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ORIGINAL RESEARCH

Factors influencing the adoption of industrial internet of things for the manufacturing and production small and medium enterprises in developing countries

Sajid Shah[1] | Syed Hamid Hussain Madni[2] | Siti Zaitoon Bt. Mohd Hashim[1] | Javed Ali[3] | Muhammad Faheem[4]

[1]Faculty of Computing, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia

[2]Department of Computer Science, University of Southampton Malaysia, Johor Bahru, Johor, Malaysia

[3]College of Computing Informatics, Saudi Electronic University, Riyadh, Madinah Munawarah, Saudi Arabia

[4]Department of Computing Science, School of Technology and Innovations, University of Vaasa, Vaasa, Finland

Correspondence

Muhammad Faheem, Department of Computing Science, School of Technology and Innovations, University of Vaasa, Vaasa, 65200, Finland.
Email: muhammad.faheem@uwasa.fi

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Abstract

Small and Medium Enterprises (SMEs) are steadily moving in the direction of implementing digital and smart technologies, including the Industrial Internet of Things (IIoT) for improving their products and services. The adoption of IIoT allows manufactures and producers to make quick decisions for improving productivity and quality in real-time. For this purpose, the era of digital industrial revolution from IR 1.0 to IR 5.0 is briefly explained. In this research study, the authors have reviewed and analysed the existing reviews, surveys and technical research studies on IIoT technologies for the manufacturing and production SMEs to highlight the concern raised. Forty-seven (47) influencing factors are identified and classified into four groups based on the TOEI framework. Based on the identified influencing factors, IIoT adoption model is proposed for the manufacturing and production SMEs to adopt the new IIoT technologies in their business environments. Furthermore, a comparative analysis of the influencing factors has been done for the adoption of IIoT to increase efficiency, productivity and competitiveness for the manufacturing and production SMEs in developing countries. The proposed IIoT adoption model will help future policymakers and stakeholders to develop policies and strategies for the successful adoption and implementation of IIoT in manufacturing and production SMEs in developing countries. Also, recommendations are suggested to encourage IIoT adoption in production and manufacturing environments so that manufacturers and producers can respond easily and quickly to highly changing demands, product trends, skills gaps and other unexpected challenges in the future.

KEYWORDS

data analysis, decision making, intelligent manufacturing systems, manufacturing industries, manufacturing systems, production engineering computing

1 | INTRODUCTION

Industrial Internet of Things (IIoT) is composed of applications, physical objects, platforms and systems that utilise embedded technologies to share data and to communicate both inside and outside the organisation with the people [1]. It also enables product designers to gather information about their product for a better understanding of the condition regarding product usage and quality; hence, differentiating themselves from their competitors. Industrial IoT is composed of operational technology, information technology, fog computing, Industry 4.0 (IR 4.0) and Industry 5.0 (IR 5.0). A large number of connected industrial systems are facilitated by the IIoT, which also serves as a catalyst to enhance industrial performance by enabling the coordination and sharing of data and data analytic [1].

Internet of Things (IoT) consists of pervasive and ubiquitous computing based on IoT sensors for data analysis, collection, monitoring and processing to integrate physical world functionality [2]. However, IoT is one of the most important concerns of IR 4.0 among other concerns such as Artificial Intelligence (AI), big data, smart factories, autonomous systems and machine learning. Product designers can take advantage of the IoT's ability to gather a huge amount of data to improve product quality during the production phase; hence, this fulfils the requirement of end-users with more reliability [3, 4].

Small and Medium Enterprises (SMEs) are business that has fewer than 250 employees, these businesses are typically privately owned, partnerships or limited companies. SMEs are local scale or small businesses, and the main focus of SMEs is to provide goods, products and services in the community. SMEs include accommodation, agriculture, construction, gas extraction, food services, manufacturing, mining, production, utilities and wholesale trade companies [5]. Manufacturing refers to those SMEs that produce goods or products from raw materials while production SMEs are the ones that provide both goods and services as shown in Figure 1 [6].

The adoption of IIoT in SMEs is rapidly growing in developed countries, such as China, Israel, Japan, Korea, Australia and New Zealand. This is due to the potential for improved efficiency, productivity, quality control, the deduction of supply chain issues and cost reduction [7]. The IIoT adoption introduces and leads to substantial benefits and enhancement for the manufacturing and production SMEs in terms of cost reduction, quality control, detection of supply chain issues, time management in the planning phase and optimal resource management [7]. Furthermore, IIoT rapidly transforms the digital landscape of industrial operations. IIoT is a network of interconnected physical devices such as sensors, controllers and actuators which are embedded into machines and systems that are connected to the internet; therefore, enabling them to collect and share data with the industrial environment [8]. IIoT is transforming the retail, construction, agriculture, finance and insurance, transportation, production, manufacturing, packaging and automation processes of SME businesses in developing countries.

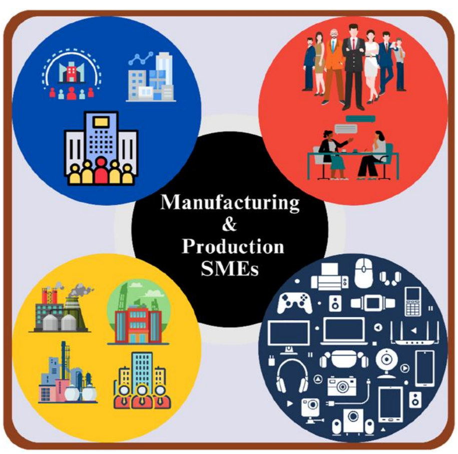

FIGURE 1 Manufacturing and production SMEs.

1.1 | The era of the digital industrial revolution

Industrial Revolution 1.0 (IR 1.0) is the beginning of the industrialisation movement in the late 18th and early 19th centuries. IR 1.0 is characterised by the invention of machines, such as steam engines, that replaced manual labour. New ways of transportation, such as railroads and steamboats, improved the efficiency of water power and increased the use of steam power. In addition, development of machine tools and water canals were introduced in IR 1.0 [9]. Industrial revolution 2.0 (IR 2.0) began with the alloys, assembly line production, chemical industries, discovery of electricity, internal combustion engine, mass production, petroleum and electrical communication technologies (telegraph, telephone, and radio) [10]. In IR 2.0, steam engines were replaced by electrical machines. Industrial Revolution 3.0 (IR 3.0), which is also known as the digital revolution, is the time of shift automation and data exchange in manufacturing and production industries. During IR 3.0, varieties of electronic devices were invented, including integrated circuits, programmable logic controllers, transistors and digital logic systems. IR 3.0 is also based on the respective derived technologies of the digital revolution, such as the internet, computers, digital cellular phones, and microprocessors [11].

The digital revolution era converts the existing analogue world into a modern and digital world. However, Industrial Revolution 4.0 (IR 4.0) defines the growing trends towards automation and data exchange in technology and processes within manufacturing and production industries including AI, cloud computing, cognitive computing, Cyber-physical systems (CPS) and IoT (smart manufacturing and smart factories) by using either one of these advance technologies in the context of IR 4.0. It also includes the development of new materials and technologies such as 3D printing, automated data entry, robotics, augmented reality and virtual reality [11]. Industrial Revolution 5.0 (IR 5.0) is the fifth phase of the industrial revolution that focuses on combination of advanced technologies, such as AI, automation, big data, cloud computing, cyber security, cobots and IoT. These components work together to drive the industrial revolution in IR 5.0 [12].

The digital revolution in SMEs has taken place in recent decades. IR 4.0 includes innovative campaigns and strategies of organisation and variation in infrastructure, production, manufacturing, human resources, management practices and technologies [13]. Human beings and machineries are affected in terms of balanced work-life by IR4.0. In IR 4.0, products, production modules, machines and field devices are composed of CPS that are used to exchange information, trigger actions and control each other independently [14].

IR 5.0 is the next step in technological advancement and is centred around the concept of smart factories. It seeks to create a fully automated, interconnected and intelligent manufacturing system. IR 5.0 relies more heavily on AI and machine learning, as well as integrating physical and digital systems that enable faster and more efficient production, as well as increased safety and better customer experience. Furthermore, IR 5.0 allows for greater product customisation and personalisation. Products are manufactured according to customer specifications through the use of sensors and robots with minimal effort [15]. Figure 2 shows the era of the digital industrial revolution from IR 1.0 to IR 5.0.

IR 4.0 and IR 5.0 have exploratory and strong associations with the Industrial IoT (IIoT) paradigm. In IIoT, IoT-based devices and sensors are used in businesses by SMEs to produce goods and services such as industrial machineries and vehicles [16]. The IIoT product is comprised of a few objects including the product, sensor, connectivity, cloud, external information and data virtualisation. IIoT adoption provides many benefits to producers and manufacturers in terms of monitoring, maintaining, downtime, throughput, cost and quality improvement [17].

In the context of IR 4.0 and the emerging IR 5.0, developed countries have successfully adopted IIoT technologies within their business environments, while taking advantage of increased efficiency, enhanced productivity and improved decision-making processes [18]. However, the adoption of IIoT in manufacturing and production SMEs in developing countries lags behind significantly and makes the manufacturing and production SMEs less competitive on a global level in these countries.

According to the European Commission's perspective, IR 5.0 extends the principles of IR 4.0 by focusing on values, such as human-centricity, ecological sustainability and social benefits [19]. It represents an evolution and a logical continuation of the existing IR 4.0 paradigm rather than a different technological revolution. IR 5.0 emphasises its centrality around values, particularly human-centricity, ecological considerations and social well-being. It shows the importance of shaping technologies to support values, by fostering and improving a more inclusive and sustainable industrial landscape for the SMEs in developing countries [20].

Furthermore, IR 5.0 is opening new challenges related to technology, socio-economy, regulation and governance. The main purpose of IR 5.0 is to support the individual and their abilities, to merge humans and technologies, and instead of replacing them, to provide a safer and more comfortable working environment where humans can use their creativity and adopt new technologies and skills [19]. New technologies based on IR 5.0 such as human-machine-interfaces, merging human brain capacities with AI or collaboration with robots and machines are used to generate products and services [20]. These products and services can be further customised to customers' needs, reduce environmental impact and allow concept such as closed loops, energy self-sufficiency, emission-neutrality or the circular economy [19].

IIoT has potential to provide a competitive advantage and to improve operational efficiency as established through several studies. However, the adoption of IIoT in manufacturing and production SMEs is slow in developing countries due to various influencing factors. To understand these factors, an empirical study needs to be conducted in order to propose the IIoT adoption model for the manufacturing and production SMEs in developing countries. The research focuses on identifying various factors that influence the adoption of IIoT in manufacturing and production SMEs as well as on understanding the underlying trends in developing countries. The recent academic literature shows a gap in IIoT adoption for production and manufacturing environments for developing nations. In current research, individual, organisational and environmental factors also need to be paid attention to during

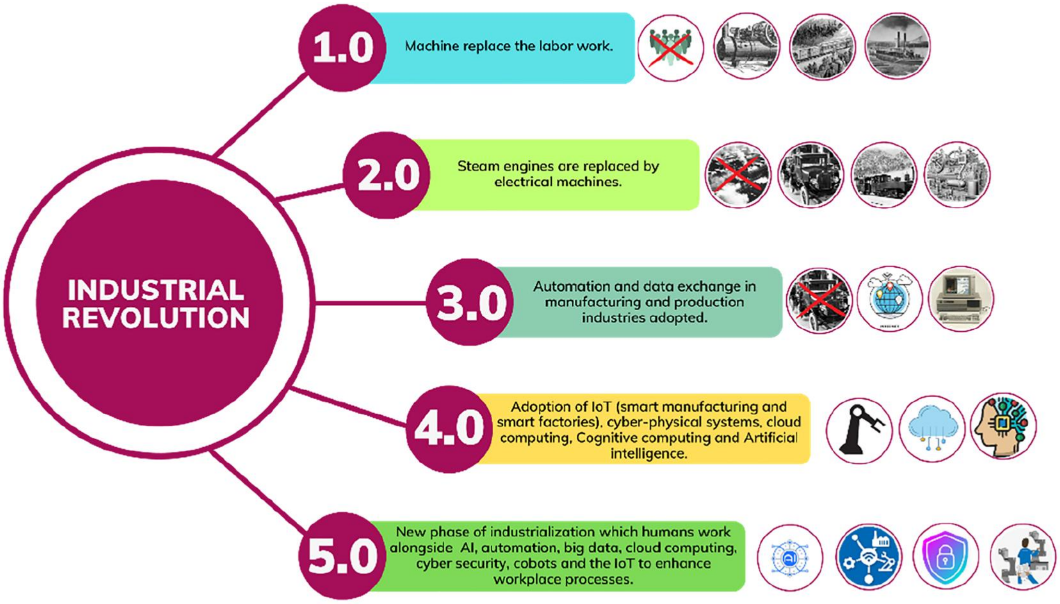

FIGURE 2 Digital industrial revolution from IR 1.0 to IR 5.0.

the adoption of advanced technologies; however, most of the studies are only focused on the technological factors. Consequently, the researchers feel that there is a robust necessity for SMEs in developing countries to transfer towards the adoption of IIoT for obtaining enhanced prospects.

Previous review and survey papers focus on a particular domain; for instance, several researchers have addressed both IIoT and IoT for both manufacturing and production SMEs [14, 21–24]. On the other hand, [25–28] exclusively focused only on IoT for the manufacturing and production SMEs, and neglected the IIoT aspects. In a similar way, [29, 30] focused on IoT but not specifically for SMEs in the context of manufacturing and production. Moreover, Majstorovic et al. [31] focused on IIoT and IoT for SMEs, but they did not differentiate between manufacturing and production. Lastly, Sira [32] covered IIoT for the manufacturing SMEs but did not include production SMEs. Therefore, this research study addresses IIoT for both manufacturing and production SMEs. Additionally, the previous research studies have identified 2–10 factors for the adoption of IIoT in manufacturing and production SMEs. However, this research study distinguishes itself by identifying an extensive number of influencing factors, forty-seven (47) in total, for the successful adoption of IIoT for manufacturing and production SMEs, and these factors were not identified in any of the previous studies.

The significance of this research study is to empower manufacturing and production SMEs in developing countries with the awareness, tools and knowledge required to adopt the IIoT technologies in the context of IR 4.0 and IR 5.0. As developed nations have already adopted these IIoT technologies, it is crucial for developing countries to also adopt these technologies within their business environment in order to remain competitive in the global market.

The contributions in this research study are mentioned as follows:

- The transformation of the digital industrial revolution from IR 1.0 to IR 5.0 is discussed to understand the status of SMEs in developed and developing countries.
- The existing reviews and surveys research articles on IIoT are analysed for the manufacturing and production SMEs.
- The IIoT adoption issue is formulated for the manufacturing and production SMEs in developing countries.
- The existing technical studies on IIoT adoption for the manufacturing and production SMEs are explored and summarised to highlight the concerns raised.
- The IIoT adoption influencing factors are classified, based on the Technological, Organisational, Environmental and Individual (TOEI) framework, into four groups for the manufacturing and production SMEs in developing countries.
- IIoT Model based on the influencing factors is proposed as a road map for the manufacturing and production SMEs to adopt new technologies in their business environments.
- A comparative analysis of the influencing factors for the adoption of IIoT is presented with a detailed description in order to determine which factors should be prioritised for efficient manufacturing and production in SMEs.
- Finally, future suggestions and recommendations for the specific IIoT adoption and implementation in manufacturing and production SMEs in developing countries are proposed.

Nonetheless, evaluation, reviews and comparison of existing relevant studies assist in understanding the general concept and identify the aspects of IoT adoption that need more attention, improvement and generate suggestions for future research. This research will help future researchers and policy makers to understand the current state of the Industrial IoT and the requirements for the adoption of IIoT for manufacturing and production SMEs in developing countries. The remaining sections of this research study are organised as follows:

Section 2 describes the existing relevant reviews and survey studies for the adoption of IIoT for the manufacturing and production SMEs in developing countries. Section 3 discusses the problem formulation that defines the loophole of the existing manufacturing and production SMEs that need to switch from traditional to Industrial IoT. The research methodology of preparing this research study including the data sources, search strategy, research questions, studies selection procedure and inclusion/exclusion criteria are addressed in Section 4. Section 5 explores the existing technical studies on IIoT adoption for the manufacturing and production SMEs in order to explain the entire used systems in manufacturing and production SMEs that are addressed by existing researchers. One of the most important portions of this research study is Section 6, which is the classification of Industrial IoT (IIoT) adoption influencing, and this section proposes the IIoT adoption model for the manufacturing and production SMEs. Section 7 presents a comparative analysis of the Influencing factors for the adoption of IIoT in manufacturing and production SMEs, and thoroughly studies and highlights the factors that need more attention. Future suggestions and recommendations for the specific IIoT adoption and implementation in manufacturing and production SMEs in developing countries are presented in Section 8. Furthermore, this research study closes in Section 9 by presenting the conclusion and several recommendations for the adoption of IIoT in manufacturing and production SMEs.

2 | RELATED WORK

In this section, the existing relevant reviews and survey studies for the adoption of IIoT for the manufacturing and production SMEs are studied. The influencing factors regarding the manufacturing and production SMEs are also explored as shown in Table 1, addressing the open issues and challenges for further research. In the existing studies, most of the researchers are focused only on IoT adoption while IIoT adoption also needs to be intended for SMEs. Moreover, several existing studies address the manufacturing and production

TABLE 1 Analysis of existing reviews on IIoT for manufacturing and production SMEs.

References	Industrial internet of things (IIoT)	Internet of things (IoT)	Small and medium enterprises (SMEs)		Number of influencing factors	Years
			Manufacturing	Production		
Ashima et al. [25]	No	Yes	Yes	Yes	4	2016–2021
Bueno et al. [21]	Yes	Yes	Yes	Yes	7	2015–2019
Estensoro et al. [33]	No	Yes	Yes	No	8	2017–2021
Ghobakhloo [26]	No	No	Yes	No	8	2016–2019
Ghobakhloo et al. [34]	No	No	Yes	Yes	7	2018–2021
Jaloudi [29]	Yes	Yes	No	No	5	2015–2017
Javaid et al. [22]	Yes	Yes	Yes	No	5	2016–2020
Kamble et al. [27]	No	Yes	Yes	Yes	10	2017–2019
Khin and Kee [35]	No	No	Yes	No	6	2019–2021
Khan et al. [30]	Yes	Yes	No	No	4	2017–2018
Majstorovic et al. [31]	Yes	Yes	Yes	No	2	2016–2020
Mittal et al. [23]	Yes	Yes	Yes	Yes	8	2016–2018
Saravanan et al. [14]	Yes	Yes	Yes	Yes	5	2017–2021
Sira [32]	Yes	Yes	Yes	No	6	2016–2022
Thoben et al. [24]	Yes	Yes	Yes	Yes	6	2015–2017
Younan et al. [28]	No	Yes	No	No	5	2016–2018
Current research study	Yes	Yes	Yes	Yes	47	2015–2023

SMEs separately; however, both SMEs need to be reviewed together for the adoption of IIoT.

The use of IR 4.0 technologies based on IoT in Additive Manufacturing (AM) processes for the mass manufacturing of smart materials is investigated. The study underlines the limitations of AM technologies in terms of mass manufacturing and size constraints, which causes industry uncertainty. The aim is to identify the benefits and applications of IoT in AM that focus on automation and IR 4.0 adoption. The study also highlights the benefits of automation in AM, such as decreased manufacturing errors, higher product quality and cheaper labour costs. Furthermore, it indicates that incorporating IoT into AM increases manufacturing process efficiency, reduces waste and meets the customer standards. It implies that combining automation and 3D printing results in a more customer-friendly and efficient manufacturing system [25].

Khan et al. [30] examine the emerging IIoT technologies, which is an extension of IoT for industrial systems with the aim of achieving high operational efficiency and increased productivity. After providing a clear definition of IIoT, the state-of-the-art research efforts are reviewed in terms of IIoT architectures, communication protocols, frameworks and data management techniques. Enabling technologies for IIoT are discussed with recent challenges faced by IIoT technological areas such as data management, interoperation between heterogeneous technologies and protocols, big data analytics, customer trust, wireless coexistence, edge decentralisation, IoT operating systems and public safety. The study delivers an overview of the current IIoT fields and suggests some vague challenges for future research.

In the same way, Majstorovic et al. [31] discuss the accomplishment of Digital Manufacturing (DM) models for SMEs in Serbia with an example of best practices for DM in specific SMEs, which uses the concept of DM as a base for the application of the IR 4.0 model. DM applications in SMEs are also provided, which includes the use of Computer Aided Design, Computer Aided Manufacturing, Enterprise Resource Planning, Cloud Computing, BDA, IIoT and smart supply-chains. In conclusion, digitalisation is a prerequisite for moment in the development of the Serbian economy that is the objective of the application of IR 4.0.

Furthermore, Javaid et al. [22] provide an overview of IIoT with its associated technologies, major benefits and features in manufacturing SMEs. The study discusses smart modification change in manufacturing field with the help of IIoT and identifies 29 significant applications of IIoT in manufacturing SMEs. Supply of goods, transport, warehouses details, product storage, condition and delivery are monitored by IIoT and allows several outsourced and dispersed operations to be monitored. According to Javaid et al. [22], IIoT is used to help reduce cyber risks, human errors, data violations and risks related to manual work. Additionally, it improves operational efficiency, enhances safety for workers and assets, optimises delivery and minimises cost sharing in the value chain.

A comprehensive review of the challenges faced in IIoT and Information Communication Technologies (ICT) is presented by Younan et al. [28] that aids in addressing these challenges. The study focuses on data science and ICT such as machine learning, big data, fog computing, cloud computing and blockchain that reduced and controlled the usage of the IoT and leverage its value. The study introduces case studies to reflect the potential of ICT integration in IIoT applications. It provides a survey of current IoT search engines and suggests how ICT is integrated to enhance the search and discovery services. Finally, future research directions of IoT are discussed [28].

Jaloudi [29] presents a study of the use of MODBUS TCP and Message Query Telemetry Transport (MQTT) protocols in IIoT communication environment in order to create a cost-effective, reliable and scalable ecosystem for various industrial applications. MODBUS is an optimal message structure in the application layer that is consecrated to industrial applications, and MQTT complements the MODBUS TCP as an event-oriented protocol to fulfil IoT requirements. Furthermore, two situations are presented for the purpose of building the IIoT environment. The first situation employs the MODBUS TCP alone, which provides efficient communications that fulfil most industrial requirements. The second situation employs MQTT in combination with the MODBUS TCP, which provides the publish–subscribe pattern for Machine to Machine (M2M) communication. The simulation results express that concurrent execution of MQTT does not impact on the efficiency of the MODBUS TCP severely. Moreover, security issues are addressed by employing transport layer security for both MODBUS TCP and MQTT protocols. The study shows that the proposed industrial protocols can be used together to build an IIoT communication environment for various industrial applications.

Similarly, Ghobakhloo [26] discusses the influencing factors of Information Digital Technologies (IDT) implementation for smart manufacturing with respect to IR 4.0. The study identifies and investigates the factors that influence the adoption and effective deployment of advanced IDT in manufacturing processes, and it highlights 11 factors in their contextual interrelationships. Perceived benefits and support of the management are the main reasons for smart manufacturing IDT deployment. The dependent determinants include operations technology maturity and cybersecurity maturity, which are influenced by the driver determinants. The findings are useful for academics, industrialists and policymakers concerned with understanding the transformation processes and conditions required for successful manufacturing digitalisation in IR 4.0 era. Furthermore, the study emphasises the importance of smart manufacturing in gaining a competitive advantage and the need for manufacturers to adopt and use the most recent IDT in order to succeed in the digital age.

Moreover, Sira [32] focuses on Cognitive Manufacturing (CM) applications in the context of IR 4.0 and their impact on maintenance in manufacturing organisations. The study discusses the integration of sensor-based information, sophisticated analytics and cognitive technologies, especially machine learning, to enhance business metrics, solve problems and produce value from manufacturing data. It also highlights four effective CM applications, namely reliability and performance management, process and quality improvement, resource optimisation, and supply chain optimisation. These applications use cognitive technology to improve the management of knowledge, business metrics including productivity and product reliability, downtime and maintenance costs, and supply chain operations. The findings show that CM enables automated data analysis, provides actionable insights and provides decision-makers with real-time knowledge.

However, Bueno et al. [21] focus on IR 4.0 smart features that improve the production, planning and control (PPC) in production system. The study uses an SLR and analytical framework to determine and understand the smart capabilities from five base technologies including Big Data, IoT, CPS and AI. Additive manufacturing includes 18 smart capabilities, 13 success indicators and the environmental factors that affect PPC smart capability development. According to Bueno et al. [21], IoT is PPC's most essential technology. CPS, big data, AI, cloud manufacturing and AM additionally increase PPC. Finally, the study suggests greater research on PPC to fit into IR 4.0.

In the same way, Saravanan et al. [14] investigate the manufacturers and sellers that are using IR 4.0. New ideas in the IR 4.0 domain come from big businesses; thus, understanding the technologies employed in the SMEs today is crucial. According to the report, IR 4.0 uses automation, internet-based methodologies and CPS to create flexible and efficient production processes. Furthermore, the study examines the machine and appliance manufacturers employed on business 4.0 and technology setups. It emphasises strategic planning based on the company's talents, goals, priorities and budget, with the financial, industrial, IT development, and information skills challenges. Moreover, Estensoro et al. [33] conduct interviews and surveys with 354 manufacturing SMEs to understand the IR 4.0 implementation stages with required resources and challenges. The SMEs that are based in Basque Country, Spain and particularly in Gipuzkoa, which is an industrialised region, are focused on the integration of advanced technologies like the IoT and automation in manufacturing with IR 4.0 adoption. Indeed, SMEs play an important role in the economy; however, the SMEs in developing countries often struggle with IR 4.0 adoption. Four stages are identified for SME development related to Industry 4.0, each with different requirements. These stages range from full implementers who have adopted IR 4.0 to non-implementers with limited resources for the adoption of technologies in SMEs. The findings highlight the importance of external factors such as market demand and internal factors such as strategy and innovation management for IR 4.0 implementation. The study also emphasises the need for SMEs to align their resources and develop a clear plan to transition to Industry 4.0 successfully.

In addition, the suitability of existing smart manufacturing and IR 4.0 maturity models (MMs) for SMEs are explored. The study examines the specific demands and challenges that SMEs face while adopting SM and IR 4.0, as well as the gaps in current MMs that fail to meet these needs. According to the findings, most MMs are built with larger organisations in mind and do not correspond to the starting point and digitisation maturity of many SMEs. The study suggests a 'level 0' specifically targeted to SMEs, reflecting their existing baseline degree of digitisation. It demonstrates the huge amount of work required for SMEs to go from this foundation level to the typical 'level 1' of MMs, which includes a mindset shift. Furthermore, the study recommends linking MMs and readiness evaluations to an SM toolkit and emphasises the need for SMEs to build their own distinctive SM or IR 4.0 vision and roadmap. Overall, the study provides useful insights and lays the groundwork for future research to develop a realistic smart manufacturing MM for SMEs [23].

Similarly, Kamble et al. [27] focus on the development of a performance measuring system for small medium and micro enterprises (SMMEs) in India's auto-component manufacturing industry that are implemented in the context of IR 4.0 in SMEs. To define and validate the parameters that are important to evaluate SMS investments in SMMEs, the study uses a combination of exploratory research and empirical investigation. It proposes an innovative Smart Manufacturing Performance Measurement System framework with 10 performance parameters including computing, cost, flexibility, integration, quality, time, optimised productivity, real-time diagnostic and prognosis, social as well as sustainability. Surveys with industry practitioners from SMMEs are used to empirically validate these measures. The findings show SMS competitive advantages over traditional production systems and provide practitioners with direction in evaluating their SMS investments. Furthermore, the study discusses the theoretical and managerial implications of the study and identifies future research opportunities, such as investigating the generalisability of the measures across different industries and investigating the influence of organisational culture on SMS performance.

Additionally, Thoben et al. [24] focus on the IR 4.0 and smart manufacturing that incorporates the integration of IoT and service-based concepts into production processes. The study focuses on the policies and programs put in place by countries such as Germany, USA, Japan and Korea to promote the manufacturing industry's transformation. The development of CPS that enable machines, vehicles, and workpieces to gather data, process information, connect with other systems and initiate actions is a critical component of the revolution. Furthermore, the study examines the possible application of CPS throughout the product life span, from design to manufacturing, distribution, maintenance and recycling. It also covers economic issues, such as innovative company methods and models. Thoben et al. [24] discuss present and future research concerns linked to the adoption of IR 4.0 and smart manufacturing in the technological, methodological and business case areas. It concludes by emphasising the momentum and traction gained by these initiatives, as well as the diverse range of applications and challenges they bring. It anticipates rapid advances in this field, driven by industrial interest and multidisciplinary interactions between researchers and industry.

Furthermore, Ghobakhloo et al. [34] discuss the factors influencing SMEs in adopting IR 4.0 technologies. It utilises the Technology Organisation Environment (TOE) framework to identify technological, organisational and environmental factors affecting SMEs' decision to adopt IR 4.0 technology. The study finds that SMEs lag behind larger organisations in embracing IR 4.0, primarily due to challenges in initial adoption decisions and a lack of understanding of the influencing factors, which can act as either barriers or challenges. The study contributes to the field by developing a digitalisation roadmap, highlighting necessary conditions for SMEs' digitalisation under IR 4.0 and providing practical implications for promoting their digital transformation. In a similar way, Khin and Kee [35] focus on identifying factors that influence the decision of manufacturing SMEs to adopt IR 4.0 technology and develop a comprehensive conceptual model for understanding this phenomenon. A qualitative method is applied based on 15 case studies from the Malaysian manufacturing industry, using face-to-face interviews and NVivo for data analysis. Three main categories of factors are identified, namely driving, facilitating and impeding. Furthermore, a triadic conceptual model of integrating factors is presented to provide a holistic view of the decision-making process for IR 4.0 adoption. This model is unique in its comprehensive inclusion of positive and negative factors along with external support mechanisms. It concludes that understanding the factors helps SMEs to prepare, mentally and technically, for digital transformation; thus, encouraging policymakers to create open environments for IR 4.0 adoption.

Furthermore, analysis of existing reviews and surveys on IIoT for the manufacturing and production SMEs is presented in Table 1. According to Table 1, only a few researchers address both the manufacturing and production sectors together for the adoption of IIoT in SMEs. Nevertheless, there is a need of addressing both sectors together in order to increase efficiency, productivity and competitiveness for SMEs. Moreover, existing research studies only highlight 2–10 influencing factors in their research. Hence, this research study identifies forty-seven (47) influencing factors for the adoption of IIoT in manufacturing and production SMEs and covers the era of research from 2015 to 2023. The main finding from Table 1 indicates that several researchers explore IoT technology instead of IIoT technologies in manufacturing and production with a specific focus on SMEs.

3 | PROBLEM STATEMENT

IIoT adoption aims to bring significant advantages and improvements to the manufacturing and production industries, encompassing cost reduction, quality control, identification of supply chain challenges, efficient time management in the planning phase and optimal resource utilisation. Incorporating IIoT technologies helps manufacturing businesses to achieve substantial benefits and enhance their overall operations [36]. The adoption of IIoT in production and manufacturing SMEs is rapidly growing in developed countries, such as China, Israel, Japan, Korea, Australia and New Zealand. However, the researchers notice that developing countries like Saudi Arabia, Pakistan, Malaysia and Bangladesh lack the adoption of IIoT in their production and manufacturing SMEs [37, 38]. Furthermore, the factors influencing the adoption of IIoT in manufacturing and production SMEs remain unclear [37]. In addition, there is a loophole in assessing the effect on individuals, organisations, technologies, and environmental contexts of IIoT adoption for both developed and developing countries. IIoT is transforming the retail, construction, agriculture, finance and insurance, transportation, production, manufacturing, packaging and automation processes of SMEs businesses. However, there is lack of research on the adoption of IIoT in manufacturing and production SMEs in developing countries. To address the crucial complications of the IIoT adoption, the core research question is:

> How can IIoT be adopted in manufacturing and production SMEs for the future of developing countries?

4 | METHODOLOGY

A comprehensive review of existing studies related to the adoption of IIoT in manufacturing and production SMEs is conducted according to Moher et al. [39]. The research methodology of preparing this research study includes data sources, search strategy, research questions, studies selection procedure and inclusion/exclusion criteria.

4.1 | Data sources

The review method involves the design of research questions, the search of various databases, the analysis and identification of various approaches. The research methodology used in this paper requires the identification of relevant papers from a variety of databases including Google Scholar, IEEE Explore, Springer, Science Direct, Web of Science, Elsevier, Scopus and ACM Digital Library as shown in Table 2, as well as a list of different questions to be addressed in Table 3. It is improved further from the identification of primary studies, then applying certain inclusion criteria and reviewing the results.

4.2 | Search strategy

To gather relevant information, various databases are searched including Google Scholar, Web of Science, Scopus, Springer, IEEE Explore and ACM Digital Library. Most of the updated information related to this research study are from 2015 until 2023; thus, ensuring that this research study is based on the most up-to-date information. The defined search keys led to enough amount of most suitable related research studies: ("Industrial" * "Internet of Things" + "IoT" + "Smart and Medium Enterprises" + "SMEs" + "Manufacturing" + "Production" + "IIoT") and ("Industrial" AND "Internet of Things" OR "IoT" OR "Smart and Medium Enterprises" OR "SMEs" OR "Manufacturing" OR "Production" OR "IIoT"). A quick search strategy is used to make this research up-to-date and well-intentioned in the area of manufacturing and production SMEs. For this purpose, the quick search strategy

TABLE 2 Database sources.

Source	URL
Google scholar	https://scholar.google.com/
IEEE explore	http://ieeexplore.ieee.org/
Springer	http://www.springer.com/
Science direct	http://www.sciencedirect.com/
Web of science	https://apps.webofknowledge.com/
Elsevier	https://www.elsevier.com/en-xs
Scopus	https://www.scopus.com/
ACM digital library	http://dl.acm.org/

TABLE 3 Research questions and motivation.

Questions	Motivations
What is meant by industrial IoT (IIoT), and how it is different from IoT?	Understanding the clear concept of industrial IoT (IIoT) and showing the difference between the IIoT and IoT.
How does the revolution of IR 4.0 and IR 5.0 impact the adoption of IIoT in manufacturing and production SMEs?	Understanding the relationship and impact of IR 4.0 and IR 5.0 on IIoT technologies in manufacturing and production in SMEs.
What are the main issues faced by manufacturing and production in SMEs in adopting IIoT?	Identify the influencing factors to address and promote successful IIoT adoption for reducing obstacles and challenges.
What are the current trends and best practices in IIoT adoption in developed countries, and how can IIoT technologies be applied to developing countries?	Analysing the influencing factors for IIoT adoption in developed countries and showing insights and guidelines for adopting IIoT for SMEs in developing countries.
How can the future policies be improved for IIoT adoption in manufacturing and production SMEs?	Proposing the IIoT adoption model based on the existing TOEI framework for future policy to increase efficiency, productivity and competitiveness for the manufacturing and production in SMEs.
How can policy-makers and stakeholders support the adoption and implementation of IIoT in manufacturing and production SMEs in developing countries?	Identifying the strategies and polices to support and encourage policy-makers and stakeholders to adopt IIoT technologies in an efficient way in manufacturing and production SMEs.

is used to add recent publications from 2020 to 2023 by using the filtering tools in the databases. Overall, after using the quick search strategy, publications from 2015 to 2023 are considered.

4.3 | Research questions

Table 3 lists the different research questions and their corresponding motivations.

4.4 | Study selection procedure

In the screening process, duplicate studies have been removed at the first stage. After that, exclusion criteria have been applied based on the title, abstract and body of the research studies. The study selection process is shown in Figure 3.

A majority of papers are eliminated because their titles are unrelated to the selection criteria or their abstracts are unrelated to be included in this research study. As shown in Figure 3, the initial search resulted a total of 1880 studies, which are then narrowed down to 469 studies based on their titles and 234 studies based on their abstracts. Following that, 234 selected papers are extensively evaluated in order to obtain a final list of 101 research based on their substance.

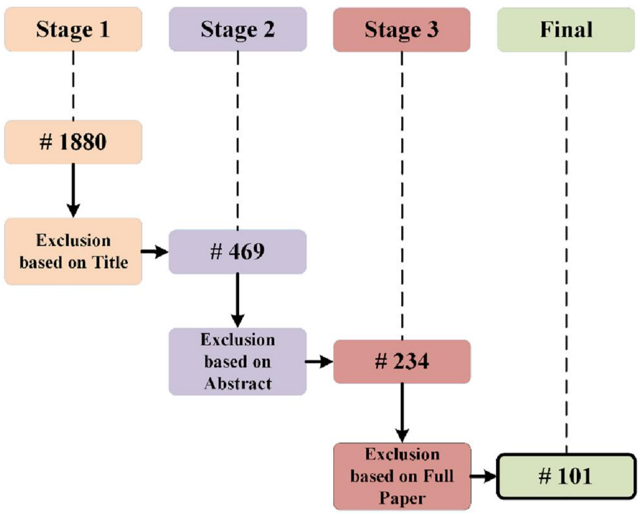

FIGURE 3 Study selection procedure.

4.5 | Studies inclusion/exclusion criteria

The inclusion and exclusion criteria are also applied on the bases that the study should focus on adopting new IIoT technology for the manufacturing and production SMEs, it is written in English, and it is published in well-recognised journals and conferences. Moreover, content analysis is performed to categorise the influencing factors and a comprehensive list of IIoT adoption influencing factors for the manufacturing and production SMEs is compiled as shown in Table 4.

5 | EXPLORING THE EXISTING TECHNICAL STUDIES ON IIoT ADOPTION FOR THE MANUFACTURING AND PRODUCTION SMEs

In this section, the existing technical studies are explored for IIoT adoption in manufacturing and production SMEs that are addressed by existing researchers. The details of all existing studies are presented in Table 5, along with the references, objectives, methodology, limitation, achievements, data collection and country. Recent academic literature shows a gap in IIoT adoption for production and manufacturing environments in developing countries. In the current research, factors such as individual, organisational, and environmental need to be paid intention to during the adoption of advanced technologies; however, most of the studies focus solely on technological factors. Consequently, the researchers feel that there is a robust necessity for SMEs in developing countries to move towards the adoption of IIoT for obtaining enhanced prospects.

Peter et al. [40] combine an expert review and literature review based on a qualitative research approach to discover the

TABLE 4 Studies inclusion/exclusion criteria.

Inclusion criteria	Exclusion criteria
The study focuses on manufacturing or production SMEs.	The study focuses on other SME categories like logistics, education etc.
The study considers the industrial IoT for the manufacturing or production SMEs.	The study does not consider the industrial IoT for manufacturing or production SMEs
The study emphasises on manufacturing or production SMEs in the context of IR 4.0 and IR 5.0.	The study does not emphasis manufacturing or production SMEs in the context of IR 4.0 and IR 5.0.
The study is written in English only.	The study is not written in the English language.
The study is peer-reviewed and published in scholarly society.	The study is not peer reviewed such as workshops, descriptions and technical reports.
The study is published in well-reputed journals or conferences.	The study is not published in the form of books, abstracts, editorials or keynotes.

TABLE 5 Existing technical studies of IIoT adoption in manufacturing and production SMEs.

References	Objectives	Theories/frameworks	Achievements	Limitations	Methods	Data collection methods	Countries
Peter et al. [40]	IIoT transformation Agenda	Not mentioned	Identify critical factors	Consider only IR4.0 as an industrial IoT. Also, focus on only technological factors	Qualitative	Interviews	South Africa
Mukherjee et al. [41]	IIoT adoption in SMEs	TOE, TOEH and SEM.	Identify adoption factors of IIoT in SMEs with respect to organisation	Focus only on improving SMEs' organisational performance with relatively small sample size	Quantitative	Survey based on questionnaire	India
Ghobakhloo and Ching [42]	Adoption of digital technology in manufacturing SMEs	TOE	Identify the factors that influence the adoption and implementation of SMIDT among manufacturing SMEs.	Limiting the generalisability of the findings to other contexts	Quantitative	Online survey based on questionnaire	Malaysia and Iran
Prisecaru [61]	IR 4.0 revolution based on Expert's opinions	Experts opinions, debated at Davos world economic forum	Provides an analysis of the main features of the IR 4.0 revolution, along with some estimations regarding its potential impact on the world economy	Certain limitations, such as dependence on opinions and interpretations, lack of empirical data, and uncertainty about implementation	Qualitative	Comparative analysis	USA, China Japan
George and George [43]	Implementation of IR 5.0 manufacturing industry	Secondary data	Improve the abilities of employees in order to achieve performance	Research carries out might not be conclusive until human-robot co-working conditions really exist	Qualitative	Secondary data	Global scope
Won and Park [44]	Smart factories for manufacturing SMEs.	TOE	Identify and examine the influencing factors	Future prediction for smart factories	Quantitative	Survey questionnaire	Korea
Kumar et al. [46]	Adoption of digital manufacturing.	e F-DEMATEL approach	Identify and evaluate the social acceptability dimensions	Focus only on acceptability	Quantitative	Survey questionnaire	India
Yang et al. [45]	Adoption of information and digital technology	q-ROF-MEREC-RS-DNMA and q-ROF-DNMA	Develop a framework for sustainable SMMEs	Focus only on sustainability	Quantitative	Interviews with industry experts and survey	China
Doyle and Cosgrove [47]	Digital manufacturing on SMEs.	BEinCPPS architecture	Implementation of cyber-physical systems (CPS) in SMEs	Focus on a single precision engineering.	Quantitative	Implementation	Ireland
Wong et al. [48]	Blockchain technology for supply chain and operation management among SMEs	TOE	Identifies and analyses the factors	Focus only on SMEs in the Klang Valley region	Quantitative	Questionnaire	Malaysia
Mittal et al. [49]	Adoption of smart manufacturing	Structural model	Identifies and analyses the factors	Focus only on two factors	Quantitative	Interviews	India

TABLE 5 (Continued)

References	Objectives	Theories/frameworks	Achievements	Limitations	Methods	Data collection methods	Countries
Marcon et al. [50]	Adoption of IR 4.0 with sociotechnical components.	European manufacturing survey (EMS)	Identify the organisational factors	Focus only on sociotechnical subsystems.	Quantitative	Questionnaire	Denmark
Beliatis et al. [51]	IIoT digitalisation	Digital maturity assessment tool	Identify the digital traceability technology positive and negative attributes.	Do not provide an in-depth review of alternative potential digital traceability solutions, nor does it address implementation challenges	Qualitative	Literature review, analysis of existing technologies	Denmark
Sanusi et al. [52]	Smart manufacturing adoption.	Not mentioned	Highlights the importance of identifying needs in the production process and leveraging new technologies to overcome challenges	Focus on only two SMEs in South Sulawesi, which may not be representative of all SMEs in Indonesia	Qualitative	Interviews	Indonesia
Trakadas et al. [53]	AI-based collaboration in IIoT production	Reference architectural model for IR 4.0 (RAMI 4.0)	Design an AI-friendly manufacturing system architecture	Do not compare with existing algorithms	Quantitative	Not mentioned	Global scope
Jung et al. [54]	Adoption of smart factories	Not mentioned	Investigate the factors impacting smart factory adoption in Korean manufacturing SMEs	Focus only on Korean manufacturing SMEs and ignores employees' perspective to consider to new technology	Quantitative	Survey	Korea
Çınar et al. [55]	Readiness and maturity of smart manufacturing enterprises:	Modular maturity model and framework	Identify the future gains and significant obstacles moving towards IR 4.0	Focus on prediction growth	Quantitative	Questionnaire	Not mentioned
Abdullah et al. [56]	Smart manufacturing	Decision making trial and evaluation laboratory (DEMATEL)	Investigate the factors affecting manufacturing strategy outputs (MSOs)	Do not provide empirical or case studies to validate the claims.	Qualitative	Survey	Saudi Arabia
Shrouf and Miragliotta [57]	Explore IoT-enabled energy-efficient production management.	IoT-based energy management framework	Facilitates comprehension of IoT-enabled energy-efficient production management	Lack quantitative results data, limiting generalisability. Framework testing and validation are recommended.	Qualitative	Not used	Italy and Spain
Arff et al. [58]	Digital twin in IIoT	Active Period method	Improve the production processes	The approach requires well-maintained shop-floor data.	Quantitative	Simulation	Germany

(Continues)

TABLE 5 (Continued)

References	Objectives	Theories/frameworks	Achievements	Limitations	Methods	Data collection methods	Countries
Seidel et al. [59]	Data mining for IIoT in electronics production	Data mining system based on SQL	Real-time tracking and storing in manufacturing execution system	Focus only on the database	Quantitative	Simulation	Germany
Cao et al. [60]	Traceability system for IIoT based on blockchain	Alliance chain model	Enhance the traceability, transparency and data security	Focus only on steel	Quantitative	Maple Calculation software	China and USA

Abbreviations: BEinCPPS, Business Experiments in Cyber-Physical Production Systems; DEMATEL, DEcision MAking Trial and Evaluation Laboratory; RAMI4.0, Reference Architecture Model Industry 4.0; SEM, Structure Equation Model; TOE, Technology Organisation Environment; TOEI, Technology Organisation Environment Individuals.

latest advancement in emerging technologies for the manufacturing transformation in emerging economics. The influencing factors are identified for the adoption of IIoT and digital capabilities in emerging economics such as Morocco, Nigeria and South Africa. Also, the study contributes to the current literature on the applications, performances and IIoT prospects to drive the future manufacturing. Similarly, Mukherjee et al. [41] investigate the adoption of IIoT in SMEs to enhance organisational performance. A questionnaire is designed and a survey on SMEs based on TOE and human perspectives is conducted in India. Mukherjee et al. [41] suggest that adopting IIoT in SMEs can help in the growth of organisational performance. Eight out of 12 hypotheses are supported, and the highlighted factors are compatibility, competitive pressure, innovativeness, organisational performance, relative advantage, technical capability, top management support and trust. The study also provides implications for managers, top management and policymakers in identifying areas to improve technology adoption in SMEs. Finally, the research also acknowledges the limitations and suggests for future work to expand the research scope.

Moreover, Ghobakhloo and Ching [42] focus on the adoption and implementation of Smart Manufacturing Information and Digital Technologies (SMIDT) among SMEs in manufacturing. The study applies the TOE framework to identify the factors of SMIDT adoption within SMEs. Data is collected through a survey of manufacturing SMEs in Malaysia and Iran. The results indicate that factors such as perceived value, costs, compatibility, information processing requirements, IDT knowledge competency, manufacturing digitalisation and environmental imposition affect the adoption of SMIDT among SMEs. The findings show the implications for SMEs, policymakers and researchers in understanding the factors that drive SMIDT adoption and implementation in the context of smart manufacturing. Furthermore, Ghobakhloo and Ching [42] suggest that SMEs need to develop digitalisation strategies and consider the compatibility of SMIDT with the organisational goals.

The anticipated advancements in manufacturing industry are due to IR 5.0. It is focused on enabling humans and machines to work together and create an innovative culture in the workforce. It introduces customer satisfaction by enabling customisation and provides a new market for companies. The study discusses the objectives, the methodology followed, the advantages of IR 5.0, the potential employment opportunities created as well as the new roles of the HR and IT departments. Ultimately, it is expected that IR 5.0 will increase global incomes, enhance the quality of life and promote social transformation [43]. On the other hand, Won and Park [44] investigates the factors and impacts of the adoption of smart factory in Korean manufacturing SMEs. The determinants of smart factory adoption intentions and execution in SMEs are helpful for executives and policymakers. Furthermore, the role of information technologies in boosting manufacturing productivity are also emphasised, as well as the impact of the IR 4.0 in manufacturing SMEs. It highlights the significance of the manufacturing industry in the Korean economy and the necessity to improve manufacturing competitiveness through the deployment of smart factories. According to the findings, organisational support, information capabilities and previous experience benefiting from information technology are the significant indicators of smart factory adoption. However, factors such as IT staff size and government certification, which were predicted to have an impact, had no effect on adoption intention. It emphasises the value of prior expertise with information systems and the need for management to consider the transformation of existing IT operational resources. Lastly, the study emphasises the significance of qualitative performance rather than quantitative expansion in policy support for smart factories for policymakers.

Next, the application of IDTs for long-term smart manufacturing systems in Small, Medium and Micro businesses (SMMEs) in the framework of IR 4.0 is discussed. The study proposes q-ROF-MEREC-RS-DNMA, an integrated decision-making framework that integrates several methodologies to rank and evaluate the main factors for IDT adoption in SMMEs. It emphasises the significance of digitisation in manufacturing sector, as well as the necessity for comprehensive frameworks to facilitate the implementation of smart manufacturing systems in SMMEs. Furthermore, the q-ROF-DNMA model is applied for examining the industry preferences over many criteria. The findings highlight the importance of parameters such as infrastructure cost, software engineering abilities, information sharing, employee inventiveness and legal compatibility. In addition, it indicates that combining the q-ROF-MEREC-RS and q-ROF-DNMA methodologies provides a reliable and flexible decision-making approach in IDT adoption for a sustainable smart manufacturing system [45]. However, Kumar et al. [46] examine the societal acceptability of IR 4.0 technology within the framework of DM, as well as to identify and prioritise social factors related to IR 4.0 adoption for assisting growth. To determine the social elements, the researchers conducted a thorough literature analysis and collected data from 121 respondents in Indian manufacturing SMEs. The dimensions are classified using exploratory factor analysis into seven categories including the behavioural, compliance, cultural, employee, market, psychological and safety. To analyse the interrelationships and prioritise the dimensions, the fuzzy decision-making trial and evaluation laboratory technique (F-DEMATEL) is applied. According to the survey findings, the most critical dimensions are security breaches, followed by data theft. Finally, the impact of IR 4.0 on social and personal behaviour are discussed, as well as offering insights for decision-makers and industry practitioners that are interested in developing a DM environment.

Additionally, Doyle and Cosgrove [47] provide a case study of an Irish manufacturing SME that digitised production operations as part of the IR 4.0 strategy and determine the advantages of taking small steps towards digitisation and integrating data from the shop floor into a single repository. MT Connect, IoT devices and open-source software components from the Business Experiments in Cyber-Physical Production Systems (BEinCPPS) architecture are employed in the project. The results demonstrate an increased operator reporting, production scheduling and overall equipment effectiveness. The initiative enables the SME to collect real-time production data, improve delivery dates and increase customer satisfaction. Additionally, the project highlights the possibilities of digitisation for SMEs and set the path for additional organisational transformations. The findings emphasise the significance of digital integration in enhancing operations and harnessing data for better decision-making in the manufacturing industry. On the other hand, Wong et al. [48] focus on the implementation of blockchain technology in Malaysian SMEs for supply chain and operations management. The TOE framework is used to explore the influencing factors of blockchain adoption including the complexity, cost, competitive pressure, market dynamics, relative advantage, regulatory support and top management support. A non-linear non-compensatory PLS-ANN technique is used to analyse data from 194 SMEs in Malaysia's Klang Valley region. The findings show that competitive pressure, complexity, cost and relative advantage all have a substantial impact on the desire for blockchain. Market dynamics, regulatory support and senior management support are found to be unimportant predictors. Furthermore, the findings imply that SMEs should examine the benefits of blockchain, handle the difficulty associated with its deployment, and control the costs connected with it in order to leverage its benefits for long-term growth.

A smart manufacturing adoption framework is developed specifically for SMEs to understand the needs and challenges of manufacturing SMEs. The study employs a multiple case study approach and proposes a five-step SM adoption framework for SMEs that includes identifying manufacturing data, assessing SM readiness, developing SM awareness, creating a smart manufacturing-tailored vision, and identifying appropriate SM tools and practices. The findings underline the significance of data analytics, raising SM awareness and matching the smart manufacturing vision with the specific needs of SMEs. Furthermore, the study discovers that implementing the smart manufacturing paradigm can give SMEs a competitive advantage and suggests workshops and training sessions to raise awareness among SME owners/managers. The study also declares its limits and advises future work that applies on the paradigm to a broader range of SMEs, and takes socio-cultural and political variables into account in smart manufacturing adoption [49]. Similarly, Marcon et al. [50] investigate the influence of organisational factors in IR 4.0 technology adoption. The study examines the evolution of sociotechnical dimensions (social, technical, work organisation, and environmental factors) and their impact on the level of IR 4.0 adoption using a sample of 231 manufacturing enterprises in Denmark. According to the data, companies that prioritise sociotechnical factors have higher levels of IR 4.0 deployment. However, not all sociotechnical components are equally important. Furthermore, from a systemic organisational perspective, the study presents empirical evidence and managerial guidance for planning the use of sophisticated technology. The findings emphasise the significance of taking into account social and organisational components, integrating people and aligning the business environment with technology adoption efforts.

Furthermore, Beliatis et al. [51] investigate the use of digital traceability technology in the production cycles of GPV Group, an electronics manufacturing service provider. The goal is to improve product traceability and manufacturing process efficiency in order to meet the IR 4.0 standards. The study examines and analyses several IoT technologies' suitability for product traceability in the metal production industry. After a thorough evaluation, the study concludes that LPWAN technology, particularly Sigfox, is better suited to the needs of GPV. Implementing digital traceability allows for real-time product tracking, optimisation of manufacturing processes, waste reduction and better logistics planning. It also improves production transparency, increases consumer understanding and contributes to GPV's overall digital transformation. In addition, the study proposes an implementation roadmap, emphasising the need for a step-by-step approach and the need to foster a digitalisation culture inside the organisation. According to Beliatis et al. [51], the deployment of digital traceability technology helps GPV's shop floor operations and serves as a platform for future digitalisation efforts. On the other hand, Sanusi et al. [52] investigate the challenges SMEs encounter while implementing smart manufacturing and look at two case studies of SMEs in the region. The study discusses two case studies. In the first case study, upon recognising the growing demand for their products, the owner decided to invest in technology tools to improve their manufacturing process. Consequently, the owner is able to greatly enhance productivity, fulfil market demand and minimise labour costs by implementing automation and modernising their machines. However, in the second case study, the proprietors recognise the value of exact time measurement and accuracy in their manufacturing process. To boost efficiency, they integrated people and machinery, particularly in the combining ingredients division. The utilisation of cutting-edge technology tools and sophisticated ovens increases product quality and uniformity, resulting in higher consumer acceptance. Additionally, in both case studies, they face challenges such as limited resources, talent and capital as well as technical constraints and coordination issues. The case study report advises that stakeholders such as the government, industry organisations, SMEs and research institutions work together to tackle these obstacles and get the full benefits of smart manufacturing. Indeed, SMEs must adopt digital technologies, standardise processes and make use of internet networks.

Similarly, Trakadas et al. [53] elaborate the collaboration in industrial IoT production with AI. The study suggests the integration of AI in its entirety and proposes for RAMI 4.0 architectural extensions. RAMI 4.0 enhancements include a human-in-the-loop layer for AI-human collaboration and a federation layer for information exchange across production facilities. The study emphasises security and interoperability in manufacturing AI systems. Cloud-native tools for data collecting, processing, and curation address security and privacy concerns in the proposed architectural approach. The study explores zero-defect and logistics optimisation applications. Indeed, AI-enabled manufacturing has potential benefits, and the research suggests topics for further research. Moreover, Jung et al. [54] focus on smart factory transformation adoption in Korean manufacturing SMEs. The study investigates the elements that influence SMEs' intentions for adopting smart factories and gives insights for practitioners looking to transition traditional manufacturing systems into smart factories. The study employs a structural equation modelling to evaluate the data from 1,067 Korean manufacturing SMEs. The findings imply that existing production systems' performance enhances the predicted benefits of smart production systems; thus, encouraging SMEs for adopting smart factories. Top management support for information systems does not affect smart production system benefits, according to the study. In-house production system development increases smart factory adoption while outsourcing affects SMEs' smart factory adoption.

Additionally, Çınar et al. [55] propose the IR 4.0 adoption in smart manufacturing organisations and a complete MM and framework coupled with technology forecasting to analyse and anticipate IR 4.0 growth. The study analyses the current MM and framework, and creates a modular MM with four dimensions, five levels, and several sub-dimensions, as well as a generic framework with four layers and seven hierarchy levels. A case study of an auto parts company obtains a maturity score of 2.73 out of five and is anticipated to completely integrate IR 4.0 between 2031 and 2034 using the indicated models. The study helps businesses and advances IR 4.0 adoption research. Also, the study uses the provided models in different sectors and areas, combines multiple maturity models to create more accurate forecasts and investigates additional technology forecasting approaches. Furthermore, Abdullah et al. [56] focus on Manufacturing Strategy Outputs (MSOs) that are affected by the use of IR 4.0 in manufacturing businesses. The fuzzy Decision making trial and evaluation laboratory (DEMATEL) method is used to look at the factors that affect MSOs. Furthermore, the study shows that MSOs find cost, quality and performance as most important. Flexibility, creativity, and success are seen as the important factors that cause it, while cost, quality and delivery are seen as the important factors that affect it. The study shows the importance to maintain a competitive edge in manufacturing by taking these factors into account. However, it has some flaws and offers future directions for empirical studies and the combination of different ways to make decisions to help us learn more about MSOs in the context of IR 4.0.

Next, energy management in production through the use of IoT technology is addressed by Shrouf and Miragliotta [57]. The study shows that energy-efficient manufacturing processes are becoming more and more important because of rising energy prices, growing environmental awareness and changing customer habits. The IoT paradigm suggests ways to improve energy management by giving real-time data and energy is being used through smart sensors and metres. The concept of digital twins is used to improve processes in the IIoT for the analysis of the life cycle of a product and its production system, with a focus on industrial layouts and their parameters. The Active Period method uses a cutting-edge way of finding bottlenecks to intelligently represent the temporal process characteristics. The results of the analysis are mixed with machine learning and eXplainable Artificial Intelligence to make a Decision Tree (DT). The study also discusses the idea of a self-learning DT and the use of it. In the future, it is planned to turn this DT into a self-learning and flexible DT that will simulate and optimise dynamic processes [58].

Data collection and Machine Learning are used in industrial applications, particularly electronics production. A data mining architecture is developed for real-time process data tracking and structured storage. The data mining solution supports manufacturing execution systems material tracking and ML real-time prediction use cases in production. Non-standardised machine vendor protocols produce large data quantities and inhomogeneous data supply. Moreover, the data mining solution allows homogenous data collection, organised storage and ML model exploitation for cross-vendor machine shop floors. ML is used to optimise productivity and efficiency, especially in brownfield settings [59]. Similarly, a traceability system for IIoT based on blockchain is developed to address steel industry information security and product traceability issues. Leveraging blockchain technology and IIoT are recommended to solve the traceability process's low transparency and information islands. Furthermore, blockchain technology for information traceability, stressing its distributed storage architecture, cryptography, consensus algorithms and smart contracts are discussed. Blockchain in IoT platforms ensures authenticity, usability, integrity and information security. Finally, the conclusion suggests that building and implementing a steel product quality traceability system are essential for supply chain quality and safety. The blockchain-based IIoT system allows producers, logistics and consumers to certify and trace the steel items, while allowing consumers to track the steel product quality and production transparency. Indeed, the method effectively promotes steel industry reform and upgrading [60].

Table 4 elaborates the existing technical studies of IIoT adoption in manufacturing and production SMEs in developed and developing countries. After reviewing and analysing the existing technical studies, we have noticed that most of the researchers focused on digital transformation, IoT adoption, Smart and DM, AI-based collaboration, IIoT digitalisation and Smart factories instead of the adoption of IIoT in manufacturing and production SMEs. DEMATEL, BEinCPPS, European manufacturing survey, RAMI4.0, TOE, TOEH and SEM models are used for the adoption of new technologies for the manufacturing and production SMEs. Both methods of research (Qualitative and Quantitative) are used with the help of interviews and online surveys in developing countries including South Africa, India, Malaysia, Iran, Denmark, Indonesia, Saudi Arabia, Italy and Spain.

6 | CLASSIFICATION OF IIoT ADOPTION INFLUENCING FACTORS FOR THE MANUFACTURING AND PRODUCTION SMEs

The success and growth of SMEs depend on individual performance in an organisation, with technological adoption in the environment. In order to achieve the success and growth with improved efficiency, increase productivity and competitiveness, we have proposed an IIoT adoption model for the manufacturing and production SMEs based on TOEI framework. This model contains forty-seven (47) influencing factors for the successful adoption of IIoT in manufacturing and production SMEs. These influencing factors are then classified into four groups: individual, organisational, technological and environmental factors as shown in Figure 4, in order to properly manage and assess IIoT adoption in manufacturing and production SMEs. The identified influencing factors based on TOEI model are further explained in detail in Tables 6–10.

6.1 | Individual factors

Individual factors refer to personal attributes, such as knowledge, skills, attitudes, values and preferences that influence the behaviour of individuals including the employees (who are hired to perform specific tasks or duties) and clients (who receives the products or services from professional companies) in manufacturing and production SMEs. In order to adopt IIoT in SMEs smoothly, individuals must have the ability to adopt themselves to new technologies and must accept changes and new ideas. Moreover, it is essential for the individuals to have the necessary knowledge and skills to effectively utilise and adapt to emerging technologies in manufacturing and production SMEs. Individuals must also adhere to safety protocols to ensure a secure work environment. Trust and reliability are fundamental aspects of the use of IIoT technologies and its adaptability in manufacturing and production SMEs, while supporting SMEs collaboration and establishing a sense of dependability within the SMEs.

6.2 | Organisational factors

Organisational factors in manufacturing and production SMEs refer to the key factors, such as cost, growth rate, compatibility, information sharing and practices that significantly influence the efficiency, productivity and overall performance of SMEs. These factors shape the internal structure and functioning of the SMEs of the organisation. In order to allow successful adoption of IIoT in manufacturing and production SMEs, it is essential to consider these organisational factors effectively. By addressing the organisational influencing factors proactively, manufacturing and production SMEs can position themselves for a seamless and successful adoption of IIoT to get the benefits of improved efficiency, enhanced productivity and competitive edge in the industries.

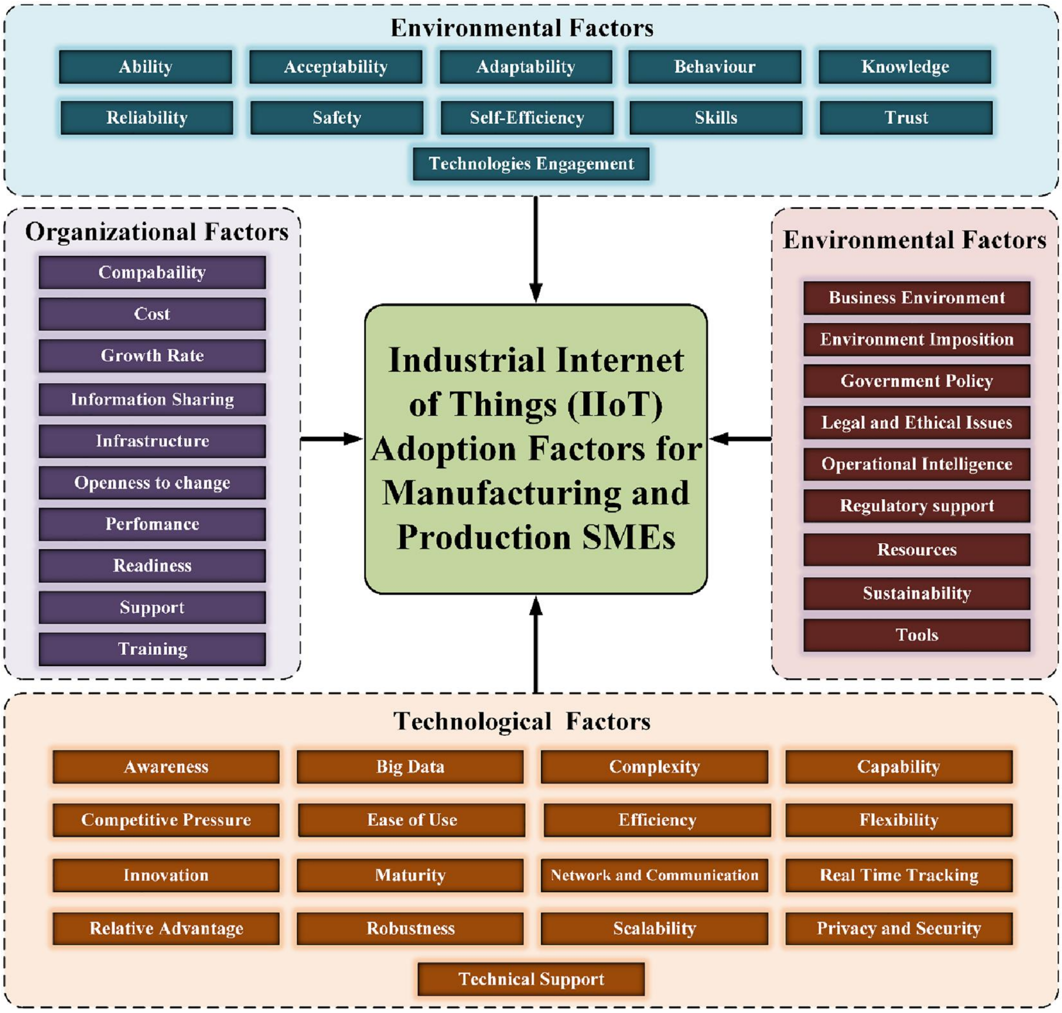

FIGURE 4 Industrial IoT (IIoT) model based on influencing factors for the manufacturing and production SMEs.

6.3 | Technological factors

Technological factors are important aspects based on smart devices and tools that determine the successful integration and implementation of IIoT technologies within SMEs' operations. These influencing factors include various technological factors, such as big data, awareness, complexity, capability, competitive pressure and maturity that play an important role in enabling SMEs to harness the potential of IIoT for improving efficiency and competitiveness. For SMEs to adopt IIoT successfully, there is a need to address some of the influencing technological factors. By scientifically addressing these technological factors, manufacturing and production SMEs can prepare themselves for successful adoption of IIoT; hence, unlocking its potential to drive efficiency, productivity and competitiveness in SMEs' operations.

6.4 | Environmental factors

Environment factor refers to the factors that influence SMEs (companies and factories) functions and performance. These influencing factors include business environment, government policy, legal and ethical issues, regulatory support, operational intelligence, resources, sustainability, imposition by the environment and tools. In order to successfully adopt the IIoT in manufacturing and production sector, SMEs need to consider these environmental influencing factors as they play the main role for SMEs to adopt IIoT. The environmental factors enable SMEs to thrive in dynamic and competitive business environments.

7 | COMPARATIVE ANALYSIS OF THE INFLUENCING FACTORS FOR THE ADOPTION OF IIoT IN MANUFACTURING AND PRODUCTION SMEs

In this section, we perform a comparative analysis of the forty-seven (47) influencing factors for the adoption of IIoT in the manufacturing and production SMEs. Adoption of IIoT technology has the potential to significantly improve operational efficiency, productivity and enable predictive

TABLE 6 Description of individual factors for IIoT adoption in manufacturing and production SMEs.

Individual Factors	Descriptions
Ability	Individual's ability is to do a job or task quickly and well by using their thinking and task competence ability. The employees' or clients' knowledge, skills and experience decide his or her ability to do tasks. If employees have the ability to understand, learn and use technology then SMEs are more likely to use IIoT in manufacturing and production [62, 63].
Acceptability	Acceptability is the level, where individuals are ready to accept new ideas, changes and technology. Acceptability affects SMEs in two ways: the use of IIoT technology and the need to fit in SMEs must be accepted by individuals. Acceptance of IIoT can be improved by giving enough money and individual's time [64].
Adaptability	Adaptability is the ability of an individual to change and adapt to new situations and tools in order to keep working well. SMEs must know about the lack of funds, technical adaptability and expertise as these are the factors that make it hard for businesses to adopt IIoT technologies without help from outside. So, SMEs need to come up with the right plans to make sure they can adapt to changes and use new technology with as little effort as possible [65].
Behaviour	Behaviour is individuals' act in different circumstances. Behaviour is the most important factor in determining whether IIoT technology will work or not. When SMEs use systems based on the IIoT, individual behaviour is very important. Employees must be open to the changes that technology brings with IIoT. There should be enough training and help for the employees to feel at ease with the IIoT technology and its usage [66].
Knowledge	Knowledge is a set of skills, abilities and facts that individuals learn in order to make choices and do tasks. When manufacturing and production are built on IIoT, it is very important to have the right knowledge about the technology itself and the steps that need to be taken to make sure that the use is successful. It is important to have employees who have the knowledge about the IIoT technology, means and usage. It will help SMEs to adopt IIoT in their production and manufacturing environment smoothly [67].
Technology engagement	Technology engagement is employee use and interactions with different kinds of technology to get a task done. It is very important for a successful adoption of IIoT-based technologies that employees are interested in technologies and it's use. In order to adopt IIoT smoothly the manufacturing and production SMEs should train the employees properly so that employees are comfortable with the new technology and use it to their advantage. Also, employees should be kept up to date on new developments in IIoT so that their information and skills are always up to date [68].
Safety	Individuals (employees/clients) use a certain technology without putting their health and well-being at risk is known as safety. IIoT-based systems are very useful, but their safety has been called into question sometimes because they have limited safety right measures in SMEs. In order to keep the individuals safe, who work with IIoT-based systems, SMEs need to make sure they have the right safety procedures and rules in working place. The SMEs that have IIoT based systems also need to train employees properly so that they follow the safety measures and procedures properly [69].
Self-efficiency	Self-efficiency is when individuals use IIoT based technologies for their benefits to perform tasks or do jobs accurately in an efficient way. Individuals must be able to use IIoT-based technologies efficiently for their own advantage first in order to make IIoT technologies to be widely used efficiently. It will help to improve the performance and lower the cost. So, SMEs must focus on the staff and employees to ensure they are using IIoT tools and technologies in an efficient way [63, 70].
Skills	Skills are the capabilities that are needed to use IIoT technologies in a perfect way by individuals. For IIoT-based systems to work efficiently in SMEs, the individuals using IIoT technologies need to know the uses of the desired technology. So, SMEs must focus on teaching and helping their employees to improve their skills for using the technology and understanding the problems associated with the IIoT technologies in SMEs [63, 71].
Trust	Trust is the sense of faith and dependability that individuals have in using new technologies. The individuals who use IIoT-based systems need to believe in and trust the IIoT technologies in order to work well in SMEs. The employees should also trust that their skills and knowledge will be put to good use in SMEs after the adoption of IIoT based technologies in manufacturing and production sectors [72].
Reliability	When it comes to IIoT-based systems, the reliability of the systems is important for successful adoption in SMEs. SMEs care about how reliable the system is because if it fails or breaks down, they will lose money [73].

maintenance in manufacturing and production SMEs. However, there are various factors that influence IIoT adoption in SMEs. In this section, an analysis of the influencing factors performed for the adoption of IIoT in manufacturing and production SMEs is presented in Table 10 and 11. The various influencing factors and their corresponding percentages are explored as shown in Figure 5, to understand the impact on the adoption of IIoT in manufacturing and production SMEs.

From Figure 5a, the adaptability factor accounts for 18.60% of the influencing factors. According to the researchers, the ability of SMEs to adapt current infrastructure and operations to accommodate IIoT influences adoption success. Furthermore, ability, safety and skills account for 13.95% of the influencing factors. According to the researchers, when SMEs have the infrastructure, resources and knowledge to adopt IIoT technologies, this has a significant impact on the adoption process. Self-efficiency, trust and reliability have the same percentage of 6.98% of the influencing factors. This shows that SMEs with strong self-efficacy show confidence, commitment and a proactive attitude towards IIoT adoption. The next factor is behaviour, which accounts for 4.65% of the influencing factors. According to the researchers, positive behaviours such as

TABLE 7 Description of organisational factors for IIoT adoption in manufacturing and production SMEs.

Organisational factors	Descriptions
Compatibility	Compatibility means current systems, processes, and infrastructure that work with IIoT technology. It includes the ways that IIoT solutions work with previous technologies and tools in manufacturing and production SMEs. SMEs easily add IIoT technologies to their operations when they are more compatible. It minimises delay and makes the most of the benefits of interoperability [74].
Cost	Cost covers the initial investment needed for implementation and adoption, the costs of keeping things running and the potential return on investment for the adoption of IIoT in manufacturing and production SMEs. SMEs need to figure out, if IIoT technology is worth the cost by looking at things like equipment upgrades, sensor installations, connectivity costs and cybersecurity investments. The cost includes financial constraints, investment in IIoT technology, profit, revenue, salaries and wages, property taxes, maintenance and repairs, and legal expenses in manufacturing and production SMEs [75].
Growth rate	The growth rate shows the business growth. It looks at IIoT solutions that are expanded to meet growing production rates, changing demand and changing market conditions. IIoT helps SMEs grow faster and more competitive by improving operational efficiency, giving real-time information and optimising processes [76].
Openness to change	Openness to change shows the willingness and capability of SMEs to use new tools, technologies and adoption methods. It shows SMEs thinking, acts and preparation for using IIoT technologies. Openness to change has a big impact on SMEs for the adoption of IIoT technologies. IIoT needs to transform on traditional practises, collaboration between stakeholders, and a proactive approach to innovation [77].
Information sharing	Information sharing is the ability of manufacturing and production SMEs to share data and ideas easily across different systems, departments and stakeholders. It includes to ensure that data flows between IIoT devices, platforms and enterprise systems in a safe and efficient way. Information sharing makes it easier for SMEs to have real-time visibility, work together and make decisions based on correct and up-to-date information. Better sharing of information leads to better production planning, inventory management, coordination of the supply chain and customer service [78].
Infrastructure	Infrastructure is the real and digital organisational structure that SMEs in manufacturing and production sectors need to use for the adoption of IIoT. It includes hardware, connection to network, cloud platforms, storage of data and security methods. Infrastructure is like a backbone for SMEs to set up, run and adopt IIoT technologies. SME can capture, handle and analyse the data more effectively when their infrastructure is strong and safe, which ensures the smooth adoption of IIoT in manufacturing and production SMEs [79].
Performance	Performance is an SME's ability to use and combine IIoT technologies and solutions into its manufacturing and production processes in an effective way. It includes operational efficiency, productivity, quality and reliability that is made by putting IIoT systems into SMEs. Performance has a direct effect on SMEs because it lets SMEs to optimise the processes, better use of the resources and increase the total output. By using IIoT technologies, SMEs track real-time data, get actionable insights and make better decisions based on the data that makes production more efficient and makes SMEs more competitive in the market [80].
Readiness	Readiness refers to whether manufacturing and production SMEs are ready to use and apply IIoT technologies and solutions. Readiness affects manufacturing and production SMEs because it affects their ability to successfully adopt IIoT systems; hence, taking advantage of their benefits. With a better level of readiness, SMEs can successfully overcome implementation and adoption problems, effectively integrate IIoT technologies and efficiently adopt IIoT. The SMEs that are well-prepared can more easily adopt IIoT devices, sensors and analytics platforms to their current infrastructure. This makes it easier for SMEs to collect, analyse and make decisions about data, which opens up new possibilities for growth and market expansion [81].
Support	Support means that an SME has access to the technical knowledge, advice and resources that are needed to set up and manage IIoT technologies. It includes help from technology suppliers, managers and experts from inside or outside the company. With the right help, SMEs can solve technical problems, deal with implementation issues and keep improving their IIoT solutions. Strong systems of support make it easier for SMEs to use IIoT in a way that works well and perfectly [82].
Training	Training refers to SME employee chances to learn new things and improve their skills so they are able to use IIoT technologies well and get the most out of them. It includes training programs, workshops and teaching materials that are meant to improve the digital literacy and technical skills of the employees. Well-trained employees are better able to comprehend and use IIoT technologies. Training helps SMEs get the most out of IIoT technologies by creating a culture of innovation and encouraging these employees to adapt to new IIoT technologies. It also helps SMEs to find and keep good employees because employees see the company cares about their professional growth [63, 83].

openness to innovation, teamwork and a culture of continuous improvement assist in a smooth adoption of IIoT in the manufacturing and production SMEs. Acceptability and technological engagement both account for 2.33% of the influencing factors. According to the researchers, participation in industry events, collaboration with technology suppliers and continuous education help SMEs to better understand and utilise IIoT. Lastly, knowledge accounts for 9.30% of the influencing factors. Well-informed employees, with the required skills and understanding of IIoT, promote successful IIoT adoption in manufacturing and production SMEs.

Among all the individual factors, adaptability, ability, safety, skills and knowledge are the factors that have the most influence on IIoT adoption for the manufacturing and production SMEs. SMEs with the flexibility to adjust their processes and infrastructure to support IIoT, as well as a competent workforce and a good understanding of IIoT concepts, are more likely to successfully adopt IIoT and utilise its benefits. These

TABLE 8 Description of technological factors for IIoT adoption in manufacturing and production SMEs.

Technological Factors	Descriptions
Awareness	Awareness is the level of understanding and knowledge that SMEs have pertaining the concept of IIoT technologies and its possible benefits. It means that IIoT is a transformative tool for the manufacturing and production SMEs. Awareness has a positive effect on SMEs by making informed decisions about adopting IIoT solutions. It helps understand the possible benefits such as greater efficiency, reduced costs and better competitiveness. Lack of awareness, on the other hand, can make it hard for SMEs to use IIoT because they may not fully understand the value proposition and may be afraid to invest in new technologies [84].
Big data	Big data refers to the large amounts of structured and unstructured data that IIoT devices and systems produce in manufacturing and production SMEs. It includes collecting, storing and analysing data to get useful insights that are used to make decisions. SMEs get a lot out of big data by using it for predictive maintenance, quality control, supply chain optimisation and tracking in real-time. It allows SMEs understand their business works and make decisions based on data. However, it is hard for SMEs to manage and analyse large amounts of data well when they do not have the right infrastructure, skills or funding [85].
Complexity	Complexity is the technical difficulty and challenges faced by SMEs when adopting IIoT in the manufacturing and production environment. It includes the integration of many different IIoT devices, networks and software systems as well as the need for competent individuals to manage and support the IIoT infrastructure. Complexity affects SMEs by making implementation, operation and maintenance difficult. If the complexity is too high, SMEs may not be able to adopt IIoT well in manufacturing and production sectors because they may have lack of technical knowledge and resources, their current processes may be interrupted [86].
Capability	Capability means technical and practical skills that SMEs need to adopt and use IIoT technologies well in the manufacturing and production sectors. It includes the skilled employees, infrastructure and tools that are needed to set up and run IIoT technologies. SMEs with strong capabilities are able to better use IIoT to improve their manufacturing and production processes [87].
Competitive pressure	Competitive pressure is the external forces and market dynamics that push SMEs to adopt IIoT in order to stay competitive in manufacturing and production sectors. This includes market trends, customer expectations, industry norms and the environment for competition. SMEs may feel pressured for adopting IIoT technologies to keep up with competitors, differentiate their offering or meet customer demands. SMEs are forced by competitors to invest in IIoT solutions in order to gain a competitive edge [88].
Maturity	Maturity is the amount of growth and readiness of IIoT technologies and solutions on the market. It includes the stability, reliability and track record of IIoT platforms. The maturity of IIoT affects SMEs in two ways. First, if IIoT technologies are mature and well-established then SMEs feel more secure and less hesitant to use them. Second, if IIoT technologies are still in the early stages of development and less mature then SMEs may be unwilling to accept them due to the unknowns and possible risks that come with new and untested technologies [89].
Ease of use	Ease of use refers to the friendly and simple use of IIoT technologies and interfaces for SMEs. It includes setsetting up, configuring, running and managing IIoT systems easily in SMEs. SMEs are more likely to use IIoT solutions if they are easy to use. As a result, so there is no need for a high level of trainings and they work well with the methods those that are already in use. Ease of use can make it easier for SMEs with limited technical skills and resources to adopt IIoT in manufacturing and production SMEs [90, 91].
Efficiency	Efficiency means that IIoT helps SMEs to optimise the manufacturing and production processes, cut down on waste and make better use of their resources. IIoT makes it possible to monitor, automate and improve things like inventory management, production scheduling and equipment utilisation in real time. By adopting IIoT technologies, SMEs streamline their processes, cut down on waste and make their businesses more efficient. Overall, better efficiency leads to lower costs, more output and better use of resources [92].
Flexibility	Flexibility refers to the level at which IIoT solutions can be changed easily and quickly to meet the specific needs and requirements of SMEs in manufacturing and production sectors. It means being able to grow up or go down, work with different devices and protocols, and connect to other systems. SMEs adopt flexible IIoT technologies to customise and fit the technology to their unique processes and needs. They easily add or remove devices, change settings and adapt to new business needs. Less flexible IIoT solution may not be a good fit for SMEs with different operating environments and needs [93].
Innovation	Innovation means the introduction of new ideas, concepts and technologies in the adoption of IIoT by manufacturing and production SMEs. It includes creating and deploying cutting-edge IIoT technologies that give SMEs new capabilities and benefits. Innovation drives IIoT adoption by giving SMEs the chance to make big improvements to their processes, products and services. Innovative IIoT solutions give SMEs new business models, income streams and competitive advantages [94].
Network and communication	Network and communication refer to when IIoT systems in manufacturing and production SMEs connect to each other and share info. It includes connecting devices, sensors and control systems through networks that are reliable and safe. Strong communication infrastructure lets individuals gather, send and work together on data in real time in manufacturing and production SMEs. For SMEs to successfully adopt IIoT, they need a strong network and good communication skills. It makes it easy to connect devices, share data between systems and watch and control things from a far location [95].

(Continues)

TABLE 8 (Continued)

Technological Factors	Descriptions
Real-time tracking	Real-time tracking means that IIoT systems can keep track of and observe assets, processes and operations in real-time. It involves collecting and analysing data in real-time to give SMEs up-to-date information on the state and performance of different parts of their manufacturing and production processes. Real-time tracking helps manufacturing and production SMEs make decisions ahead of time, act quickly, and be more flexible. SMEs can improve processes, find bottlenecks and deal with problems quickly with the help of real-time tracking [96].
Relative advantage	Relative advantage is how better and more beneficial IIoT adoption is seen to be compared to current practises or other technologies in SMEs. SMEs are more likely to use IIoT if they think it will give them a big edge, like saving money, increasing productivity, improving quality or making better decisions [97].
Robustness	Robustness refers to reliable, resilient, and tolerant IIoT systems in manufacturing and production settings of SMEs. It involves IIoT solutions that consistently work in various operating situations such as when the environment changes, when the network goes down or when hardware breaks. IIoT systems that are strong can handle problems and keep running without significant interruptions [98].
Scalability	Scalability means IIoT solutions can handle more data, device connections, and complicated systems as the needs of SMEs grow. It means being able to add and change IIoT systems without causing major problems. Scalable IIoT adoption in manufacturing and production sectors allows SMEs to add more devices, integrate new apps and handle bigger data sets as their operations grow [99].
Privacy and security	Privacy and security mean protecting sensitive data and preventing unauthorised entry, breaches, or misuse of information within IIoT systems in manufacturing and production SMEs. It includes keeping the IIoT systems under strong security measures, encryption, access controls and following privacy regulations. Privacy and security worries stop SMEs from adopting IIoT. To get SMEs to trust and believe in IIoT, strong privacy and security steps are a must [100].
Technical support	Technical support means that SMEs have access to help, knowledge and resources that support SMEs to set up, manage and fix IIoT systems within the manufacturing and production sectors. It includes getting help from documentation and training programs. SMEs need the right kind of technical help to overcome obstacles, solve problems, and get the most out of IIoT adoption. SMEs may be more likely to use IIoT if they have access to reliable technical help; that therefore, makes it possible to adopt IIoT in the manufacturing and production sectors [91, 101].

factors provide a solid foundation for adopting IIoT and achieving operational advantages. However, factors such as acceptability, behaviour, technologies engagement, self-efficiency, reliability and trust have less impact on IIoT adoption for the manufacturing and production SMEs. Although they still play a great role in shaping the adoption of IIoT, their percentages show that they have a comparatively smaller influence. Positive attitudes, openness to change and faith in IIoT technology and suppliers are more likely to be taken into consideration for SMEs to adopt IIoT confidently. However, issues in these areas might lead to resistance, dissatisfaction and uncertainty that will possibly hinder adoption progress.

From Figure 5b, organisational factors play a significant role in the adoption of IIoT by manufacturing and production SMEs to leverage their benefits. Cost is an important influencing factor that has an influence of 24.39% of all influencing factors. Based on the researchers' findings, significant implementation expenses, such as hardware, software and infrastructure are too expensive for resource-constrained manufacturing and production SMEs. In addition, performance contributes 21.95% of the influencing factors. According to the researchers' findings, IIoT adoption enables SMEs to improve productivity, quality and efficiency by providing real-time monitoring, predictive maintenance and process optimisation capabilities.

Infrastructure is the physical and technological base required for IIoT adoption in manufacturing and production SMEs, accounting for 17.07% of the influencing factors. As per the researchers' findings, a strong and dependable infrastructure is required for uninterrupted connectivity, data transfer and IIoT device integration for the adoption of IIoT technologies. Support, which accounts for 12.20% of the total influencing factors, emphasises the necessity of external assistance, such as technical support, direction and knowledge, in ensuring effective IIoT deployment. In addition, information sharing contributes 7.32% of the influencing factors. This highlights the necessity of data sharing and collaboration among stakeholders inside the manufacturing and production SMEs, as well as the broader supply chain. Based on the researchers' analysis, IIoT technologies provide real-time data collection and sharing; hence, resulting in increased visibility and collaboration in SMEs. Readiness and training have the same percentage of 4.88% in the adoption of IIoT. According to researchers, without proper training, SMEs may face opposition, skill gaps and lack of IIoT capabilities; consequently, leading to delays and poor use of IIoT technology. Compatibility, growth rate and openness to change are three key factors contributing 2.44% each to the total influencing factors for IIoT adoption in SMEs. As per researchers' findings, compatibility enables a smoother transition and minimises disruptions.

According to the organisational influencing factors analysis, certain factors have a larger influence on IIoT adoption for the manufacturing and production SMEs, while others have a comparatively lower influence. Cost, performance, information sharing, infrastructure and support are all important factors in

TABLE 9 Description of environmental factors for IIoT adoption in manufacturing and production SMEs.

Environmental factors	Descriptions
Business environment	Business environment is made up of all the outside things that affect manufacturing and production works. In the context of IIoT adoption by manufacturing and production SMEs, the business environment includes market competition, customer demands, technology advances and economic conditions, which affect SMEs by giving them chances to grow and innovate through the adoption of IIoT. SMEs are more likely to adopt IIoT technologies if the business market is good and there is a growing demand for connected products and services [102].
Government policies	Government policies have a big impact on SMEs adoption of IIoT in the manufacturing and production sectors. Policies include rules, incentives and other actions taken by the government to support and encourage the adoption of IIoT technologies in the manufacturing and production sector. Positive government policies include giving SMEs financial incentives, tax breaks and grants to adopt IIoT. On the other hand, unfavourable policies or a lack of government support can create barriers for SMEs, making it harder for them to adopt IIoT because of financial constraints or compliance problems [103].
Legal and ethical issues	Legal and ethical issues are all the legal and moral questions that come up when manufacturing and production SMEs adopt IIoT. To make sure that IIoT technologies are used in a responsible and ethical way, it is important to follow data protection rules, privacy regulations and intellectual property rights. If SMEs do not deal with these problems, they may face legal trouble and damage to their image. So, when adopting IIoT solutions, SMEs need to be careful about legal and ethical issues such as data collection surety and data storage as well as its usage should secure privacy rights [104].
Regulatory support	Regulatory support means that regulatory bodies have set up guidelines and standards to guide and govern IIoT adoption in manufacturing and production SMEs to adopt IIoT. With regulatory support, SMEs receive guidelines, best practices and certifications to make sure that IIoT technologies are adopted in a safe and effective way. This helps SMEs solve problems with interoperability, security and managing data. SMEs may be less likely to use IIoT if there is less governmental support or if the rules are unclear. These reasons may be the cause of uncertainty and reluctance to use IIoT technologies [48].
Operational intelligence	Operational intelligence is the ability of SMEs to collect, analyse and use real-time data for improving operating efficiency, productivity and decision-making to adopt IIoT. IIoT makes it possible to collect a vast amount of data from different devices, sensors and machines, which gives SMEs useful information about how their businesses work. With the help of operational intelligence SMEs improve their manufacturing and production capabilities by optimising processes, finding abnormalities and making decisions based on data [105].
Resources	Resources include money, technology and individuals that SMEs have access to in adopting IIoT. Investing in IIoT infrastructure, hardware, software and training requires enough money. Technological tools include reliable internet connections, compatible devices, and systems that support IIoT adoption in manufacturing and production SMEs. Human resources are the skills and knowledge that are needed to create, manage and support IIoT adoption [106].
Sustainability	Sustainability means that a system, process or SMEs lasts and grows over time while having as few bad effects as possible on the environment, society and economy. Sustainability factors include energy efficiency, waste reduction, resource optimisation and responsibility for the environment when it comes to the adoption of the IIoT by manufacturing and production SMEs. By using IIoT technologies, SMEs improve their operational performance, use less energy, make the best use of their resources and make their manufacturing more environmentally friendly. This leads to cost savings, compliance with rules, a better image for the SMEs and a smaller impact on the environment. However, putting IIoT into place may require investments up front and changes to how things are done now. This can be hard for SMEs with limited resources and resistance to change [107].
Imposition by the environment	Imposition refers to the environmental, health and safety rules that SMEs have to follow when adopting IIoT. SMEs use IIoT technologies to meet certain environmental requirements such as lowering carbon pollution, improving air quality, or using less hazardous materials. SMEs that want to follow the law, avoid fines and stay competitive in the market are more likely to adopt IIoT technologies [108].
Tools	Tools are technological methods, hardware, software and supporting systems that are needed to set up and adopt IIoT in manufacturing and production SMEs. Tools include sensors, actuators, devices that connect to the internet, data analytics platforms, cloud computer resources and security solutions. Tools that are available and easy to use are a key part of SMEs being able to adopt IIoT properly. With the right tools, SMEs can collect, analyse and use data from their operations. This helps SMEs make better decisions, be more productive and make better use of their resources. However, the complexity and cost of buying, deploying, and maintaining these tools can be hard for SMEs that have less money, technical knowledge or IT infrastructure [91, 109].

IIoT adoption. However, factors such as compatibility, growth rate, openness to change, readiness and training have a comparatively lower influence on IIoT adoption for the manufacturing and production SMEs. Though these factors have a lower influence, they still play a high role in shaping the adoption of IIoT in manufacturing and production SMEs.

From Figure 5c, technological factors also play an important role in the adoption of IIoT by manufacturing and production SMEs. Efficiency contributes a significant percentage, with 12.66% based on existing studies. According to the researchers, by integrating sensors, devices and connectivity, IIoT enables real-time data collection, analysis and automation. This results in enhanced efficiency across various aspects of manufacturing and production SMEs. Finally, capability contributes 11.39% of the influencing factors. Capability refers to SME's technical knowledge and capacity to

TABLE 10 Individual and organisational influencing factors for the manufacturing and production SMEs.

	Individual factors											Organisational factors									
	Employees/clients											Small and medium enterprises									
References	Ability	Acceptability	Adaptability	Behaviour	Knowledge	Technologies engagement	Safety	Self-efficiency/	Skills	Trust	Reliability	Compatibility	Cost	Growth rate	Openness to change	Information sharing	Infrastructure	Performance	Readiness	Support	Training
Mukherjee et al. [41]								✓		✓		✓					✓	✓	✓	✓	
Javaid et al. [22]							✓	✓									✓				
Wiboonchutikula [110]												✓		✓							✓
Ayyagari et al. [111]													✓	✓							
Ghobakhloo and Ching [42]					✓							✓	✓			✓					
Prisecaru [61]													✓								
Jaloudi [29]													✓								
Khan et al. [30]										✓											
Younan et al. [28]			✓		✓																
George and George [43]	✓		✓										✓								
Won and Park [44]																		✓		✓	
Kumar et al. [46]		✓												✓							
Yang et al. [45]									✓							✓					
Doyle and Cosgrove [47]	✓																				
Wong et al. [48]				✓									✓							✓	
Mittal et al. [23]			✓		✓												✓				
Kamble et al. [27]							✓									✓		✓			
Ashima et al. [25]											✓										
Marcon et al. [50]			✓						✓				✓								✓
Ghobakhloo [26]					✓										✓					✓	
Mittal et al. [49]			✓						✓												✓
Sira [32]			✓				✓		✓		✓		✓				✓				
Thoben et al. [24]							✓		✓												
Beliatis et al. [51]						✓							✓								✓
Sanusi et al. [52]	✓																✓		✓		
Trakadas et al. [53]	✓									✓											
Jung et al. [54]	✓																	✓		✓	

TABLE 10 (Continued)

	Individual factors											Organisational factors									
	Employees/clients											Small and medium enterprises									
References	Ability	Acceptability	Adaptability	Behaviour	Knowledge	Technologies engagement	Safety	Self-efficiency/	Skills	Trust	Reliability	Compatibility	Cost	Growth rate	Openness to change	Information sharing	Infrastructure	Performance	Readiness	Support	Training
Çınar et al. [55]									✓				✓				✓				
Abdullah et al. [56]																		✓			
Bueno et al. [21]	✓		✓								✓							✓			
Shrouf and Miragliotta [57]				✓									✓								
Saravanan et al. [14]							✓						✓					✓			
Arf et al. [58]			✓	✓				✓										✓			
Seidel et al. [59]																	✓				
Cao et al. [60]							✓														

adopt and integrate IIoT technology into their present operations.

Real-time tracking as well as privacy and security are factors that contribute equally at 10.33% to the adoption of IIoT in manufacturing and production SMEs. According to the researchers, real-time tracking enables SMEs to have real-time visibility of their operations, to facilitate better decision-making, to enable proactive monitoring and to allow efficient resource allocation. Big data, flexibility, network and communication contribute the same percentage; each accounting for 8.86% of the influencing factors. As per researchers' findings, Big Data plays a significant role as SMEs leverage the vast amount of data generated by IIoT technologies to improve decision-making, enhance operational efficiency and enable predictive maintenance. Innovation carries 7.59% of the influencing factors. According to the researchers, SMEs that prioritise innovation are more likely to adopt IIoT, which offers the opportunity for product and service differentiation, greater customer experiences and increased competitiveness.

Another influencing element for IIoT adoption in manufacturing SMEs is competitive pressure, which accounts for 6.33%. Researchers have emphasised the importance of competitive pressure as a motivator for SMEs to invest in IIoT adoption for manufacturing and production. In addition, awareness accounts for 5.06% of the influencing factors. According to the researchers, it is important to raise awareness among SMEs in order to overcome the initial uncertainties and unwillingness in adopting new technologies. Another technological impacting factor is complexity, which accounts for 2.53% of the total percentage. According to the researchers, the adoption of IIoT requires an in-depth understanding of multiple technologies, protocols and standards. It is found that SMEs encounter difficulties in choosing the correct IIoT solutions, configuring and customising them to their individual needs, and guaranteeing interoperability with current systems.

Factors namely maturity, ease of use, relative advantage, robustness, scalability and technical support all have the same percentage, each with 1.27% of the influencing factors. According to the researchers' findings, Maturity reflects the level of confidence and the presence of a strong ecosystem; hence, establishing best practices in mature IIoT systems for the manufacturing and production SMEs. Similarly, Relative advantage highlights the benefits and advantages SMEs perceive when adopting IIoT compared to the existing systems or practices. As per researchers' findings, robustness ensures the reliability, resilience and durability of IIoT systems; therefore, minimising disruptions, reducing downtime and maintaining consistent productivity levels. Scalability allows SMEs to accommodate growth and adapt to changing needs, avoiding technological limitations and optimising resource allocation. Lastly, according to the researchers' findings, technical support also plays an important role by providing assistance, guidance and expertise during the adoption and implementation of IIoT in manufacturing and production SMEs.

According to the analysis of technological influencing factors for the adoption of IIoT in manufacturing and production SMEs, factors such as efficiency, capability, real-time

TABLE 11 Technological and environmental influencing factors for the manufacturing and production SMEs.

	Technological factors												
	Smart devices/tools												
References	Awareness	Big data	Complexity	Capability	Competitive pressure	Maturity	Ease of use	Efficiency	Flexibility	Innovation	Network and communication	Real time tracking	Relative advantage
Peter et al. [40]											✓		
Mukherjee et al. [41]				✓	✓								✓
Majstorovic et al. [31]													
Javaid et al. [22]												✓	
Wiboonchutikula [110]								✓					
Ayyagari et al. [111]													
Ghobakhloo and Ching [42]					✓								
Jaloudi [29]		✓									✓		
Khan et al. [30]			✓					✓	✓				
Younan et al. [28]											✓	✓	
George and George [43]				✓						✓			
Won and Park [44]				✓				✓					
Kumar et al. [46]													
Yang et al. [45]										✓			
Doyle and Cosgrove [47]								✓			✓	✓	
Wong et al. [48]			✓		✓								
Mittal et al. [23]	✓			✓	✓				✓		✓		
Kamble et al. [27]		✓		✓				✓	✓			✓	
Ashima et al. [25]								✓		✓			
Marcon et al. [50]	✓							✓	✓			✓	
Ghobakhloo [26]				✓		✓							
Mittal et al. [49]				✓	✓								
Sira [32]													
Thoben et al. [24]		✓						✓			✓		
Beliatis et al. [51]				✓			✓						
Sanusi et al. [52]	✓									✓			
Trakadas et al. [53]								✓					
Çınar et al. [55]	✓	✓								✓		✓	
Abdullah et al. [56]		✓						✓	✓	✓			
Bueno et al. [21]		✓		✓					✓				
Shrouf and Miragliotta [57]	✓							✓					
Saravanan et al. [14]											✓		
Arff et al. [58]								✓					
Seidel et al. [59]		✓										✓	
Cao et al. [60]									✓			✓	

tracking, and privacy and security emerge as important drivers for IIoT adoption in manufacturing and production SMEs. On the other hand, factors such as maturity, ease of use, robustness, scalability, technical support and relative advantage have relatively lower percentages and are less likely to have a substantial impact on IIoT adoption in manufacturing and production SMEs. While these factors may still be relevant and should not be completely ignored, they are not the primary drivers for SMEs when considering IIoT adoption. SMEs are more likely to prioritise factors that directly contribute to their operational efficiency and competitiveness, rather than factors that are more abstract or subjective in nature.

Lastly, the key environmental factors influencing the adoption of IIoT in SMEs are business environment, government policy, legal and ethical issues, regulatory support, operational intelligence, resources, sustainability, and imposition by the environment and tools. Figure 5d highlights the environmental factors for the adoption of IIoT in manufacturing and production SMEs. Sustainability and tools both contribute 23.3% of the influencing factors, driving the adoption of IIoT in

Technological factors				Environmental factors								
Smart devices/tools				Factories/companies								
Robustness	Scalability	Privacy and security	Technical support	Business environment	Government policy	Legal and ethical issues	Regulatory support	Operational intelligence	Resources	Sustainability	Imposition by the environment	Tools
		✓										
											✓	✓
								✓				
						✓						
						✓					✓	
	✓	✓										
✓												
		✓										
				✓						✓		
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manufacturing and production SMEs. According to the researchers' findings, manufacturing and production SMEs are increasingly recognising the environmental benefits offered by the adoption of IIoT, such as energy efficiency, waste reduction and optimised resource utilisation, which align well with their sustainability goals.

Business environment, government policies as well as legal and ethical issues have the same percentage for the adoption of IIoT in manufacturing and production SMEs, each contribute 10.00% of the influencing factors. According to the researchers' findings, business environment encourages SMEs to adopt IIoT in manufacturing and production sectors by providing a supportive ecosystem encompassing funding access, technological partnerships and networking opportunities. Government policies that promote digitalisation, innovation and investment in emerging technologies motivate SMEs to adopt IIoT solutions in their manufacturing and production processes. However, weak or inconsistent policies create uncertainties and barriers; therefore, discouraging SMEs from implementing IIoT due to compliance or legal concerns. Indeed, legal and ethical issues significantly impact IIoT adoption. Compliance with legislation governing data privacy, security and intellectual property rights is crucial for SMEs in considering IIoT adoption.

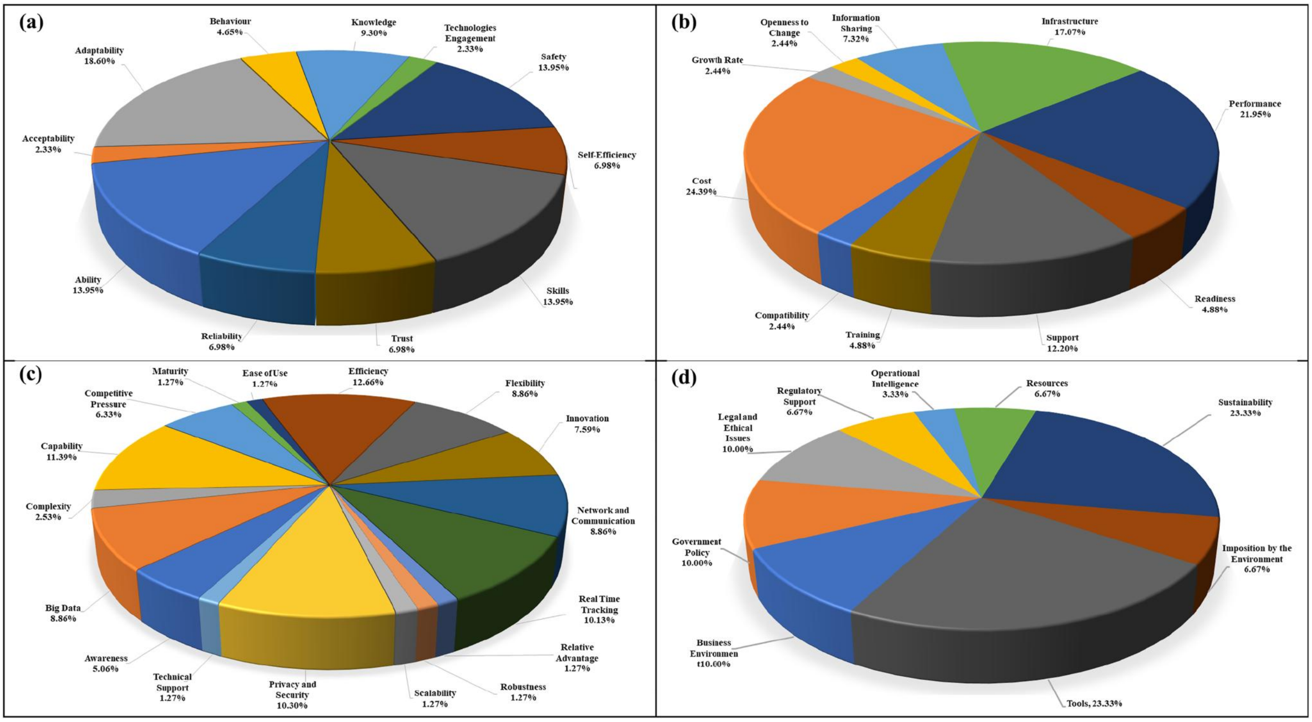

FIGURE 5 Analysis of Influencing Factors for the Manufacturing and Production SMEs based on TOEI Framework, (a) Individual Factors, (b) Organisational Factors, (c) Technological Factors and (d) Environmental Factors.

Regulatory support, resources and imposition by environment also have the same contribution to the adoption of IIoT in manufacturing and production SMEs, each with 6.67% influence. According to the researchers, well-defined IIoT laws and standards provide clarity and guidance; consequently, fostering trust in the technology. In addition, operational intelligence has an influence of 3.33% of the influencing factors. According to the researchers' findings, operational intelligence can considerably improve efficiency, productivity and decision-making in manufacturing and production. However, its impact on IIoT adoption may be restricted due to complexity and expenses associated with adopting advanced analytics and data management systems.

Environmental factors, such as the business environment, government policies, and tools, can significantly drive the adoption of IIoT in manufacturing and production SMEs. However, factors like legal and ethical issues, regulatory support and operational intelligence have a limited influence on the adoption of IIoT in manufacturing and production SMEs. Factors such as a business environment, government policies, tools and sustainability have emerged as the key drivers with comparatively larger percentages of influence. A favourable business environment, government policies that favour digitalisation and the availability of user-friendly technologies can inspire SMEs to adopt IIoT technologies; thus, supporting innovation, growth and alignment with sustainability goals. These elements create an enabling environment for SMEs to adopt IIoT technology and gain their benefits. On the other hand, factors like legal and ethical issues, regulatory support, operational intelligence, and resource availability have relatively lower percentages of influence. While these factors still play a role, their impact on IIoT adoption may be limited. Legal and ethical compliance, clear regulations and adequate operational intelligence can facilitate adoption, but they are not the primary drivers for SMEs in their decision-making process. Similarly, limited availability of resources can pose challenges, but it does not have as much significant influence as other factors.

In conclusion, understanding these factors and their varying degrees of influence is important for SMEs in considering IIoT adoption. It allows SMEs to prioritise their efforts and resources in areas that have a greater impact on successful implementation. By focusing on factors with higher influence, SMEs can navigate the adoption process more effectively and unlock the full potential of IIoT in their manufacturing and production operations.

Hence, researchers need to pay more attention to the influencing factors that depend upon TOEI framework for the adoption of IIoT in manufacturing and production SMEs in developing countries.

8 | EXISTING CHALLENGES AND FUTURE RESEARCH DIRECTIONS

The main issues commonly associated with the adoption of IIoT in manufacturing and production SMEs are mentioned below for future research work, as shown in Table 12.

Managerial Implications: This research study offers several important managerial implications. First and foremost, it provides manufacturing and production SMEs in developing

TABLE 12 Future suggested works for IIoT technology in manufacturing and production SMEs.

Future suggested works	Descriptions
Cost-effective and scalable IIoT technology for SMEs	One of the biggest challenges faced by SMEs is the cost of implementing IIoT technology. Therefore, future research needs to focus on developing affordable and scalable IIoT technology that will be integrated with the existing systems of SMEs. This will make it easier for SMEs to adopt and implement IIoT as well as enable SMEs to leverage the benefits of IIoT technology [112, 113].
Investigate the impact of IIoT on SMEs	To investigate the impact of IIoT on SMEs can be significant. By leveraging IIoT, SMEs can improve their productivity, efficiency and profitability. Therefore, future research should focus on the investigation of the impact of IIoT on SMEs' productivity, efficiency and profitability. This will enable SMEs to make informed decisions for adopting and implementing IIoT technology [40, 41].
Exploring the potential of IIoT	The potential of IIoT for SMEs is vast and can bring about significant benefits including the operational efficiency, predictive maintenance and cost efficiency. Future research needs to explore the potential of IIoT in improving the supply chain management, inventory control and logistics for SMEs. By leveraging IIoT technology, SMEs can improve their operational efficiency, predictive maintenance and reduce costs [40, 114].
Real-time monitoring and control	IIoT enables SMEs to implement real-time monitoring and control of their operations. With IIoT, sensors can be installed on machines and equipment, allowing for real-time data collection and analysis. This can improve quality control and reduce waste, leading to increased profitability [115, 116].
IIoT related security and privacy issues	Examining the security and privacy issues associated with IIoT adoption in SMEs and developing strategies to mitigate these risks. The large amount of data collected by sensors can be vulnerable to cyber-attacks, and unauthorised access to this data can lead to theft of sensitive information or disruption of operations. Therefore, future research needs to focus on examining these issues and to develop strategies to mitigate these risks [117, 118].
Government policies and regulations	Investigating the role of government policies and regulations in promoting IIoT adoption among SMEs and identifying the barriers that hinder their adoption. Overall, government policies and regulations can play a critical role in shaping the development and adoption of IIoT, ensuring that it is used in a safe, secure and responsible manner. Therefore, future research should investigate the role of government policies and regulations in promoting IIoT adoption among SMEs and identify the barriers that hinder their adoption [119, 120].
Training and education programs	Developing training and education programs for SMEs to enhance their understanding of IIoT technology and its benefits. As IIoT continues to grow, there is a need for skilled professionals who can design, implement and maintain these systems. To address this need, many organisations and governments are investing in training and education programs, to enhance their understanding of IIoT technology and its benefits for SMEs [121, 122].
Implementation of IIoT in SMEs	Implementation of IIoT in SMEs involves the actual integration of IIoT technology into the operations and processes of SMEs. This includes the installation of sensors, connectivity devices as well as data analytics tools to collect and analyse data from various industrial equipment and processes. The implementation of IIoT in SMEs also involves addressing challenges related to cybersecurity, data privacy and interoperability. Additionally, ensuring that different IIoT devices and systems can communicate and work together seamlessly is essential for maximising the benefits of IIoT in SMEs [40, 123].

countries with a well-defined roadmap for the adoption of IIoT technologies by presenting a model. The insights, derived from the TOEI framework, can guide managers and decision-makers in formulating strategies that are beneficial to their specific needs and challenges in manufacturing and production SMEs in developing countries. Furthermore, this research study highlights the importance of adopting IIoT technologies, not only for improved operational efficiency but also for enhanced competitiveness on a global level for the manufacturing and production SMEs in developing countries.

Theoretical Implications: This research study contributes to the literature by extending the application of the TOEI framework to the context of IIoT adoption in developing countries in the context of IR 4.0 and IR 5.0 for the manufacturing and production SMEs. It elaborates the existing body of knowledge by highlighting the unique challenges and opportunities faced by SMEs in developing countries. Additionally, it highlights the theoretical underpinnings of technology adoption in the context of IR 4.0 and IR 5.0, providing a deeper understanding of the dynamics.

Limitations: Firstly, the study's generalisability may be constrained by the context of the developing countries under investigation. Variations in socio-economic factors, regulatory environments and technological infrastructure could influence the applicability of the proposed model. Secondly, the research relies on data collected up to the present, and the rapidly evolving nature of IIoT may render some findings subject to change over time. Finally, while efforts have been made to mitigate biases, the study's conclusions are based on the existing studies of SMEs specifically targeting the manufacturing and production sectors, which may not fully represent the diversity of the SME sector in developing countries.

9 | CONCLUSION AND RECOMMENDATIONS

An explicit category of IoT emphasises its use cases and applications in advanced industries and intellectual manufacturing and production is known as the IIoT. It is measured to be a complex system of an extensive diversity of systems. Understanding the key factors that influence IIoT may help the manufacturing and production SMEs. It is advised for the ministry of Small Medium Enterprises and decision-makers to plan strategies for the successful adoption of IIoT. The research study examines the influencing factors that are significant for IIoT adoption for the manufacturing and production SMEs in developing countries. After the identification of influencing factors, IIoT adoption model has been proposed based on the TOEI framework for the manufacturing and production SMEs with respect to future policy-making in developing countries. These influencing factors are categorised into four groups including the individual, organisational, environmental and technological. A comparative analysis of these influencing factors is presented in a detailed description in order to determine which factors that should be prioritised for an efficient use of IIoT by the manufacturing and production SMEs. It will help provide support and encourage the manufacturing and production SMEs to incorporate these technologies into their business environment. The findings will be helpful for the manufacturing and production SMEs, policy-makers and the government to address the factors as well as to make well-informed decisions regarding IIoT adoption in the manufacturing and production SMEs. Lastly, recommendations are offered for an efficient IIoT adoption in the manufacturing and production SMEs in developing countries.

AUTHOR CONTRIBUTIONS

Conceptualization: Sajid Shah, Syed Hamid Hussain Madni. Data curation: Sajid Shah, Javed Ali. Formal analysis: Sajid Shah, Syed Hamid Hussain Madni. Funding acquisition: Muhammad Faheem. Investigation: Sajid Shah, Muhammad Faheem. Methodology: Sajid Shah, Syed Hamid Hussain Madni. Project administration: Syed Hamid Hussain Madni, Javed Ali. Resources: Muhammad Faheem. Software: Sajid Shah, Javed Ali, Muhammad Faheem. Supervision: Syed Hamid Hussain Madni, Siti Zaitoon Bt. Mohd Hashim. Validation: Syed Hamid Hussain Madni, Siti Zaitoon Bt. Mohd Hashim. Visualization: Sajid Shah. Writing – original draft: Sajid Shah. Writing – review & editing: Sajid Shah, Syed Hamid Hussain Madni. All authors contributed equally to accomplish this study. In addition, all authors read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interests.

DATA AVAILABILITY STATEMENT

The data will be available upon request to the corresponding author.

ORCID

Sajid Shah https://orcid.org/0009-0006-9980-101X
Muhammad Faheem https://orcid.org/0000-0003-4628-4486

REFERENCES

1. Sivathanu, B.: Adoption of industrial IoT (IIoT) in auto-component manufacturing SMEs in India. Inf. Resour. Manag. J. 32(2), 52–75 (2019). https://doi.org/10.4018/irmj.2019040103
2. Korte, A., Tiberius, V., Brem, A.: Internet of things (IoT) technology research in business and management literature: results from a co-citation analysis. J. Theor. Appl. Electron. Commer. Res. 16(6), 2073–2090 (2021). https://doi.org/10.3390/jtaer16060116
3. Khan, I.H., Javaid, M.: Role of internet of things (IoT) in adoption of industry 4.0. J. Ind. Integrat. Manag. 7(04), 515–533 (2022). https://doi.org/10.1142/s2424862221500068
4. Rana, A.K., Sharma, S.: Industry 4.0 manufacturing based on IoT, cloud computing, and big data: manufacturing purpose scenario. In: International Conference on Advanced Communication and Computational Technology, pp. 1109–1119. Springer (2019)
5. Belhia, Y., Bentaouaf, K.: Promoting SMEs sector for development: the Algerian experience. المشكاة في الاقتصاد التنمية والقانون 7, 85–100 (2022)
6. Anuar, A., Mohd Yusuff, R.: Manufacturing best practices in Malaysian small and medium enterprises (SMEs). Benchmark Int. J. 18(3), 324–341 (2011). https://doi.org/10.1108/14635771111137750
7. Chowdhury, A., A Raut, S.: Benefits, challenges, and opportunities in adoption of industrial IoT. Int. J. Comput. Intell. IoT 2 (2019)
8. Boyes, H., et al.: The industrial internet of things (IIoT): an analysis framework. Comput. Ind. 101, 1–12 (2018). https://doi.org/10.1016/j.compind.2018.04.015
9. Mohajan, H.: The First Industrial Revolution: Creation of a New Global Human Era (2019)
10. Mohajan, H.: The Second Industrial Revolution Has Brought Modern Social and Economic Developments (2019)
11. Xu, M., David, J.M., Kim, S.H.: The fourth industrial revolution: opportunities and challenges. Int. J. Financ. Res. 9(2), 90–95 (2018). https://doi.org/10.5430/ijfr.v9n2p90
12. Elangovan, U.: Industry 5.0: The Future of the Industrial Economy. CRC Press (2021)
13. Jung, W.-K., et al.: Appropriate smart factory for SMEs: concept, application and perspective. Int. J. Precis. Eng. Manuf. 22(1), 201–215 (2021). https://doi.org/10.1007/s12541-020-00445-2
14. Saravanan, G., et al.: Implementation of IoT in production and manufacturing: an Industry 4.0 approach. Mater. Today: Proc. 51, 2427–2430 (2022). https://doi.org/10.1016/j.matpr.2021.11.604
15. Zameer, H., Shahbaz, M., Vo, X.V.: Reinforcing poverty alleviation efficiency through technological innovation, globalization, and financial

development. Technol. Forecast. Soc. Change 161, 120326 (2020). https://doi.org/10.1016/j.techfore.2020.120326
16. Dhirani, L.L., Armstrong, E., Newe, T.: Industrial IoT, cyber threats, and standards landscape: evaluation and roadmap. Sensors 21(11), 3901 (2021). https://doi.org/10.3390/s21113901
17. Kalsoom, T., et al.: Impact of IOT on manufacturing industry 4.0: a new triangular systematic review. Sustainability 13(22), 12506 (2021). https://doi.org/10.3390/su132212506
18. Fanoro, M., Božanić, M., Sinha, S.: A review of 4IR/5IR enabling technologies and their linkage to manufacturing supply chain. Technologies 9(4), 77 (2021). https://doi.org/10.3390/technologies9040077
19. Kassim, N.L.A.: 4IR, 5IR, society 5.0, and values in education. IIUM J. Educ. Stud. 11, 1–2 (2023). https://doi.org/10.31436/ijes.v11i1.486
20. Ahamed, M., Abd Rahim, M.F., Ahmad, A.A.: Humanizing the fourth industry revolution in sustainable supply chain management. In: International Conference on Technology and Innovation Management (ICTIM 2022), pp. 354–363. Atlantis Press (2022)
21. Bueno, A., Godinho Filho, M., Frank, A.G.: Smart production planning and control in the Industry 4.0 context: a systematic literature review. Comput. Ind. Eng. 149, 106774 (2020). https://doi.org/10.1016/j.cie.2020.106774
22. Javaid, M., et al.: Upgrading the manufacturing sector via applications of industrial internet of things (IIoT). Sens. Int. 2, 100129 (2021). https://doi.org/10.1016/j.sintl.2021.100129
23. Mittal, S., et al.: A critical review of smart manufacturing & Industry 4.0 maturity models: implications for small and medium-sized enterprises (SMEs). J. Manuf. Syst. 49, 194–214 (2018). https://doi.org/10.1016/j.jmsy.2018.10.005
24. Thoben, K.-D., Wiesner, S., Wuest, T.: "Industrie 4.0" and smart manufacturing-a review of research issues and application examples. Int. J. Autom. Technol. 11(1), 4–16 (2017). https://doi.org/10.20965/ijat.2017.p0004
25. Ashima, R., et al.: Automation and manufacturing of smart materials in Additive Manufacturing technologies using internet of things towards the adoption of industry 4.0. Mater. Today Proc. 45, 5081–5088 (2021). https://doi.org/10.1016/j.matpr.2021.01.583
26. Ghobakhloo, M.: Determinants of information and digital technology implementation for smart manufacturing. Int. J. Prod. Res. 58(8), 2384–2405 (2020). https://doi.org/10.1080/00207543.2019.1630775
27. Kamble, S.S., et al.: A performance measurement system for industry 4.0 enabled smart manufacturing system in SMMEs-A review and empirical investigation. Int. J. Prod. Econ. 229, 107853 (2020). https://doi.org/10.1016/j.ijpe.2020.107853
28. Younan, M., et al.: Challenges and recommended technologies for the industrial internet of things: a comprehensive review. Measurement 151, 107198 (2020). https://doi.org/10.1016/j.measurement.2019.107198
29. Jaloudi, S.: Communication protocols of an industrial internet of things environment: a comparative study. Future Internet 11(3), 66 (2019). https://doi.org/10.3390/fi11030066
30. Khan, W.Z., et al.: Industrial internet of things: recent advances, enabling technologies and open challenges. Comput. Electr. Eng. 81, 106522 (2020). https://doi.org/10.1016/j.compeleceng.2019.106522
31. Majstorovic, V., et al.: Digital manufacturing in SMEs based on the context of the Industry 4.0 framework–one approach. Procedia Manuf. 54, 52–57 (2021). https://doi.org/10.1016/j.promfg.2021.07.009
32. Sira, M.: Efficient practices of cognitive technology application for smart manufacturing. Manag. Syst. Prod. Eng. 30(2), 187–191 (2022). https://doi.org/10.2478/mspe-2022-0023
33. Estensoro, M., et al.: A resource-based view on SMEs regarding the transition to more sophisticated stages of Industry 4.0. Eur. Manag. J. 40(5), 778–792 (2022). https://doi.org/10.1016/j.emj.2021.10.001
34. Ghobakhloo, M., et al.: Drivers and barriers of Industry 4.0 technology adoption among manufacturing SMEs: a systematic review and transformation roadmap. J. Manuf. Technol. Manag. 33(6), 1029–1058 (2022). https://doi.org/10.1108/jmtm-12-2021-0505
35. Khin, S., Kee, D.M.H.: Factors influencing industry 4.0 adoption. J. Manuf. Technol. Manag. 33(3), 448–467 (2022). https://doi.org/10.1108/jmtm-03-2021-0111
36. Umair, M., et al.: Impact of COVID-19 on IoT adoption in healthcare, smart homes, smart buildings, smart cities, transportation and industrial IoT. Sensors 21(11), 3838 (2021). https://doi.org/10.3390/s21113838
37. Vuković, M., et al.: Digital twins in industrial IoT: a survey of the state of the art and of relevant standards. In: 2021 IEEE International Conference on Communications Workshops (ICC Workshops), pp. 1–6. IEEE (2021)
38. Jadala, V.C., et al.: Need of intenet of things, industrial IoT, industry 4.0 and integration of cloud for industrial revolution. In: 2021 Innovations in Power and Advanced Computing Technologies (i-PACT), pp. 1–5. IEEE (2021)
39. Moher, D., et al.: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst. Rev. 4, 1–9 (2015). https://doi.org/10.1186/2046-4053-4-1
40. Peter, O., Pradhan, A., Mbohwa, C.: Industrial internet of things (IIoT): opportunities, challenges, and requirements in manufacturing businesses in emerging economies. Proc. Comput. Sci. 217, 856–865 (2023). https://doi.org/10.1016/j.procs.2022.12.282
41. Mukherjee, S., et al.: Achieving organizational performance by integrating industrial Internet of things in the SMEs: a developing country perspective. TQM J. 36(1), 265–287 (2023). https://doi.org/10.1108/tqm-07-2022-0221
42. Ghobakhloo, M., Ching, N.T.: Adoption of digital technologies of smart manufacturing in SMEs. J. Ind. Inf. Integrat. 16, 100107 (2019). https://doi.org/10.1016/j.jii.2019.100107
43. George, A.S., George, A.: Industrial revolution 5.0: the transformation of the modern manufacturing process to enable man and machine to work hand in hand. J. Seybold Rep. ISSN NO 1533, 9211 (2020)
44. Won, J.Y., Park, M.J.: Smart factory adoption in small and medium-sized enterprises: empirical evidence of manufacturing industry in Korea. Technol. Forecast. Soc. Change 157, 120117 (2020). https://doi.org/10.1016/j.techfore.2020.120117
45. Yang, L., et al.: Adoption of information and digital technologies for sustainable smart manufacturing systems for industry 4.0 in small, medium, and micro enterprises (SMMEs). Technol. Forecast. Soc. Change 188, 122308 (2023). https://doi.org/10.1016/j.techfore.2022.122308
46. Kumar, A., et al.: A framework for assessing social acceptability of industry 4.0 technologies for the development of digital manufacturing. Technol. Forecast. Soc. Change 174, 121217 (2022). https://doi.org/10.1016/j.techfore.2021.121217
47. Doyle, F., Cosgrove, J.: Steps towards digitization of manufacturing in an SME environment. Procedia Manuf. 38, 540–547 (2019). https://doi.org/10.1016/j.promfg.2020.01.068
48. Wong, L.-W., et al.: Time to seize the digital evolution: adoption of blockchain in operations and supply chain management among Malaysian SMEs. Int. J. Inf. Manag. 52, 101997 (2020). https://doi.org/10.1016/j.ijinfomgt.2019.08.005
49. Mittal, S., et al.: A smart manufacturing adoption framework for SMEs. Int. J. Prod. Res. 58(5), 1555–1573 (2020). https://doi.org/10.1080/00207543.2019.1661540
50. Marcon, É., et al.: Sociotechnical factors and Industry 4.0: an integrative perspective for the adoption of smart manufacturing technologies. J. Manuf. Technol. Manag. 33(2), 259–286 (2022). https://doi.org/10.1108/jmtm-01-2021-0017
51. Beliatis, M.J., et al.: Next generation industrial IoT digitalization for traceability in metal manufacturing industry: a case study of industry 4.0. Electronics 10(5), 628 (2021). https://doi.org/10.3390/electronics10050628
52. Sanusi, A., et al.: Smart manufacturing adoption in supporting technologies infrastructure in Indonesia: the case of South Sulawesi SMEs. In: IOP Conference Series: Earth and Environmental Science. IOP Publishing (2020).012175
53. Trakadas, P., et al.: An artificial intelligence-based collaboration approach in industrial iot manufacturing: key concepts, architectural

extensions and potential applications. Sensors 20(19), 5480 (2020). https://doi.org/10.3390/s20195480
54. Jung, S., Kim, D., Shin, N.: Success factors of the adoption of smart factory transformation: an examination of Korean manufacturing SMEs. IEEE Access 11, 2239–2249 (2023). https://doi.org/10.1109/access.2022.3233811
55. ÇıNAR, Z.M., Zeeshan, Q., Korhan, O.: A framework for industry 4.0 readiness and maturity of smart manufacturing enterprises: a case study. Sustainability 13(12), 6659 (2021). https://doi.org/10.3390/su13126659
56. Abdullah, F.M., Al-Ahmari, A.M., Anwar, S.: Analyzing interdependencies among influencing factors in smart manufacturing. Sustainability 15(4), 3864 (2023). https://doi.org/10.3390/su15043864
57. Shrouf, F., Miragliotta, G.: Energy management based on Internet of Things: practices and framework for adoption in production management. J. Clean. Prod. 100, 235–246 (2015). https://doi.org/10.1016/j.jclepro.2015.03.055
58. Arff, B., et al.: Analysis and visualization of production bottlenecks as part of a digital twin in industrial IoT. Appl. Sci. 13(6), 3525 (2023). https://doi.org/10.3390/app13063525
59. Seidel, R., et al.: Data mining system architecture for industrial internet of things in electronics production. In: 2020 IEEE 26th International Symposium for Design and Technology in Electronic Packaging (SIITME), pp. 75–80. IEEE (2020)
60. Cao, Y., Jia, F., Manogaran, G.: Efficient traceability systems of steel products using blockchain-based industrial internet of things. IEEE Trans. Ind. Inf. 16(9), 6004–6012 (2019). https://doi.org/10.1109/tii.2019.2942211
61. Prisecaru, P.: Challenges of the fourth industrial revolution. Knowl. Horiz. Econ. 8, 57 (2016)
62. Kaewboonchoo, O., et al.: Work ability and its related factors among workers in small and medium enterprises: comparison among four ASEAN countries. Asia Pac. J. Publ. Health 28(5), 438–449 (2016). https://doi.org/10.1177/1010539516651957
63. Madni, S.H.H., et al.: Factors influencing the adoption of IoT for E-learning in higher educational institutes in developing countries. Front. Psychol. 13, 915596 (2022). https://doi.org/10.3389/fpsyg.2022.915596
64. Gordian, B.: Kaizen as a Strategy for Improving SMEs' Performance: Assessing its Acceptability and Feasibility in Tanzania (2014)
65. Rauch, E., et al.: SME requirements and guidelines for the design of smart and highly adaptable manufacturing systems. In: Industry 4.0 for SMEs: Challenges, Opportunities and Requirements, pp. 39–72 (2020)
66. Anser, M.K., et al.: How to unleash innovative work behavior of SMEs' workers through knowledge sharing? Accessing functional flexibility as a mediator. Eur. J. Innovat. Manag. 25(1), 233–248 (2022). https://doi.org/10.1108/ejim-11-2019-0332
67. Giauque, D., Resenterra, F., Siggen, M.: The relationship between HRM practices and organizational commitment of knowledge workers. Facts obtained from Swiss SMEs. Hum. Resour. Dev. Int. 13(2), 185–205 (2010). https://doi.org/10.1080/13678861003703716
68. Srinivas, K., Yasmeen, S.: A study on employee engagement in small and medium enterprises in digital economy. In: Millennial Workforce—A Contemplation, pp. 57–64. Zenon Academic Publishing, Hyderabad (2017)
69. Bluff, E.: How SMEs respond to legal requirements to provide information, training, instruction and supervision to workers about work health and safety matters. Saf. Sci. 116, 45–57 (2019). https://doi.org/10.1016/j.ssci.2019.02.036
70. Golam Hassan, A.A.: The impact of entrepreneurial self efficiency and enabling business environment on business performance of female-led handicraft manufacturing SMEs in Sri Lanka. Aust. J. Basic Appl. Sci. 8, 523–528 (2014)
71. Lange, T., Ottens, M., Taylor, A.: SMEs and barriers to skills development: a Scottish perspective. J. Eur. Ind. Train. 24(1), 5–11 (2000). https://doi.org/10.1108/03090590010308219
72. Ushada, M., et al.: Development of Kansei engineering-based system for agro-industry (KESAN) for worker trust assessment in food small medium-sized enterprises. Eng. Agric. Environ. Food 13(2), 49–59 (2020). https://doi.org/10.37221/eaef.13.2_49
73. Kim, D.-W., et al.: Reliability assessment on different designs of a SMES system based on the reliability index approach. J. Electr. Eng. Technol. 7(1), 46–50 (2012). https://doi.org/10.5370/jeet.2012.7.1.46
74. Al-Shboul, M.D.A.: Towards better understanding of determinants logistical factors in SMEs for cloud ERP adoption in developing economies. Bus. Process Manag. J. 25(5), 887–907 (2019). https://doi.org/10.1108/bpmj-01-2018-0004
75. Haddara, M.: ERP adoption cost factors in SMEs. In: Proceedings of the European, Mediterranean & Middle Eastern Conference on Information Systems (2011)
76. Douglas, J., et al.: An exploratory study of critical success factors for SMEs in Kenya. In: Toulon-Verona Conference" Excellence in Services, pp. 223–234 (2017)
77. Santoro, G., et al.: The interplay among entrepreneur, employees, and firm level factors in explaining SMEs openness: a qualitative microfoundational approach. Technol. Forecast. Soc. Change 151, 119820 (2020). https://doi.org/10.1016/j.techfore.2019.119820
78. Jermsittiparsert, K., Rungsrisawat, S.: The supply chain management and information sharing as antecedents of operational performance: a case of SMEs. Humanit. Soc. Sci. Rev. 7(2), 495–502 (2019). https://doi.org/10.18510/hssr.2019.7258
79. Fernández, J.L., Camacho, J.: Effective elements to establish an ethical infrastructure: an exploratory study of SMEs in the Madrid region. J. Bus. Ethics 138(1), 113–131 (2016). https://doi.org/10.1007/s10551-015-2607-3
80. Hsu, C.-H., Chang, A.-Y., Luo, W.: Identifying key performance factors for sustainability development of SMEs–integrating QFD and fuzzy MADM methods. J. Clean. Prod. 161, 629–645 (2017). https://doi.org/10.1016/j.jclepro.2017.05.063
81. Nugroho, M.A., et al.: Exploratory study of SMEs technology adoption readiness factors. Proc. Comput. Sci. 124, 329–336 (2017). https://doi.org/10.1016/j.procs.2017.12.162
82. Jere, J.N., Ngidi, N.: A technology, organisation and environment framework analysis of information and communication technology adoption by small and medium enterprises in Pietermaritzburg. S. Afr. J. Inf. Manag. 22, 1–9 (2020). https://doi.org/10.4102/sajim.v22i1.1166
83. Yahya, A.Z., Othman, M.S., Shamsuri, A.L.S.: The impact of training on small and medium enterprises (SMEs) performance. J. Prof. Manag. 2, 15–25 (2012)
84. Gadenne, D.L., Kennedy, J., Mckeiver, C.: An empirical study of environmental awareness and practices in SMEs. J. Bus. Ethics 84(1), 45–63 (2009). https://doi.org/10.1007/s10551-008-9672-9
85. Sen, D., Ozturk, M., Vayvay, O.: An overview of big data for growth in SMEs. Procedia Soc. Behav. Sci. 235, 159–167 (2016). https://doi.org/10.1016/j.sbspro.2016.11.011
86. Jeansson, J., Bredmar, K.: Digital Transformation of SMEs: Capturing Complexity (2019)
87. Saunila, M.: Innovation capability in SMEs: a systematic review of the literature. J. Innovat. Knowl. 5(4), 260–265 (2020). https://doi.org/10.1016/j.jik.2019.11.002
88. Kalita, A., Chepurenko, A.: Competitiveness of small and medium businesses and competitive pressure in the manufacturing industry. Форсайт 14(2), 36–50 (2020). https://doi.org/10.17323/2500-2597.2020.2.36.50
89. Zentner, H., Spremić, M., Zentner, R.: Measuring digital business models maturity for SMEs. In: 2021 IEEE Technology & Engineering Management Conference-Europe (TEMSCON-EUR), pp. 1–6. IEEE (2021)
90. Lubua, E.W., Semlambo, A.: The influence of the ease of use and perceived usefulness to the adoption of mobile money services in SMEs in Tanzania. Inf. Technol. 14, 131–141 (2017)
91. Ali, J., et al.: IoT adoption model for E-learning in higher education institutes: a case study in Saudi Arabia. Sustainability 15(12), 9748 (2023). https://doi.org/10.3390/su15129748
92. Yang, J.-C.: The efficiency of SMEs in the global market: measuring the Korean performance. J. Pol. Model. 28(8), 861–876 (2006). https://doi.org/10.1016/j.jpolmod.2006.07.004

93. Levy, M., Powell, P.: SME flexibility and the role of information systems. Small Bus. Econ. 11(2), 183–196 (1998). https://doi.org/10.1023/a:1007912714741
94. Lee, S., et al.: Open innovation in SMEs—an intermediated network model. Res. Pol. 39(2), 290–300 (2010). https://doi.org/10.1016/j.respol.2009.12.009
95. Vásquez, G.A.N., Escamilla, E.M.: Best practice in the use of social networks marketing strategy as in SMEs. Procedia Soc. Behav. Sci. 148, 533–542 (2014). https://doi.org/10.1016/j.sbspro.2014.07.076
96. Zeimpekis, V., Giaglis, G.M.: Urban dynamic real-time distribution services: insights from SMEs. J. Enterprise Inf. Manag. 19(4), 367–388 (2006). https://doi.org/10.1108/17410390610678304
97. Jahanshahi, A.A., et al.: The role of real options thinking in achieving sustainable competitive advantage for SMEs. Global Bus. Organ. Excel. 35(1), 35–44 (2015). https://doi.org/10.1002/joe.21643
98. Vlajic, J.V.: Vulnerability and robustness of SME supply chains: an empirical study of risk and disturbance management of fresh food processors in a developing market. Organ. Resilience, 85–102 (2015)
99. Osano, H.M.: Factors influencing global expansion/scalability of small and medium enterprises: a Kenyan case. World Technopolis Rev. 8, 21–42 (2019)
100. Senarathna, I., et al.: Security and privacy concerns for Australian SMEs cloud adoption: empirical study of metropolitan vs regional SMEs. Australas. J. Inf. Syst. 20 (2016). https://doi.org/10.3127/ajis.v20i0.1193
101. Hillemane, B.S.M.: Technological innovation in Indian SMEs: need, status and policy imperatives. Curr. Opin. Creativ. Innovat. Entrepren. 1(2) (2012). https://doi.org/10.11565/cuocient.v1i2.4
102. Gaganis, C., Pasiouras, F., Voulgari, F.: Culture, business environment and SMEs' profitability: evidence from European Countries. Econ. Modell. 78, 275–292 (2019). https://doi.org/10.1016/j.econmod.2018.09.023
103. Eniola, A.A., Entebang, H.: Government policy and performance of small and medium business management. Int. J. Acad. Res. Bus. Soc. Sci. 5(2), 237–248 (2015). https://doi.org/10.6007/ijarbss/v5-i2/1481
104. Clarke, T., Klettner, A.: Governance issues for SMEs. J. Law Govern. 4, 23–40 (2009). https://doi.org/10.15209/jbsge.v4i4.169
105. Rajulu Lanke, G., Bhuvaneswari, T.: Giving intelligence to SMEs business. Int. J. Bus. Intell. 4, 5 (2015)
106. Williams, D.A.: Resources and failure of SMEs: another look. J. Dev. Enterpren. 19(01), 1450007 (2014). https://doi.org/10.1142/s1084946714500071
107. Prasanna, R., et al.: Sustainability of SMEs in the competition: a systemic review on technological challenges and SME performance. J. Open Innovat. 5(4), 100 (2019). https://doi.org/10.3390/joitmc5040100
108. Machado, M.C., Vivaldini, M., de Oliveira, O.J.: Production and supply-chain as the basis for SMEs' environmental management development: a systematic literature review. J. Clean. Prod. 273, 123141 (2020). https://doi.org/10.1016/j.jclepro.2020.123141
109. Moultrie, J., Clarkson, P.J., Probert, D.: Development of a design audit tool for SMEs. J. Prod. Innovat. Manag. 24(4), 335–368 (2007). https://doi.org/10.1111/j.1540-5885.2007.00255.x
110. Wiboonchutikula, P.: Small and medium enterprises in Thailand: recent trends. Small Bus. Econ. 18(1/3), 211–224 (2002). https://doi.org/10.1023/a:1015143709196
111. Ayyagari, M., Beck, T., Demirguc-Kunt, A.: Small and medium enterprises across the globe. Small Bus. Econ. 29(4), 415–434 (2007). https://doi.org/10.1007/s11187-006-9002-5
112. Vuković, M., et al.: Low-cost digitalization solution through scalable IIoT prototypes. Appl. Sci. 12(17), 8571 (2022). https://doi.org/10.3390/app12178571
113. Schmitt, R., Borck, C.: Industrial internet of things (IIoT). In: The Future of Smart Production for SMEs: A Methodological and Practical Approach towards Digitalization in SMEs. Springer (2022)
114. Pizoń, J., Klosowski, G., Lipski, J.: Key role and potential of industrial internet of things (IIoT) in modern production monitoring applications. In: MATEC Web of Conferences. EDP Sciences (2019)
115. Nuratch, S.: The IIoT devices to cloud gateway design and implementation based on microcontroller for real-time monitoring and control in automation systems. In: 2017 12th IEEE Conference on Industrial Electronics and Applications (ICIEA), pp. 919–923. IEEE (2017)
116. Salem, R.M., Saraya, M.S., Ali-Eldin, A.M.: An industrial cloud-based IoT System for real-time monitoring and controlling of wastewater. IEEE Access 10, 6528–6540 (2022). https://doi.org/10.1109/access.2022.3141977
117. Gebremichael, T., et al.: Security and privacy in the industrial internet of things: current standards and future challenges. IEEE Access 8, 152351–152366 (2020). https://doi.org/10.1109/access.2020.3016937
118. Alcaraz, C.: Security and Privacy Trends in the Industrial Internet of Things. Springer (2019)
119. Madakam, S., Uchiya, T.: Industrial internet of things (IIoT): principles, processes and protocols. Internet Things Ind. Sect. 4, 35–53 (2019)
120. Li, J., Maiti, A., Fei, J.: Features and scope of regulatory technologies: challenges and opportunities with industrial internet of things. Future Internet 15(8), 256 (2023). https://doi.org/10.3390/fi15080256
121. Corallo, A., et al.: Cybersecurity awareness in the context of the industrial internet of things: a systematic literature review. Comput. Ind. 137, 103614 (2022). https://doi.org/10.1016/j.compind.2022.103614
122. Bezumnov, D.N., Voronova, L.I.: Specialists' training of in industrial internet of things systems development. In: Proceedings of the International Conference Technology & Entrepreneurship in Digital Society (TEDS), 40–43 (2019)
123. Kumar, R., Sindhwani, R., Singh, P.L.: IIoT implementation challenges: analysis and mitigation by blockchain. J. Glob. Oper. Strat. Sourc. 15(3), 363–379 (2022). https://doi.org/10.1108/jgoss-08-2021-0056

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