSION

This research examines the role of IoT and Industry 4.0 in enhancing Malaysia's manufacturing industry. IoT is a rapidly expanding technology that connects physical and virtual worlds, enabling global connectivity and improving operational efficiency. By embracing IoT, businesses can achieve cost savings, waste reduction, and respond to market demands more effectively. Integrating IoT with innovations like big data and cloud computing under Industry 4.0 further enhances production setups, offering self-maintainability and autonomy. However, challenges such as cost, security, and privacy must be addressed.

The study emphasizes the importance of Malaysia's manufacturing industry adopting IoT and recommends investments in IoT development, research, and employee training. The government should also create awareness and support the adoption of IoT. Implementing an Industry 4.0 approach prioritizing smart manufacturing and digitalization is recommended, as it can improve product quality, profitability, and innovation while addressing challenges. To ensure successful implementation, the study suggests starting with small-scale pilot projects aligned with business needs and gathering insights through industry surveys. Overall, adopting IoT and Industry 4.0 can enhance Malaysia's manufacturing competitiveness, stimulate the economy, and position the country as a regional leader in IoT implementation.

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