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Determinants to Adopt Industrial Internet of Things in Small and Medium-Sized Enterprises

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Abstract: The Industrial Internet of Things (IIoT) enhances and optimizes operations and product quality by reducing expenses and preserving critical factory components. The IIoT can also be integrated into the processes of small and medium-sized enterprises (SMEs). However, several factors and risks have discouraged SMEs from adopting the IIoT. This study aims to identify the factors influencing IIoT adoption and address the challenges by conducting semi-structured interviews with experienced stakeholders in SME factories. Group quotations and thematic analysis indicate essential themes from these interviews, suggesting two primary categories, human- and machine-related factors, that affect implementation. The main human-related factor is the decision making of high-level management and owners to implement the IIoT in their plants, which requires skilled individuals to achieve IIoT solutions. Machine-related factors present several challenges, including device compatibility-, device management-, and data storage-associated issues. Comprehending and addressing these factors when deploying the IIoT can ensure successful implementation in SMEs, maximizing the potential benefits of this technology.

Keywords: Industrial Internet of Things; small and medium enterprises; thematic analysis

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1. Introduction

Recent advancements in communication and reduced costs of IoT technologies have enhanced the adoption of IoT applications in diverse fields. Thus, manufacturing, healthcare, agriculture, and retail SMEs have considered these solutions. Small and medium-sized factories can use these technologies to enhance production quality and operational efficiency and reduce costs. A McKinsey and Company survey of over a thousand companies indicates a growing trend toward investing in digital technology: 51% expressed willingness to invest in technologies such as the IoT to gain a competitive edge, while 28% aimed to stay relevant with their industry practices [1]. Despite these benefits, approximately 58% of IoT projects in industrial settings fail, with only 12% succeeding, as reported by Software AG [2]. This high failure rate presents significant challenges for SMEs planning to adopt IIoT solutions. Identifying these challenges and emphasizing the short-term benefits and organizational changes brought by IIoT implementation is crucial, particularly in industrial settings. This study highlights factors beyond technical issues, revealing the value of implementing the IIoT. To address these challenges and factors, we conducted an evidence assessment of the related literature using keywords such as IIoT, IIoT factors, IoT determines, IoT security challenges, and IoT adoption in SME manufacturing. The collected research articles are limited to peer-reviewed published articles between 2015 and 2024. This evidence assessment helped us curate and design open-ended interview questions. The following section discusses the papers collected in this rapid literature review.

SMEs encounter several significant constraints when implementing the IIoT, such as more human resources and financial limitations. SMEs' production lines often rely on reliable legacy machinery and systems. Thus, integrating the IIoT into these systems necessitates extensive modifications and retrofitting. This requires a deep understanding

of the legacy machinery and systems and how to modernize them with new IoT devices and sensors. Thus, SMEs must implement the IIoT while considering how this can enhance customer production. Therefore, a customer-centric approach to adopting the IIoT can benefit the SME stakeholders in promoting long-term success for this implementation [3].

Integrating the IIoT into SMEs necessitates considering costs, seamless usage, and the need for skilled personnel. Many SMEs require support to discover suitable equipment and training for their human resources. Additionally, the technological complexity of adoption leads some SMEs to outsource and employ off-the-shelf solutions. This can be counterproductive, expensive, and limiting [4]. Moreover, the complexity of technology and the rapid and evolving landscape requires highly skilled workers, which requires collaboration between industry, academia, and government to develop education programs, equipping them with the essential knowledge and skills to use IoT systems [5,6]. Furthermore, cybersecurity remains a critical issue that hinders SMEs' efforts to use the IIoT. Threats include data breaches or operational sabotage, which can affect productivity. To mitigate this, well-developed and robust security protocols and teams are essential for ensuring data confidentiality and system integrity for IoT systems [7].

The rise of IoT applications presents significant challenges to the 5Vs owing to their strong connection with big data. Both small- and large-scale applications of the IoT have these issues [8]. However, in practical applications for IIoT in SMEs, these issues must be investigated when designing the IIoT application. Therefore, it is essential to address the 5Vs of big data when adopting IIoT solutions in SMEs. Additionally, the connectivity among IoT devices is overlooked. Therefore, addressing these issues regarding connectivity from the hardware and software aspects is another factor that must be considered. Despite standards evolving to enhance data transmission, the goal of seamless and real-time connectivity, essential to connected devices [9], is compounded by the variability in access to crucial infrastructure, particularly in remote areas. Moreover, the security issues and the heterogeneity of IIoT systems pose constraints [10]. This gap may affect the widespread adoption of the IIoT by SMEs. Furthermore, SMEs aiming to adopt the IIoT must navigate the challenges of integrating these devices into existing systems, a task complicated by legacy machinery that lacks modern data transmission interfaces [11].

Decision makers must ensure compatibility and seamless integration regarding IIoT implementation in SMEs. The IIoT enables effective monitoring and management of supply chains, optimizing decision-making processes and actions based on data-centric approaches [12]. Moreover, the manufacturer's critical production stream must be undisrupted. Newly introduced production line systems will require significant investment in training and acquiring skilled staff to ensure effective management [13]. Additionally, the decision makers' considerations of technical complexity and implementation costs must be addressed before implementation. Moreover, robust cybersecurity measures and policies must be introduced to protect against sabotage or data breaches [14]. These considerations must be acknowledged and communicated to decision makers alongside the benefits of transitioning SMEs to IIoT systems implemented on the plant floor.

Previous studies attempted to investigate the factors influencing IoT adoption in manufacturing. First, top management significantly influences the desire to implement IoT technologies [15]. Besides top management's eagerness and support to implement the IoT, technology readiness and competitive pressure can boost the intention to adopt these emerging technologies [16]. In addition, the complex and challenging factors that arise from adopting the IoT need to be assessed as justifiable without extracting these challenges to ensure successful implementation [17]. Moreover, several studies investigate, specifically, transportation and logistics in IoT adoption [18–20]. One study observes that the level of IoT adoption is related to the company's size, where big companies can adopt these technologies more easily [21]. Limited studies focus on SME manufacturers keen to implement IIoT solutions, which we aim to investigate and address in this study.

This study investigates the challenges and potential benefits of IoT adoption in SMEs, such as enhanced efficiency and competitive advantage [22], as well as the high rate of

project failures caused by budget constraints and legacy system integration issues. Additionally, it aims to identify key challenges, develop integration strategies, elucidate cybersecurity significance, and propose workforce development through industry–academia–government collaboration. The remainder of this study is organized as follows: Section 2 outlines the interview methodology and setting. Section 3 presents the results and thematic analysis of the interviews. Moreover, the themes extracted from the interviews are noted with participants' quotations. Section 4 discusses the findings from the thematic analysis and analyzes the most significant factors. Section 5 concludes with key findings and highlights open research problems for future exploration.

2. Materials and Methods

This study attempts to explore the factors and challenges of adopting the IIoT in SMEs by interviewing stakeholders with different levels of management experience. The interviewees were managers, IT specialists, and decision makers interested in implementing the IIoT in their workplaces, as stated in the demographic table Table 1 and detailed in Section 2.1. We conducted semi-structured interviews. We implemented a four-stage methodology, starting with collecting and reviewing the recent IIoT-related literature to capture all the related factors and challenges SMEs could face when implementing IIoT solutions Figure 1. We tested the synthesized questions from related research in a pilot interview with one researcher with a background in the IoT and qualitative methodologies to ensure the correctness of the questions and the associated factors in the IIoT. Following that, the participants in this study were recruited via e-mail and phone contacts and consented to recorded interviews. The contents of each interview were coded for analysis, as discussed in Section 3. This study aimed to identify critical factors influencing IIoT adoption in SMEs, determine their impacts, and recommend ways to address challenges that can contribute practical insights into implementing the IIoT.

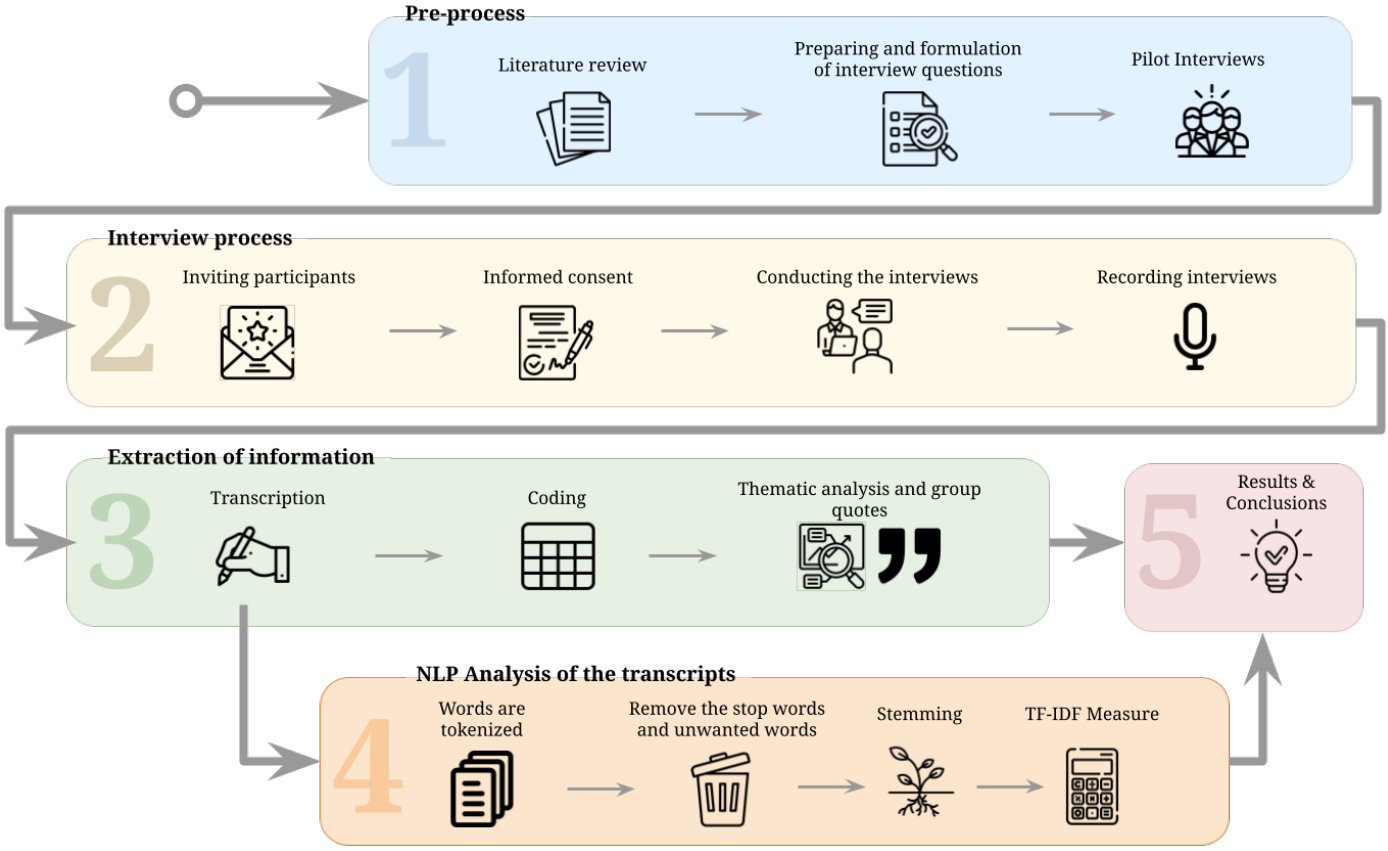

Figure 1. Overview of the method for the interviews process.

Table 1. Demographic information of the interviewees in this study.

Participant	Age	Experience (Years)	Education (Degree)	Management Level
Participant 1	53	29	Bachelor's	Senior level
Participant 2	40	18	Master's	Mid-level
Participant 3	38	14	Bachelor's	Operations
Participant 4	47	23	Ph.D.	Senior level
Participant 5	33	8	Bachelor's	Mid-level
Participant 6	28	6	Master's	Mid-level
Participant 7	32	8	Master's	Mid-level

2.1. Participant Recruitment and Demographics

Participants were selected from a group that had attended a workshop on IoT concepts and applications. However, some participants had applied IIoT solutions in diverse settings, including intelligent farming and supply chain management. Through extensive interviews, we aimed to highlight the most critical issues and identify potential solutions as we sought to uncover the main obstacles these businesses face when attempting to adopt the IIoT. The selection criteria for the subjects in this study are based on the following:

- Whether the participants were decision makers or owners of small or medium-size factories.
- Whether they understood the concept of IoT devices, communications, and platforms.
- Whether they have experience in the supply chain or manufacturing of at least one year.
- Whether they were implementing or considering the commission of an IoT solution in their workplaces.

Table 1 shows the demographics of interviewees, all working in SME factories in Saudi Arabia. The participants ranged from 28 to 53 years old, showing experiences ranging from 6 to 29 years in the field. The educational backgrounds of the participants were as follows: Three had earned a bachelor's degree, three had a master's degree, and one held a Ph.D. degree. Regarding their roles within the organizational structure, two carried senior-level roles, four occupied mid-level positions, and one worked at the operations level. However, considering the limited number of participants in this study, we adhere to the number of subjects that would be sufficient in this thematic and open-ended interview research based on Fugard and Potts [23]'s recommendations on the number of subjects in similar research methodology.

2.2. Semi-Structured Interviews and Thematic Analysis

The participants went through a semi-structured interview format, including multiple open-ended questions and one ranking question. Since the interview was an open-ended format, the participants often presented new ideas and opinions that required follow-up questions related to their responses to further clarify and comprehend the question discussed. The ranking question was designed to order the influencing factors synthesized from the related literature on IIoT implementation in SMEs. This was undertaken to understand the relative importance of these factors as perceived by the participants. The factors that influence the implementation of the IIoT in SMEs are presented in Figure 2. We presented the ranking question at the end of each interview to ensure that the factors presented in the question would not influence the participants' responses when answering the open-ended questions phase. After the interviews and transcripts were collected, a thematic content analysis was performed. In this research, rather than relying on predetermined factors, we aimed to find common patterns throughout the interview transcripts to identify the patterns and themes. In addition, we utilized natural language processing (NLP) techniques to analyze the collected transcripts and discussed observations derived from these tools before initiating the thematic analysis to uncover underlying insights. In Section 2.4, we elaborate on how we utilize NLP techniques in this study.

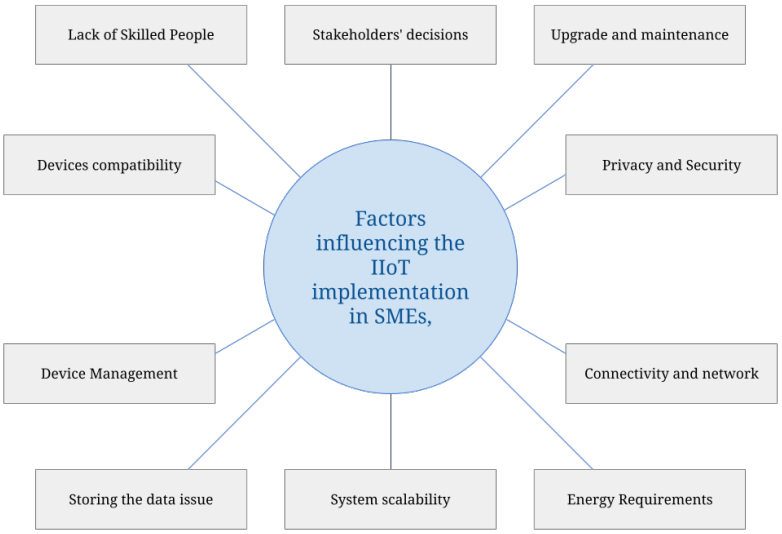

Figure 2. List of factors influencing the success of IIoT implementation.

2.3. Ethics

This study received approval from the Committee for Scientific Research Ethics at Najran University. All participants gave informed consent to participate in the interviews, have their discussions audio-recorded, and have the recordings transcribed and translated from Arabic to English by a third-party service.

2.4. Natural Language Processing for Transcripts

The natural language toolkit (NLTK) Python package [24] was employed to analyze the transcripts collected from the interviews. We identified the patterns and frequent words used in the interview sessions. Figure 3 shows a word cloud that highlights the most frequent words mentioned in the interviews, such as "factories", "IoT", "devices", and "systems", derived after cleansing the raw transcripts from unnecessary words such as stop words. In addition to the stop words, we removed additional words, revealed in Figure 4, that are highly frequent in the transcripts and do not convey additional information for the analysis. Moreover, the NLP pipeline was performed on the interview transcripts by tokenizing words, removing stop words, and stemming the words to apply term frequency (tf) and the reciprocal document frequency (tf) (idf). We used the Porter Stemming algorithm (or Porter Stemmer), which removes the suffixes from an English word and obtains its stem. The research method illustrates this process Figure 1, part 4 of the proposed framework. For example, "manufacturer" will be stemmed to "manufacture", and the NLP algorithms and equations can be applied to the resulting textual data, which is displayed in Figures 3 and 5. The word size indicates how frequently the word is mentioned in the interviews, where it is most frequent if it is a bigger font size. The words went through stemming, revealing their roots in the word cloud Figure 3. Figure 5 shows another visualization employed to help us understand the transcript topic and theme, indicating the top 20 terms and their frequency.

$$tf_{i,j} = \frac{n_{i,j}}{\sum_k n_{i,j}}. \quad (1)$$

In Equation (1), the term's frequency is denoted by tf. i denotes the number of times the term occurred in document j. $n_{i,j}$ is the term frequency in a document j and $\sum_k n_{i,j}$ is the total number of words in the document j. Moreover, we have the following Equation (2) to calculate the inverse document frequency:

$$idf(w) = log(\frac{N}{df_t}) \quad (2)$$

where $idf(w)$ is the inverse document frequency, N is the total documents, and df_t is the documents with term i. Finally, we multiply $tf_{i,j}$ by $idf(w)$ to obtain a score between 0 and 1 for each term.

$$w_{i,j} = tf_{i,j} \times idf(w). \quad (3)$$

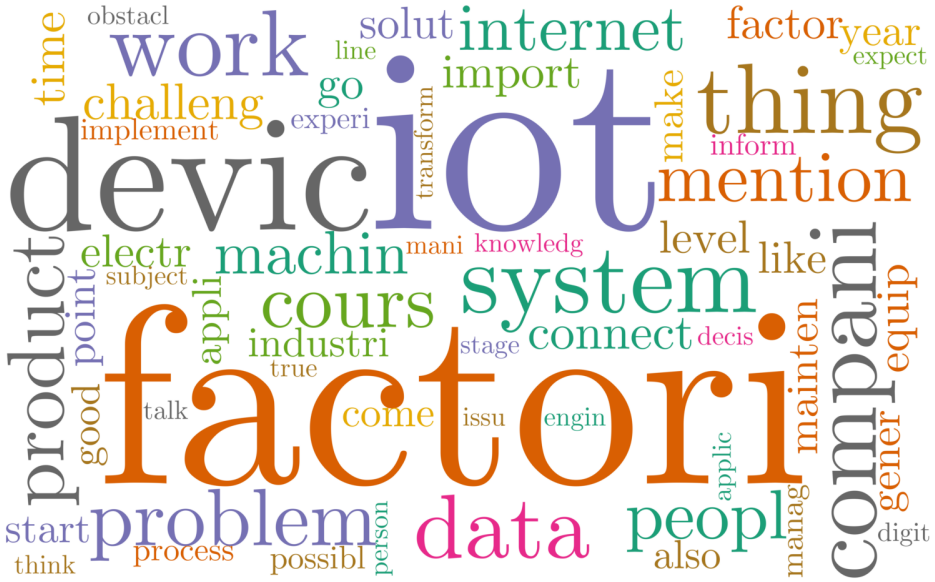

Figure 3. Word cloud of words used by the interviewees.

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unwanted_words = ["example", "mean", "speaker", "first", "second", "god",
"question", "new", "almost", "say", "said", "exactly", "correct",
"today", "ask", "factor", "one", "two", "three", "four", "five", "six",
"seven", "eight", "nine", "ten", "beautiful", "number", "need", "know",
"even", "present", "excellent", "us", "ok", "okay", "doctor", "yes",
"no", "want", "may", "well", "frankly", "give", "thank", "simply",
"means", "really", "something", "agree", "disagree", "not", "see",
"let", "take", "use", "used"]
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Figure 4. List of words eliminated from the interview transcripts for NLP analysis.

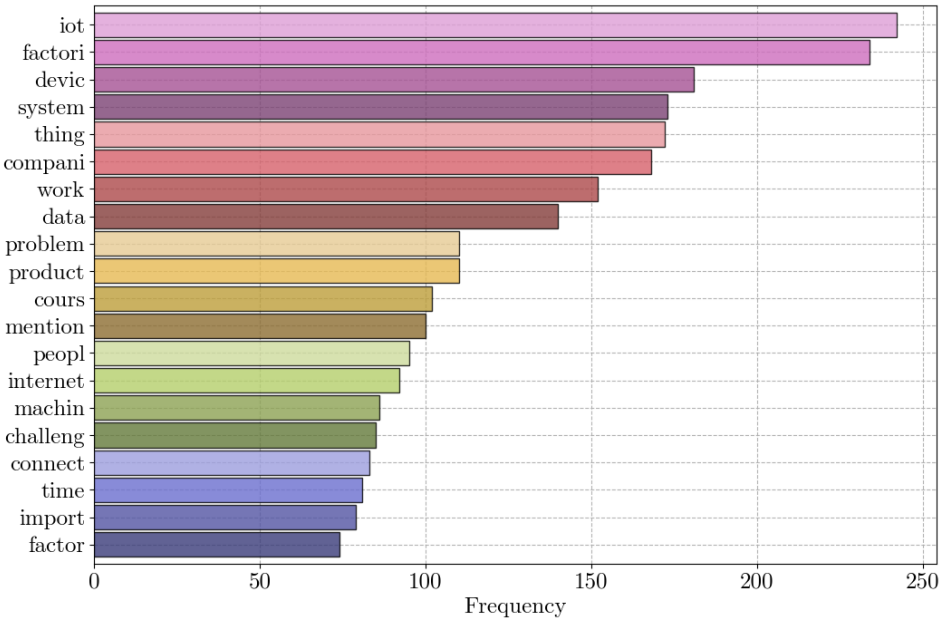

Figure 5. Top 20 terms' frequency in the transcriptions.

To generate the heatmap in Figure 6, we calculate the tf for each document and then use the idf of all conducted interview transcripts to score the significance of the words in the interviews performed. Moreover, the diverse experiences, job titles, and levels reflect the various usages of terms in the interviews. However, the most important words are generally presented in each interview, particularly the top three words with higher scores than other terms. Red indicates a word of high importance, whereas blue indicates a word with a low score in each interview. Therefore, the highest-scored stemmed terms are IoT, factori, and devic in all interview transcripts Figure 6. However, different scores were observable for each interview, approximately 0.15 for the other most frequent words. Therefore, it reflects the diverse opinions that were discussed in each interview.

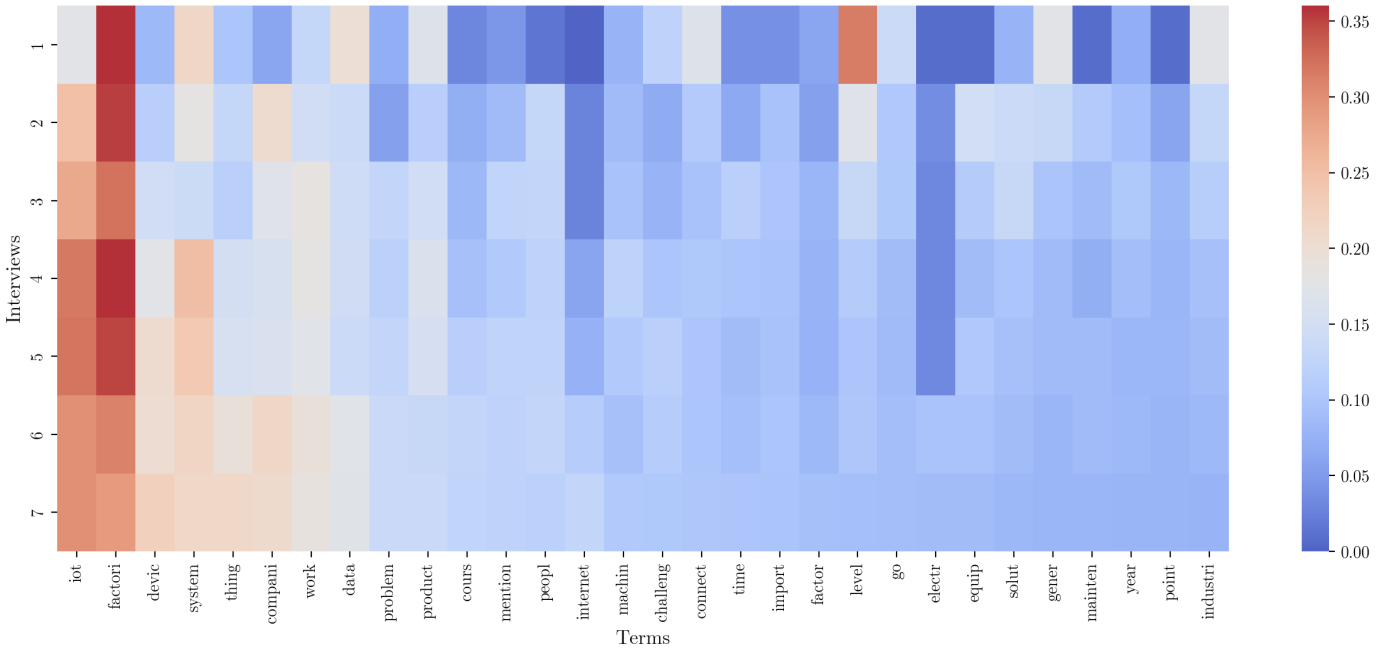

Figure 6. The heatmap diagram shows TF-IDF values of the top 30 terms mentioned in the interview transcripts.

3. Results

This section examines the outcomes of the interview analysis, which identifies three predominant themes: (1) Determinants influencing the successful adoption of the IIoT in SMEs. (2) Ramifications of IIoT adoption on factory productivity. (3) Repercussions of challenging adoption factors on IIoT solutions within the purview of decision makers in manufacturing settings. These themes, which are congruent with the aims and research questions of this study, seek to clarify three critical research inquiries:

- To determine the most influential factors in adopting the IoT and the solutions to overcome the challenge.
- To assess the impact of challenging adoption factors on IoT solutions in the decision makers' factories.
- To determine the effect of IoT adoption on factories' productivity.

This study utilized inductive thematic analysis, in which the categories and themes that emerged from the analysis of the interview transcripts were categorized into refined and interrelated themes. There were no predefined categories or themes. Therefore, the significant statements in each interview were categorized into refined and interrelated themes.

3.1. Theme 1: Factors Contributing to the Successful Implementation in SMEs

This section highlights the points for mandated preconditions for a successful IIoT implementation. This analysis is derived from a review of the interview transcripts, with quotations reflecting each founded theme shown in Figure 7.

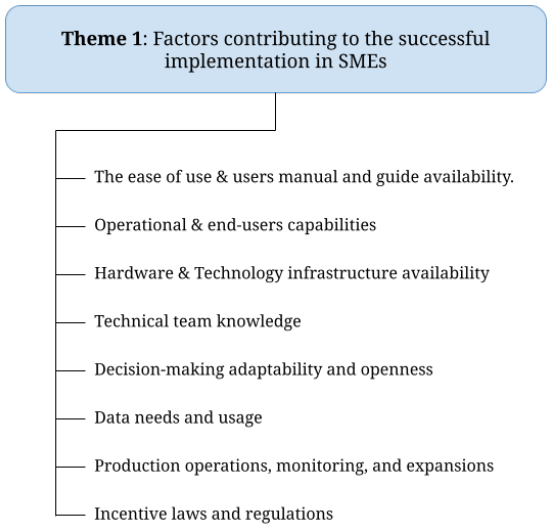

Figure 7. Taxonomy of the first theme.

First, comprehensive manuals explaining the IoT devices and their operations and interactions, including the devices' communication, troubleshooting, data scheme, and device maintenance, can improve the chances for a successful IIoT implementation. Moreover, user-friendly support from vendors and suppliers of IoT devices can ensure smooth technology adoption. As highlighted by a participant,

> "Is there a user manual that explains the interaction between the user and the device? Relationships of technological capabilities related to factory equipment, such as technical specifications and integration. For example, capabilities related to cloud storage capabilities. Furthermore, the capabilities related to the organization's hardware, infrastructure, knowledge, and technology". (Participant 2)

A dedicated technical team with the necessary resources is crucial for ensuring successful IIoT implementation in SMEs.

> "The technical team must have clear tasks to do. Usually, the technical team has several tasks. Some of these are minor and irrelevant tasks, and it is time-consuming to do all these tasks". (Participant 5)

Operational and management capabilities and understanding are other factors that can affect the success of the IIoT in SMEs. Thus, the design of the system architecture, data management, device connectivity, and data analytics must adhere to the organization's operational abilities, embracing the IIoT project.

> "Operational and management capability are divided into several areas, including how the IoT devices are used and the system is built. However, formulating the system, managing it, and integrating data require consideration. For example, how do you connect devices with some controller and analyze the data analytics?" (Participant 6)

Production efficiency and improvements enable the adoption of IIoT solutions. Automated data collection and analysis can enhance SMEs' business practices. By integrating the IIoT, the data collection process, usually performed manually, can be improved and automated by integrating the IIoT into the different systems in the organization. Therefore, dependable data storage solutions are crucial for the data stream generated from the

various devices and the significance of the collected data. These data are required for the long term. Therefore, a suitable storage solution for different data types is crucial. Daily decisions require up-to-date data; long-term decisions require efficiency and compressed data that can be saved on-premise or as promised. Participant 3 stated one of the factors in adopting IIoT solutions in SMEs:

> "Currently, each production line has three or four sensors on each machine to collect data; in contrast, holding a paper and pen to write all this information will be time-consuming; thus, we are forced to apply IoT". (Participant 3)

Challenges appear when decision making is centralized, with top management resistant to change. Therefore, educated and informed decision makers who foster change and adopt new technologies such as the IIoT are mandated. Moreover, empowering employees with technical knowledge to contribute their expertise in their work environment is crucial to ensuring the successful adoption of the IIoT.

> "One person controls the company, and all employees have nothing to do but listen, particularly if this person is from an uneducated background, is a non-academic person, or is interested in making profit only". (Participant 3)

The following quotes highlight the transition from manual to automated data collection. Moreover, Participant 3's statement highlights the amount of data and their long-term use. The IIoT requires data collection and storage, and ensuring the suitability of data management strategies is crucial to IIoT implementation. It enforces the need to consider efficient data collection and storage.

> "We have ceramic design images and printable files. For ceramic tile printers, each image is approximately 6 GB. The amount of data required to be handled in an IoT system must to be considered. You will receive files that can be stored and used for years". (Participant 3)

> "The existing devices and the information they produce force us to use IoT systems". (Participant 3)

The benefits of the IIoT for SMEs include improving production line output. Thus, it enables the minimization of risks, refines operations, and amplifies productivity by ensuring no disruptions caused by IIoT implementation. Pursuing these technologies that enable real-time monitoring and control that sharpens production oversight and operational efficiency is vital.

> "If it does not cause a loss in production and the factory assets, then it is one of the three most significant factors that can push me to implement the IoT system". (Participant 7)

> "We have approximately nine production lines operating 24 hours, seven days a week throughout the year. Four production lines will start work within the next three months". (Participant 3)

3.2. Theme 2: Benefits from Implementing IoT Solutions

Figure 8 represent the second theme that emerged from collected interview transcripts and lists the potential benefits of implementing IIoT solutions in SMEs. The following are quotes from the interviews and reflections on each point discussed during the interview.

Implementing IoT solutions in factories can offer benefits that positively impact operations and production, including the ability to predict and mitigate calamities. By utilizing the IoT, factories could proactively respond to potential disruptions by providing raw materials and energy requirements. This can also help in natural disasters, such as storms or blackouts, allowing quick recovery and minimizing any further impacts on production capabilities.

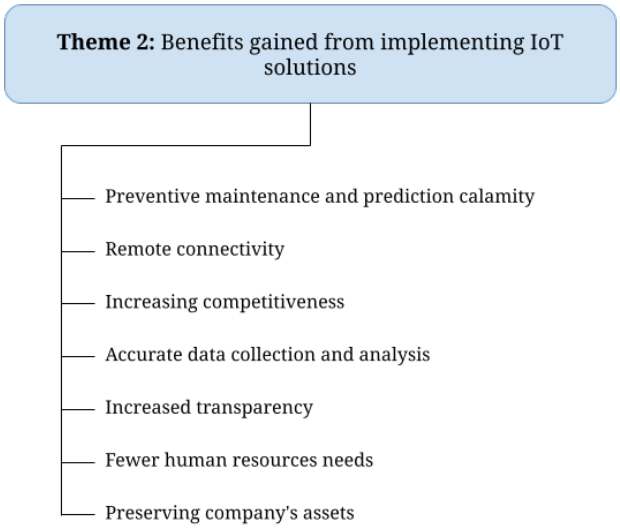

Figure 8. Taxonomy of the second theme.

> "Connectivity is at the core of any manufacturing transformation program in general". (Participant 6)

The IoT enables enhances connectivity between devices and workstations, eliminating manual linking and streamlining operations. Additionally, it facilitates efficient communication and data exchange, improving overall productivity and efficiency in the manufacturing process. Cloud connectivity, computing capability, and storage capacity can significantly impact the requirements for implementing the IIoT. For example, businesses can leverage the cloud to enhance data processing, storage, and accessibility, improving the efficiency and scalability of the SME's operations and capabilities.

> "Cloud connectivity, cloud computing, and cloud storage can accelerate the ease of implementation of the IIoT". (Participant 2)

Another advantage of implementing the IIoT was enhancing competitiveness and adaptability. By embracing IIoT technologies, factories positioned themselves to meet the evolving needs of the latest generation and university graduates, ensuring long-term relevance and growth.

> "Increase the competitiveness of factories in the future". (Participant 1)

By capturing real-time data, companies can gain valuable insights to make informed decisions without minimizing their dependency on traditional processes such as meetings or manual data collection and analysis. Moreover, it can improve communication between different stakeholders in SMEs, such as factory floor employees and management. Real-time updates and immediate communication can facilitate efficient problem solving, improving collaboration and transparency. Thus, SMEs will enhance transparency and strengthen trust by tracking production processes and sharing relevant information with stakeholders.

> "You will discover that zones A or B always have waste in these production areas. Without you going through investigations by asking people and having several meetings... you can make the right decision without all those traditional processes". (Participant 3)

> "The presence of IoT helps keep everyone aware of any progress and problems. Because employees can communicate directly with the factory decision-makers about what is happening and how we can solve the problem, it speeds up communication between the factory floor and management". (Participant 7)

IIoT implementation can create opportunities for young, tech-savvy talents. IoT automation and digitization creates demands of the younger workforce. By automating processes and leveraging IIoT technologies, factories can provide an environment suitable for a young, tech-savvy workforce and increase efficiency, which results in cost savings.

> "Fewer workers are required on the factory floor; thus, fewer workers must be trained. However, more skilled people must be hired". (Participant 1)

Preserving company assets is one of the major appeals of IIoT implementation. By maintaining the existing assets through IoT applications and helping with maintenance, factories can ensure optimal operational conditions and the longevity of critical assets.

> "My goal is to preserve the company's assets through IoT applications. For example, some machines in the production line keep working for fifteen to twenty years; therefore, a solution is required to maintain these essential assets". (Participant 1)

The IIoT is crucial in preventive and predictive maintenance. Preventive maintenance minimizes issues before they happen, which is regarded as predictive maintenance. Predictive maintenance allows factories to identify potential problems before they occur, ensuring equipment's optimal functioning and longevity. Based on the interviews, the maintenance and monitoring activities are usually accomplished manually and conducted with low accuracy. Sensors can collect and monitor this machinery more accurately, yielding enhanced warnings to prevent failures.

> "Preventive maintenance and predictive maintenance means to protect the machines from failure, which can be achieved using the IoT. "(Participant 1)

3.3. Theme 3: Impediments and Challenges Preventing IIoT Implementation in SME Environment

The third theme, as shown in Figure 9, identified from the interview data which share the impediments and chanllegnes of adopting IIoT in SMEs, is divided into three main subthemes: factors related to human elements and those about machinery, both critical in adopting IIoT solutions within SMEs. Hence, the last subtheme in this theme is focused on how to overcome the two subthemes.

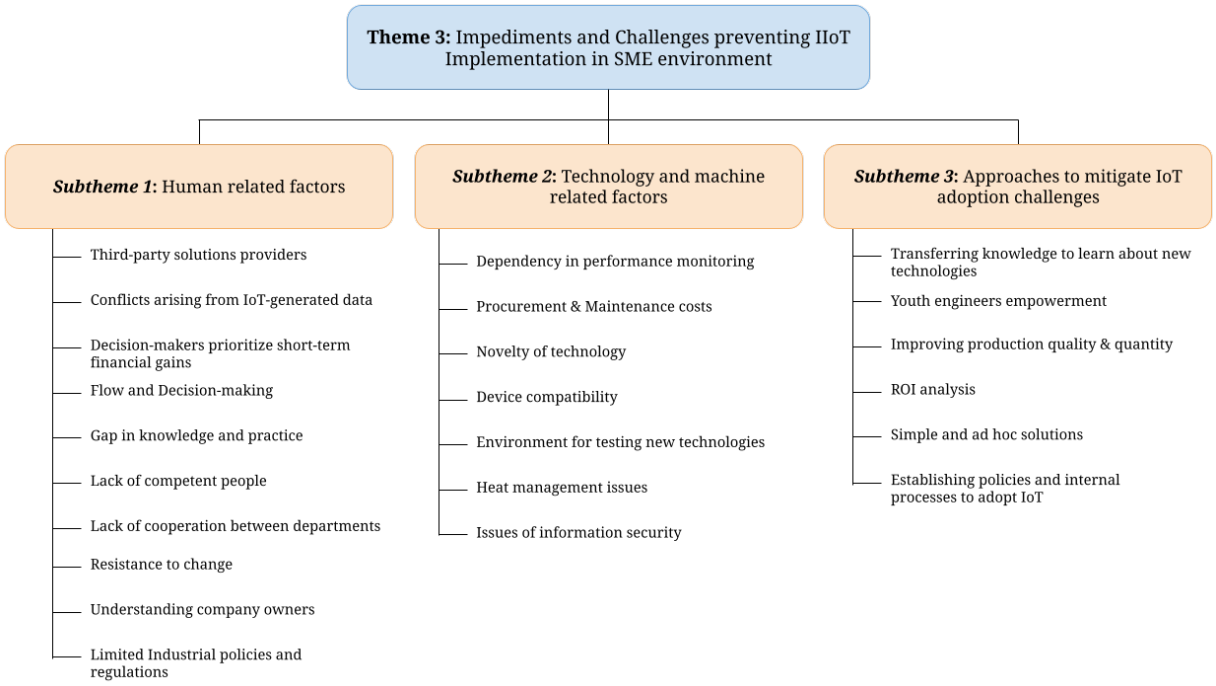

Figure 9. Taxonomy of the third theme.

3.3.1. Human-Related Obstacles and Factors Prevent Implementing IoT in SMEs (Subtheme 1)

Participant 1 stated that one of the challenges was the cost of outsourcing the implementation of IoT systems. For example, in Saudi Arabia, a company can offer integrated solutions for digital transformation for factories, but it is costly to achieve that with the service provider. Additionally, the cost is a significant challenge for IIoT implementation in SMEs. Despite well-equipped electrical and delivery systems, the need for extra infrastructure and data transmission capabilities for digital transformation adds to this barrier.

> "To date, only one company exists in Saudi Arabia offering integrated solutions from A to Z. However, we face challenges with pricing and restricted conditions for their solutions". (Participant 1)

> "One of the most critical elements is the cost... Factories can be well equipped at the level of electrical and data communication systems; the infrastructure of industrial cities is good in many ways, but as far as digital transformation is still lacking, there is a need for more to be done". (Participant 1)

In some cases, decision makers in SMEs prioritize short-term financial gains over the long-term IoT investments required for IoT adoption. The structure of SMEs can affect how fast the company can adopt emerging technologies such as the IoT. Thus, the decision-making flow and process, from the CEO to the end users, can pose challenges. According to Participant 4, the decisions made by high-level executives are lengthy in terms of time to reach the employees who would be responsible for implementing IoT solutions. Therefore, approving the adoption and changes required by IoT implementation on the factory floor can require much time.

> "The owner who wants quick money directly tells you: What will I benefit from this technology?" (Participant 3)

> "The meaning of the flow messages from the head of the pyramid, from the CEO to the end user, worker, or ordinary employee on the front desk. If we decide today, how long it will take to reach all the parties in the flow, and who must receive the message? In the company's case, today, it decided to apply the IoT for a few months to all levels, which may change the decision of the CEO or the decision-maker whose implementation has not reached the bottom of the administrative hierarchy". (Participant 4)

As Participant 2 highlighted, effective IoT systems require skilled workers who can operate and manage IoT technologies. However, SMEs may find recruiting these workers challenging.

> "There is a shortage of skills or a lack of competent people for these operations. Those who can operate this technology are rare in the industry, and few people know the industry". (Participant 2)

Another challenge when implementing IoT solutions is that in some cases, resistance to adopting these changes occurs. This can cause disagreements between different company departments. Cooperation between departments within SMEs is required to ensure a successful IoT implementation. Participant 3 explained that when IIoT solutions lead to the discovery of inefficiencies or waste in a particular department, it can lead to tensions. This may lead to resistance, hindering the collaborative efforts required for successful IoT system deployment.

> "Lack of cooperation between departments because hostilities occur when a particular department has inefficiency or significant problems and you have uncovered them through the use of the IoT. Attempting to implement this creates a fierce hostility between all sections, particularly for the departments with shortcomings". (Participant 3)

The analysis identifies resistance to change within IT departments as a crucial factor, particularly in SMEs that employ enterprise resource planning (ERP) systems. These systems must be updated to ensure continued functionality. However, limited ERP systems provide open-source solutions, which emerged as a significant obstacle within IT departments to ensure compatibility between the existing and IoT systems.

> "There is a resistance issue in IT departments. In many companies and factories, we have ERP software. Unfortunately, some of the software is very old, and it is crucial to update it, but they refuse to open the software source completely. This is one of the obstacles they have now presented". (Participant 1)

Considering the regulations and laws regarding the IoT in SMEs is critical to deploying the IIoT. Organizations must ensure that their implementations adhere to the rules concerning device imports, operations, and data privacy and protection.

> "Regulations and laws are relevant within the organization or the country of manufacturing the IoT devices, operating devices, or operating power means required to operate the IoT. These three needs involve knowledge capabilities, technical capabilities, or, say, administrative capabilities, systems, and laws". (Participant 2)

Knowledge of the technology presents a challenge for the adoption of the IoT in SMEs. Thus, experts with theoretical and practical experience deploying and implementing IoT solutions are needed to ensure their success.

> "It is rare to find anyone with theoretical knowledge and, at the same time, practical knowledge of this technology". (Participant 2)

The previous challenges and factors preventing the implementation of the IoT in SMEs include complex solution providers, conflicts arising from IoT-generated data, cost considerations, short-term financial priorities, decision-making processes, knowledge gaps, lack of competent individuals, departmental cooperation issues, lack of encouragement and economic incentives, insufficient understanding, resistance to change, specialized technical requirements, and other specific factors. Overcoming these challenges is crucial to successfully adopting the IoT in SMEs and harnessing its benefits.

3.3.2. Technology and Machine-Related Obstacles and Factors Prevent the Implementation of IoT in SMEs (Subtheme 2)

Several obstacles hinder the implementation of the IoT in SMEs, such as the dependency on human monitoring for performance assessment. As Participant 2 explained, this leads to limited benefits and makes it challenging to scale when designing and implementing IoT systems.

> "All are human-based; one person watches and monitors the data on the computer. This reliance on human intervention limited the efficiency and scalability of IoT systems". (Participant 2)

Moreover, the limited availability of devices compatible with the current market poses challenges for IoT integration with SME machinery and infrastructure. Participant 2 highlighted this issue in their interview.

> "The devices I have or those in the market are unfortunately incompatible with purchasing devices from other vendors to fit in the ecosystem. Unfortunately, this is the state of the market currently in the Kingdom, but compatible devices are limited". (Participant 2)

Robust testing for IoT integration is another criterion for ensuring the success of its implementation. However, it must be tested to ensure mitigating risks, such as the safety and efficiency of current machinery on the factory floor. These tests are crucial for risk mitigation and guaranteeing uninterrupted operation.

> "Without considering the risks, you cannot create IoT solutions because it requires a full test before it gets down to work". (Participant 5)

Maintenance of existing equipment and the acquisition of new machinery were additional burdens. Participant 1 emphasized that many factories needed more time to upgrade or replace their equipment to accommodate IoT systems or digital transformation. Thus, if IoT systems need to modify existing machinery or production line hardware, it may cause delays or be disregarded.

> "Most factories, from what I know, are happy if they have good maintenance services. However, they are not ready to upgrade these machines and will not bring new equipment. Consequently, digital transformation and the application of the IoT are being held up or delayed". (Participant 1)

Participant 3 highlighted that the environment can affect the implementation of IoT devices. The high-temperature functions, such as a heater, create a harsh environment for many electronic devices. These extreme temperatures can lead to IoT devices' failure, as they are often not designed to withstand such conditions. This problem emphasizes the physical environment that can affect the IoT hardware, which requires consideration of rugged IoT devices that can operate reliably in environments with high heat, stressful repetitive readings, and harsh chemical environments.

> "The first and biggest problem is heat. The high temperature works in our factory like a heater. Devices can fail or die under extreme temperatures". (Participant 3)

In addition, information security is a critical issue that must be considered. Participant 4 highlighted the need for security measures to safeguard IoT systems and the sensitive data they generate. Strengthening security measures is vital for building trust with stakeholders and protecting against cyber threats.

> "Information security is crucial in the IoT. We must ensure our systems and data are secure from potential breaches". (Participant 4)

3.3.3. Approaches to Mitigate IoT Challenges (Subtheme 3)

The understanding of individuals and the collective knowledge of organizations are crucial to successful IIoT implementation. Organizations must seize the opportunities and eliminate the obstacles, ensuring effective implementation. However, individuals responsible for implementing these solutions must acquire the required skills to commission IoT technologies in their workplaces. Thus, adequate training and workshops are required to provide practical insights and procedures to guarantee a successful IIoT commission. Tech-savvy employees in SMEs often find it trivial to adopt IIoT systems in their workplaces. However, this can be challenging for another workforce, indicating the increasing reliance on high technical skills because IIoT solutions can alter the processes in SME factories. Therefore, proposing workshops can benefit SMEs by educating different levels of stakeholders.

> "The use of the IoT in the industrial sector depends on several capabilities. These capabilities are divided into knowledge capabilities related to the organization and individuals". (Participant 2)

> "Factories usually outsource IoT deployment to international companies from abroad because they already have the experience and skilled people to build the system. Subsequently, the factory workers will follow and use the system as it is. I do not see significant challenges in adopting technology for workers because the labor force that requires manual skills will be significantly reduced, and most factory workers will depend on technical skills, computer things, and other things. It will be easy for them to match the IoT system". (Participant 7)

> "We must give young people a chance to work and let them experiment in some companies. Technical programs for designing hardware and software systems must be provided. At least three to five years of training and fully developing skilled workforce assets". (Participant 1)

Enabling youth workforce involvement by providing an inclusive environment is crucial for employing innovative solutions such as the IIoT. Another crucial factor is providing generous training programs to deploy IoT solutions to ensure sustained development and successful implementation. Moreover, it is essential to enable them to implement and design IIoT systems in their workplaces.

> "We must give young people a chance to work and let them experiment in some companies. Technical programs for designing hardware and software systems need to be provided. At least three to five years of training and fully developing skilled workforce assets". (Participant 1)

Cost-effectiveness is crucial when planning to adopt the IIoT. Thus, by implementing IIoT solutions within the specific budget that the cost of development and deployment will cover, the SME stakeholders will be motivated to invest in this technology. Thus, affordable and effective results are a top priority. For example, using an affordable IoT kit on legacy machinery such as compressors can be a significant benefit in allowing for early warnings and timely maintenance, reducing the costs associated with equipment failures, compared to replacing new machinery with IoT sensors and technologies, which will cost more than adopting ad hoc solutions.

> "If the cost we pay by implementing the IoT system is what we will reap from sales, then it is feasible to adopt it". (Participant 7)

> "Effective and cost-effective steps can be taken in these areas. Using IoT kits installed on the compressor can help mitigate any failure that could occur and provide an early warning". (Participant 1)

Adopting the IIoT in SMEs to increase production output is beneficial. Moreover, the IIoT can help optimize production, automate repetitive tasks, and minimize downtime. This leads to faster production cycles, efficient meeting of customer demand, and a competitive edge over other competitors for SMEs adopting the IIoT.

> "It improves production by speeding up the output rate from the production line". (Participant 7)

The analysis of return on investment (ROI) and the ability to integrate with software used on-premise is critical in adopting IoT systems. Companies assess the financial feasibility of implementing the IoT by evaluating the expected returns and considering the existing investment in software integration. This analysis helps determine the IoT's potential benefits and values for the business.

> "It depends on the ROI and the current investment in software integration". (Participant 6)

Two options for adopting IoT technologies in SMEs include retrofitting or replacing equipment, which is the primary consideration when implementing the IIoT. Retrofitting existing equipment with IoT capabilities by adding IoT sensors and actuators can effectively minimize the costs of creating new machines with IoT capabilities. Thus, companies can save and leverage their infrastructure while benefiting from IoT functionalities. Businesses without skilled IT workers can have challenges when employing this method. Retrofitting involves more than a one-size-fits-all approach or solution to the same problem [25]. Thus, it adds complexity to retrofitting the old machinery into IoT-capable devices.

> "Retrofitting IoT solutions for the company is a temptation. Its development is tempting because it seems to reduce costs, avoid throwing away equipment, and bring other new equipment that will be expensive". (Participant 4)

Adopting IoT solutions in SMEs to establish internal corporate divisions that tackle and address IoT challenges by dedicating a team or divisions to focus on IoT implementation, management, and organization is another way of overcoming these challenges. This ensures the allocation of resources and expertise to drive successful IoT projects. However, if that is not viable, an expert team or company must be outsourced to ensure the success of implementing IoT solutions despite the usual high costs for SMEs.

> "This can be achieved only by building internal divisions and contracts. Outsourcing expert professional companies can be costly and may strain the companies' budgets". (Participant 1)

4. Discussion

The first theme addressed various factors influencing the adoption of the IIoT, which has two subthemes. The first subtheme identified the factors that can accelerate the implementation of IIoT solutions in SMEs, such as the availability of manuals and guides for installation that influence seamless implementation. Second, the availability of hardware and technology to implement IIoT technologies can affect the adoption of the IIoT in SMEs [4]. Third, the technical team must know how to implement and design solutions in SMEs, as highlighted by numerous studies emphasizing the significance of technical teams in understanding IoT implementation [6]. Additionally, decision making can be open to adopting and embracing IIoT solutions. Moreover, data requirements and usage are other factors that can help to necessitate the importance of IIoT implementation, and considering these needs helps ensure the success of IIoT solutions implemented. The IIoT can enhance production operations and monitoring needs. Finally, in some cases, government regulations and incentive programs can help SMEs adopt IIoT solutions [26]. The second subtheme focused on ideas for mitigating the challenges of adopting IoT solutions. First, SMEs must receive training on cutting-edge technologies. Moreover, by understanding and embracing the challenges of implementing the IIoT, the ROI from IIoT-adopted operations can encourage SMEs. Finally, it is essential to have policies and processes that consider IIoT solutions.

The second theme highlighted the benefits of implementing IoT solutions. The first benefit is regarding the prevention, maintenance, and prediction of calamities utilizing the sensors and the data analysis from IIoT systems. This extends to other benefits, such as preserving the company's assets by sensing potential issues regarding critical devices in the production line. Moreover, it can help with accurate data collection for the production pipeline. The precise data can be related to increased transparency in SMEs [27]. However, reduced human resources benefit stakeholders, such as the owners and senior management.

The third theme focused mainly on the challenges preventing or delaying the implementation of IIoT systems in SMEs. This theme was divided into two main categories: (1) human-related factors and (2) machine-related factors. The top human-related factors included stakeholders' decision-making processes regarding IIoT implementation and the shortage of skilled personnel capable of executing the solutions [28]. The decisions made by stakeholders were crucial because they significantly influenced the implementation of IoT solutions within SMEs. The second major factor was the need for skilled workers, highlighting the necessity for technical expertise to implement these solutions and navigate successful applications. Consequently, adequate training is crucial for the existing workforce to equip them with the required technical skills and solutions.

The next part of the discussion is to validate the consistency of thematic analysis and NLP in Section 3 and the factors ranking. The ranking was presented to the interviewees during the structured questions segment of the interviews. In addition, it is noticeable that the decision making by stakeholders and top management is the dominant factor that ensures the success of IIoT implementation in SMEs. This confirms previous studies that investigate the adoption of the IoT in manufacturing [15,17]. Similarly, the availability of skilled personnel is noticed during the quantitative analysis of the interview transcripts and in the ranking, which emphasizes its importance in ensuring a successful implementation.

This convergence from the different analytical approaches is quantitative by examining the transcripts with thematic analysis and qualitative using the ranking and the NLP approach. This holds for a considerable number of cases of development and deployment of software systems. Human-related factors greatly influence the successful deployment and usage of the system.

Machine-related factors, such as the need for maintenance upgrades and compatibility with specific machines, were also mentioned. These factors were assigned a lower priority than human factors. In addition, policy-related factors such as privacy and security were identified as potential influencers of IIoT implementation. At the end of each interview, the interviewees subsequently ranked several factors, as illustrated in Figure 10, which shows the elements that have the most significant impact on the implementation process of the IIoT in SMEs. The *x*-axis represents the individual interviewee, whereas the *y*-axis on the left shows the factors stated. The right side indicates the rank, where one is the highest influencing factor and ten is the lowest.

Figure 10 shows the factors categorized into two main groups: human-related and machine-related components. From the thematic analysis and ranking questions, human-related factors were ranked higher, while machine-related factors were assigned lower rankings. For example, decisions made by stakeholders can either accelerate or hinder the implementation process, emphasizing the need to educate these decision makers about the potential impacts and benefits of the IIoT. Moreover, for machine-related factors, an observation from the study identified that devices and solutions were obtainable for IIoT implementation. However, these often require better standardization and resources for effective implementation within SMEs with limited skilled workers and resources. This highlights the demand for more resource-efficient IIoT solutions tailored specifically to this sector, facilitating broader adoption of these technologies.

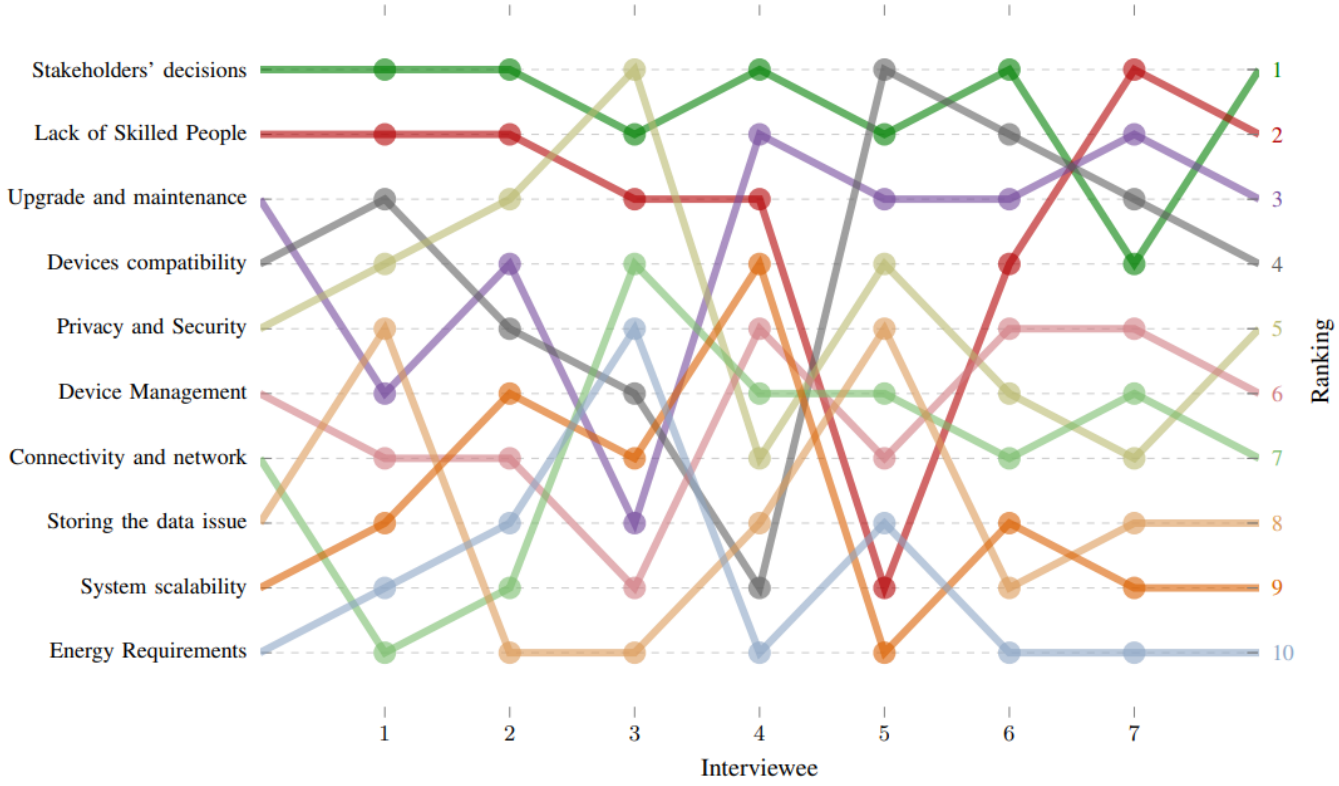

Figure 10. Bump chart shows the factors ranking by the interviewees, where the most influential factor affecting IoT implementation is 1, and the least is ranked 10.

Significant opportunities are limited by challenges such as decision-making openness and willingness to adopt IIoT solutions, the demanding technological infrastructure and knowledge required for IoT integration, and the need for customized IoT solutions for each SME. Decision makers' reluctance often poses high barriers to SMEs adopting IIoT solutions. The necessity for specific IoT applications and the deficit in technical knowledge within the workforce also restrain adoption, highlighting the significance of targeted training and upskilling. The IIoT's potential to revolutionize SMEs can only be realized by overcoming these challenges through enlightening decision makers, taking educational initiatives, implementing supportive governmental policies, and fostering a cultural shift towards technological adaptation.

5. Conclusions

IIoT implementation offers benefits; however, understanding factors that prevent successful implementation can benefit SMEs aiming to integrate the IIoT into their operations. The thematic analysis performed in this study revealed several themes that highlight the aspects that could influence the implementation of the IIoT. We identified mainly human- and machine-related factors that deter the implementation. Foremost, top management or decision makers need to understand the benefits and the ROI in their workspaces to authorize the implementation of these solutions. Another significant obstacle for SMEs is the need for qualified people capable of effectively managing and deploying IIoT systems. In addition, this study identifies several machine-related challenges, such as device compatibility, management, and data storage. Since the human factors highly influence the success of executing the IIoT in SMEs, as a future research direction, it is noteworthy to investigate the decision-making processes and tools that enable top management of SMEs to evaluate and plan for IIoT adoption based on their requirements. Finally, evaluating the organizational changes that occur when implementing IIoT solutions in SMEs is noteworthy.

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