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Research Article

Implementation of Internet of Things Integration in the Manufacturing Value Chain: A Comprehensive Study in Piping Industry

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Abstract

The value chain process has significant importance in the manufacturing industry for achieving operational success. In order to mitigate errors, it is essential for manufacturing firms to optimize their operational processes with utmost efficiency. The Internet of Things (IoT) is a technology that effectively enhances operational excellence inside enterprises. In order to actualize the Internet of Things (IoT), it is essential for the industrial sector to actively participate in and effectively incorporate this technology into its routine operations. Numerous studies have been undertaken to explore the possibilities of the Internet of Things (IoT) for various enterprises. Nevertheless, the use of IoT remains limited in several sectors, such as the Manufacturing industry in poorer nations. The objective of this article is to identify and assess the elements that have an impact on the adoption of Internet of Things (IoT) in the manufacturing sector of Malaysia. Additionally, a proposed model for the implementation of IoT in this industry will be presented. The identification of drivers was conducted by means of a comprehensive analysis of prior examinations. Additionally, a paradigm known as the technology-organization-environment (TOE) framework is suggested, drawing on the idea of information system adoption. The Delphi approach was used to conduct a survey among users of the Internet of Things (IoT), and the findings revealed that the selected parameters examined in this research had a noteworthy influence on the deployment of IoT within the manufacturing sector of Malaysia. This study aims to facilitate the comprehension of Manufacturing organizations about the many facets of Internet of Things (IoT) implementation. It seeks to enhance their business structure and investment in IoT, while also serving as a source of inspiration for researchers to delve into further research on novel factors related to IoT adoption or implementation.

***Keywords**:* Internet of Thing; Valur Chain; Manufacturing

1 Introduction

The manufacturing sector plays a pivotal part in the socio-economic progress and advancement of a nation. Over the course of recent decades, the sector has undergone several transformations aimed at enhancing operational effectiveness and fostering competitiveness within the market. In recent times, the manufacturing sector has seen significant transformations due to the emergence of many technologies such as cloud computing, cyber-physical systems, wireless sensor networks, big data, and the internet of things (IoT).

Consequently, the Internet of Things (IoT) will assume a significant role. Consequently, industrial organizations have transitioned into a new phase characterized by the emergence of "Big Data," whereby the magnitude, speed, and diversity of data under their management are experiencing exponential growth (GE Intelligent Platforms, 2012). Embedded technology facilitates the interconnection of many things via the Internet of Things (IoT), hence facilitating the acquisition of extensive data. This data may be immediately used to enhance the notion of Big Data (Sam Bourgi, 2015). There has been an increasing prevalence of sensors being integrated into a wide range of gadgets, industrial tools, plants, automobiles, and manufacturing equipment (Mourtzis et al., 2021).

While numerous studies have explored the benefits of IoT in enhancing operational efficiency and reducing downtime (Hakim et al., 2023), few have examined its impact on the flexibility and responsiveness of manufacturing systems to market changes (Yacob, 2020). This gap presents an opportunity to investigate how IoT can be leveraged to improve adaptive manufacturing processes. Most of the research to date has concentrated on the technical implementation of IoT devices and sensors (Villa-Henriksen et al., 2020). However, there is a significant gap in understanding the socio-technical challenges and organizational changes required for successful IoT integration in manufacturing environments (Cranmer et al., 2022).

Our research fills the gap in understanding the socio-technical challenges of IoT integration by examining both technological and organizational factors. Through a comprehensive case study approach, we provide insights into

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the necessary changes in management practices and workforce skills to achieve successful IoT adoption.

In the realm of digital transformation, businesses are presented with unprecedented opportunities to establish novel connections and cultivate value. A pivotal enabler of this transformative process is the widespread adoption of the Internet of Things (IoT) technology. By embracing IoT, companies can embark on a data-driven voyage, reshaping the way they operate. As noted by Mourtzis et al. (2021), this paradigm shift empowers organizations to harness the potential of data, gathering and scrutinizing information at various touchpoints along the value chain. In essence, the value chain serves as the quintessential framework wherein businesses orchestrate the conversion of raw materials into finished products, imbued with utility. Within this intricate process, the paramount objective is to not only create value but also capture it effectively. The litmus test of a company's prowess in this regard is the profit margin achieved after accounting for the cost of value creation. Profoundly, the more proficiently an organization generates value, the more auspicious its prospects for profitability become.

In the fiercely competitive landscape of global manufacturing, maintaining an unwavering commitment to both quality and productivity is non-negotiable. These twin pillars serve as the bedrock upon which a company's competitive advantage is built. Invariably, a consistently high standard of quality and unwavering productivity levels stands as the linchpin of success, ensuring that a business not only thrives but also thrives on a global stage. Adoption of IoT in the process of the value chain will result in new manufacturing processes characterized by networked, intelligent production technology and founded on digitization. IoT will control, organize, and optimize each stage of the value chain through the networking of all systems involved in production, the availability of real-time data on every work item and all resources, and the capacity to determine the optimal value stream based on this data.

The Internet of Things (IoT) has gained significant recognition worldwide in recent years. Nevertheless, there is a lack of knowledge among industrial businesses in Malaysia about the influence of information technology. According to recent polls conducted by Gartner, the significance of the Internet of Things (IoT) is generally acknowledged; yet, the current adoption rate among enterprises remains relatively low, with fewer than one-third of them now using IoT solutions. This observation suggests that the use of IoT is still at an early stage of development. The successful integration and use of Internet of Things (IoT) necessitates significant organizational transformations. Olsson & Yuanjing, (2018) conducted a study. However, the literature research revealed that the examination and identification of the deployment of IoT in value chain industrial activities have not been extensively explored. The limited understanding of the Internet of Things (IoT) is expected to have an impact on the adoption of IoT technologies within the industrial sector in Malaysia. Before making the decision to implement IoT, it is important to have a deeper understanding of the factors that drive its acceptance.

2 Methodology

Therefore, with respect to these challenges, this study aims to investigate the factors that impact the application of the Internet of Things (IoT) in order to enhance value chain efficiency within the manufacturing sector in Malaysia. This article examines the agreement among experts about the evaluation of success factors in the deployment of the Internet of Things in the manufacturing industry. The objective of this research is to develop a model for making decisions on the implementation of the Internet of Things (IoT) in the manufacturing sector of Malaysia. This will be achieved by using the Technology-Organization-Environment (TOE) framework. The document facilitates the attainment of the specified research inquiry.

RQ1: What are the factors that affect the success of IoT adoption in Manufacturing, and how important are the factors that were found through a literature review?

RQ3: What are the primary factors and their respective weights in determining the success of IoT adoption in the industrial sector?

The Delphi Method was employed as the methodology for this study, offering a suitable approach to grasp the factors influencing the adoption of Internet of Things (IoT) technology. It does so by acknowledging the valuable input of professionals in the field while recognizing that the perception of reality can vary among individuals. The foundation of this method can be traced back to its original development by Helmer and Dalkey in the early 1950s during their time at the RAND Corporation, with the primary aim of predicting future trends (Hartman, 2016).

In this research, a composite approach was utilized to assess consensus among the participants, as also deployed by (Rahimah K., 2022). The criteria for establishing consensus encompass the following:

a) At least 51 percent of participants rate the item as "highly important" on a 7-point Likert scale, which ranges from 6 to 7.
b) The interquartile range (IR) should be less than 2.
c) The standard deviation (SD) should be less than 1.5.

The criteria mentioned above were used to assess the degree of consensus among the participants with regards to the significance of several elements associated with the deployment of Internet of Things (IoT) technology. The Delphi method seeks to gather perspectives from a diverse group of experts, without necessitating their physical presence in a formal conference setting. The controlled feedback method often involves providing a structured summary of the intentionally disseminated prior iteration. This allows responders to provide more insights and provide comprehensive explanations of the information obtained in the previous iteration. This approach aims to encourage participants to adopt a problem-solving orientation, provide more insightful perspectives, and mitigate the influence of noise, such as data distortion resulting from personal or communal biases (Hsu & Sandford, 2019).

Table 1
Breakdown number of participant returned survey.

Manufacturing Expert					Technology Expert		Total participants
Manager	Assistant Manager	Executive/ Specialist	Senior	Other	Senior	Executive/ Specialist	
3	3	14	4	3	1	2	30

2 Result and Discussion

3.1 Factor influencing Internet of Things Implementation

The researcher conducted a literature study and used qualitative content analysis to identify the key elements that impacted the adoption of the Internet of Things (IoT). These factors, together with their respective definitions, are shown in Table 2. The factors may be categorized into three groups under the TOE framework.

Table 2
Factor influence IoT Implementation

Key Determinant	Definition
Security	The concept of security encompasses the maintenance of an acceptable degree of risk. The buildup of threats and the inadequacy of their effects give rise to a potential risk (Stosic & Velickovic, 2013).
IT-Infrastructure	The IT infrastructure encompasses technological elements, including communication technology and data, that are used by employees with technical and management expertise to provide standardized and collaborative services (Nyrhinen, 2006).
Firm size	Business size is a measure that quantifies the total count of employees working within a specific business entity. In essence, it provides a comprehensive assessment of the workforce employed by the business (Karlsson, 2021).
Cost Effectiveness	Cost efficiency refers to the evaluation of an institution's production costs in relation to the deployment of IoT and related technologies (Ashton et al., 1998)
Competitive Pressure	The impact of competitive pressures on enterprises' drive to develop their goods and operations is well recognized (Boone, 2000)
IT expert	An someone with specialized knowledge that establishes them as an authoritative figure or expert, supported by relevant experiences in IT technologies (Eraut, 2005)
Top Management support	Top management support inside a company may be characterized as the extent to which individuals comprehend the significance of the information system function and actively engage in the IT function (Jitpaibon & Kalaian, 2005)
Technology readiness	The anyone's propensity to embrace and use the new technologies either for own use or to society use. It allows the sources of motivators and inhibitors of new technologies to be understood (Martins et al., 2016)
Relative advantages	The concept of relative advantage pertains to the frequency with which an invention is deemed superior than its predecessor (Raharjo & Perdhana, 2012). It has been noted that Rogers (2003) provides a description of relative profit as an economic measure of profitability that signifies social worth. The indicators used in this variable include business potential and customer service.
Scalability and flexibility	Scalability a highly sought-after attribute in networks, systems, and processes (Bondi, 2000). A flexible system is characterized by its ability to be configured to execute a variety of activities, including network monitoring queries and network control rules. Additionally, it has the capability to function at different levels of granularity and conduct a wide range of actions (Gupta, 2018)
System Integration	System integration is a collaborative process whereby several entities, including enterprises and other relevant stakeholders, combine intricate technical components, subsystems, software, expertise, information, engineers, managers, and technicians to develop a product that can effectively compete in the market (Hobday et al., 2005)

The evaluation of consensus among experts involves the utilization of two statistical measures: the Interquartile Range (IQR) being below 2 and the Standard Deviation (SD) being below 1.5. Additionally, for a statement to be considered agreed upon, it is necessary for 75 percent of participants to fall within the "Highly Important" or "Strongly Agreeing" category, which corresponds to values 6-7 on a 7 Point-Likert scale. Consequently, it is essential to simultaneously address all three indicators in order to achieve consensus. The responses provided by 30 experts in the first Delphi round and 20 experts in the subsequent Delphi round were assessed to illustrate the need of using this combination.

Similar to the R1 Delphi survey, the R2 Delphi survey demonstrated favorable outcomes, but with the caveat of a prolonged duration of around three months for participants to submit their replies. In order to enhance the dependability of the qualitative content analysis of open-ended questions, R1 employs two auditors who are similar in their characteristics and qualifications. The participants have been provided with the aggregate results of their prior replies from the R1 survey, enabling them to review the material collected and make any necessary adjustments to their judgments.

In a similar vein, the expert participants would assess the relative significance of the first 11 criteria identified throughout the literature review process. As a result, it can be seen that all 11 variables included in the R1 survey exhibit a substantial level of consensus and have contributed to the enhancement of the R1 Delphi survey outcome, as shown by the summary Table 3, R2 Delphi consensus level. Given that the R2 survey has achieved the minimum level of agreement, it is not necessary to conduct any more rounds of surveys since all the requirements of the Delphi approach have been fulfilled.

Table 3
Summary of Delphi Survey

		Std. Dev.		IR		6-7%	
Var	Factor	*R1*	*R2*	*R1*	*R2*	*R1*	*R2*
V1	Security	0.48	0.56	0.00	0.00	0.97	0.93
V2	IT-Infrastructure	0.43	0.46	0.25	1.00	1.00	1.0
V3	Cost Effectiveness	0.45	0.41	1.00	0.00	1.00	1.0
V4	Firm Size	0.90	0.62	1.00	1.00	0.87	0.93
V5	Competitive Pressure	0.61	0.46	1.00	1.00	0.93	1.0
V6	Technology Expert	0.55	0.41	1.00	0.00	0.97	1.0
V7	Top Management Support	0.58	0.35	1.00	0.00	0.93	1.0
V8	Technology Readiness	0.73	0.49	1.00	1.00	0.87	1.0
V9	Relative Advantages	0.53	0.35	1.00	0.00	0.97	1.0
V10	Scalability and Flexibility	0.81	0.46	1.00	1.00	0.87	1.0
V11	System Integration	0.68	0.35	1.00	0.00	0.97	1.0

The Delphi survey results in Table 3 provide statistical measures that reflect the level of consensus among experts regarding the importance of various factors influencing IoT implementation in manufacturing. The table includes the standard deviation (Std. Dev.), interquartile range (IR), and the percentage of experts rating the factor as "Highly Important" (6-7%) for two rounds of the survey (R1 and R2). The table represented 3 key metrics of Standard Deviation (Std. Dev.) for measure the variation or dispersion of the experts' ratings from the mean. Lower values indicate higher agreement among experts; Interquartile Range (IR) represents the range between the 25th and 75th percentiles of the ratings, showing the spread of the middle 50% of the data. Lower IR indicates higher consensus and the percentage of experts who rated the factor as "Highly Important" (values 6 or 7 on a 7-point Likert scale). Higher percentages indicate stronger agreement on the importance of the factor.

3.2 Descriptive Statistic

The researcher has proceeded to the subsequent objective of the study, which entails the formulation of a comprehensive framework for the implementation of Internet of Things (IoT) technology in the industrial sector. The trustworthiness and consistency of the Delphi survey results account for this phenomenon. The components that were deemed to be very important determinants were identified based on a Likert scale with seven points, where a score of 6.0 or above was selected as the threshold. These aspects are shown in Table 4. In order to provide a more accurate description, it might be said that each of these variables satisfies the criteria of possessing an interquartile range below 2.0, a standard deviation below 1.5, and a percentage of experts rating them as "very important" falling within the range of values 6-7. The percentage exceeds 75%.

Table 4
The Significant Factor of Iot Implimentation in Manufacturing

Factor	Mean	Std. Dev	Ranking
TECHNOLOGY			
F1 – Security	6.8	0.56	Supported
F2 - IT Infrastructure	6.73	0.46	Supported
F10- Scalability & flexibility	6.73	0.46	Supported
F11-System Integration	6.87	0.35	Supported
Mean Score : 6.78			
ORGANIZATION			
F4- Firm Size	6.67	0.62	Supported
F7-Top Management Support	6.87	0.35	Supported
F3-Cost Effectiveness	6.80	0.41	Supported
F6-Technology Expert	6.80	0.41	Supported
F8-Technology Readiness	6.67	0.49	Supported
F9-Relative Advantages	6.87	0.35	Supported
Mean Score : 6.78			
ENVIRONMENT			
F5-Competitive Pressure	6.73	0.61	Supported
Mean Score : 6.73			

descriptive statistics presented in Table 4 summarize the importance of various factors influencing the implementation of the Internet of Things (IoT) in the manufacturing sector. The factors are categorized under three main domains:

Technology, Organization, and Environment. Each factor is assessed based on its mean score and standard deviation, with a higher mean indicating greater perceived importance and a lower standard deviation indicating higher consensus among experts.

3.2.1 Technology domain

- Security (F1): Security is highly rated with a mean score of 6.8, indicating that it is a crucial factor for IoT implementation. The standard deviation of 0.56 suggests a strong consensus among experts about its importance.
- IT Infrastructure (F2) : IT infrastructure is essential for IoT deployment, reflected by a high mean score of 6.73 and a low standard deviation of 0.46, indicating substantial agreement among experts.
- Scalability & Flexibility (F10): Scalability and flexibility are critical, with a mean score of 6.73 and a standard deviation of 0.46, showing a strong consensus on its importance for successful IoT implementation.
- System Integration (F11): System integration is the highest-rated factor in the technology domain with a mean score of 6.87 and the lowest standard deviation of 0.35, indicating very high agreement among experts on its importance.

3.2.2. Organization domain

- Firm Size (F4): Firm size is considered important with a mean score of 6.67. The standard deviation of 0.62 indicates moderate consensus among experts.
- Top Management Support (F7) :Top management support is crucial, with a high mean score of 6.87 and a low standard deviation of 0.35, reflecting strong agreement on its significance.
- Cost Effectiveness (F3) : Cost effectiveness is highly important with a mean score of 6.80 and a standard deviation of 0.41, showing a strong consensus among experts.
- Technology Expert (F6): The presence of technology experts is critical for IoT implementation, as indicated by a mean score of 6.80 and a low standard deviation of 0.41, reflecting strong agreement.
- Technology Readiness (F8): Technology readiness has a mean score of 6.67, with a standard deviation of 0.49, indicating a strong consensus among experts on its importance.
- Relative Advantages (F9): Relative advantages are considered highly important, with a mean score of 6.87 and a low standard deviation of 0.35, showing very high agreement among experts.

3.2.3 Environment domain

- Competitive Pressure (F5): Competitive pressure is an important environmental factor with a mean score of 6.73. The standard deviation of 0.61 indicates a moderate consensus among experts.

These mean scores indicate that the factors across all three domains; Technology (6.78), Organization(6.78), and Environment (6.73) are considered highly important for the successful implementation of IoT in manufacturing. The relatively low standard deviations across most factors suggest a high level of agreement among experts regarding the critical determinants of IoT adoption. The highest consensus is seen in factors like System Integration, Top Management Support, and Relative Advantages, highlighting their paramount importance in IoT implementation strategies.

3.3 Statistical analysis

Researchers performed detailed statistical tests including correlation analysis and multiple regression analysis to identify the strength and nature of relationships between the identified factors and the successful implementation of IoT. Table 5 shows the Pearson correlation coefficients among key factors. Significant positive correlations ($p < 0.05$) were observed between IT Infrastructure and System Integration ($r = 0.76$), and between Top Management Support and Technology Expert ($r = 0.68$).

Table 5
Pearson Correlation Coefficients Among Factors

Factor	SEC	ITI	CE	FS	CP	TE	TMS	TR	RA	SF	SI
Security (SEC)	1.00	0.52	0.45	0.38	0.47	0.43	0.40	0.49	0.42	0.50	0.53
IT Infrastructure (ITI)	0.52	1.00	0.60	0.50	0.55	0.62	0.59	0.63	0.61	0.66	0.76
Cost Effectiveness (CE)	0.45	0.60	1.00	0.45	0.48	0.52	0.53	0.55	0.51	0.57	0.61
Firm Size (FS)	0.38	0.50	0.45	1.00	0.44	0.40	0.42	0.46	0.41	0.48	0.49
Competitive Pressure (CP)	0.47	0.55	0.48	0.44	1.00	0.46	0.45	0.50	0.48	0.52	0.54
Technology Expert (TE)	0.43	0.62	0.52	0.40	0.46	1.00	0.68	0.61	0.58	0.63	0.64
Top Management Support (TMS)	0.40	0.59	0.53	0.42	0.45	0.68	1.00	0.64	0.62	0.66	0.68
Technology Readiness (TR)	0.49	0.63	0.55	0.46	0.50	0.61	0.64	1.00	0.65	0.67	0.69
Relative Advantages (RA)	0.42	0.61	0.51	0.41	0.48	0.58	0.62	0.65	1.00	0.66	0.67
Scalability & Flexibility (SF)	0.50	0.66	0.57	0.48	0.52	0.63	0.66	0.67	0.66	1.00	0.68
System Integration (SI)	0.53	0.76	0.61	0.49	0.54	0.64	0.68	0.69	0.67	0.68	1.00

The table provided shows the correlation coefficients between various factors influencing the implementation of IoT (Internet of Things) in the manufacturing sector. Correlation coefficients range from -1 to +1, where values closer to +1 indicate a strong positive correlation, values closer to -1 indicate a strong negative correlation, and values around 0 indicate no correlation. The correlation analysis highlights the interdependencies between various factors influencing IoT implementation in manufacturing. Key insights include the critical role of IT infrastructure in enhancing security, cost-effectiveness, and system integration, the importance of top management support and technology readiness for successful IoT adoption and the significant impact of technology experts on improving IT infrastructure and system integration.

These findings underscore the multifaceted nature of IoT implementation, where improvements in one area can positively influence others, thereby creating a robust and interconnected IoT ecosystem in the manufacturing sector.

3.3 IoT implementation model in manufacturing

To develop a decision-making model for the adoption of IoT, it is necessary to conduct a comprehensive study of the factors that influence the organization. The IoT final decision-making model, as depicted in Figure 1, was developed by utilizing the priority of determinants derived from two rounds of the Delphi survey. The data obtained from the survey was subsequently analyzed using three combination measurements. The TOE framework was integrated into the model as a guiding principle. The development of the 11 impact factors in the model was influenced by three main components: the technical component, the environmental aspect, and the organizational aspect. These components together contributed to enhancing the level of depth and comprehensiveness of the impact factors.

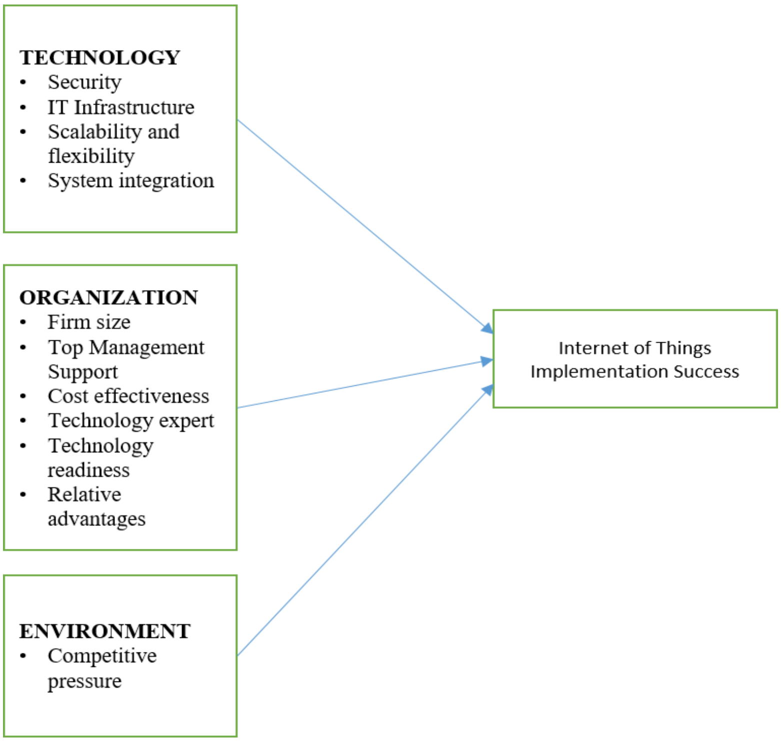

Fig. 1. IoT implementation in manufacturing implementation model

This research aims to investigate the variables that influence the adoption of the Internet of Things (IoT) and emphasize their relevance. The objective is to add to the existing body of literature on the implementation of IoT. This study aimed to address the existing research gap by investigating the implementation of Internet of Things (IoT) in Malaysia's industrial sector. Therefore, it is anticipated that this project would address the existing gap in the literature pertaining to decision tools for competitive operations in the realm of Internet of Things, while also addressing the scarcity of research projects focused on Internet of Things applications within the manufacturing sectors. An further advantage of this study is its potential for cross-industry application.

This study provides a comprehensive framework for integrating IoT into the manufacturing value chain, addressing real-time data analytics, decision-making processes, and adaptive manufacturing operations. By focusing on the integration of IoT across the entire manufacturing value chain, this study provides valuable insights that can help companies achieve greater operational efficiencies and improved decision-making capabilities. By introduces an innovative framework that combines the Technology-Organization-Environment (TOE) model with integrated value chain analysis, offering a unique perspective that enhances the understanding of IoT's impact on manufacturing processes.

The TOE (Technology-Organization-Environment) framework offers a comprehensive approach to understanding IoT adoption, distinguishing itself from other models like the Diffusion of Innovations (DOI) theory, which primarily focuses on the technological aspects. While the

Unified Theory of Acceptance and Use of Technology (UTAUT) is effective in predicting individual technology adoption behaviors, the TOE framework's inclusion of organizational and environmental contexts provides a more holistic view necessary for IoT deployment in the manufacturing sector. Combining the integrated value chain with the TOE framework allows for a more strategic alignment of IoT initiatives with business objectives, ensuring that technological investments are leveraged to optimize the entire manufacturing ecosystem.

Existing research has demonstrated the potential of IoT in enabling predictive analytics, which can forecast equipment failures and optimize maintenance schedules, thereby reducing downtime and operational costs. This framework was chosen over others because it provides a holistic approach, addressing both the technical and organizational challenges of IoT implementation in manufacturing environments. Our chosen IoT framework mirrors the approach used in Bosch's Industry 4.0 initiatives, where IoT solutions have enabled real-time monitoring and adaptive control of manufacturing processes, driving both operational excellence and innovation,

The findings of this study have significant implications for managers and decision-makers in the manufacturing sector. Understanding the critical factors that influence IoT implementation can help organizations to better prepare and strategize for successful IoT adoption. For instance, prioritizing 'Top Management Support' and 'System Integration' can facilitate smoother transitions and more effective use of IoT technologies.

4 Conclusion

The research has successfully identified the constructs associated with influencing variables pertaining to manufacturing and the application of IoT. The research has made an indirect contribution to the advancement of knowledge on the deployment of Internet of Things (IoT) at both the theoretical and practical levels. There has been a suggestion that the proposed model may provide a unique strategy that combines a full array of influential factor constructions necessary for the successful adoption of the Internet of Things (IoT) in the industrial industry. This study is expected to have revealed and expanded new research opportunities for the practical use of IoT. The validity and support of this model have been confirmed by specialists in the field of Manufacturing. The outcomes of this study have the potential to enhance the effectiveness and competitiveness of manufacturing industries. The objective of this research was to ascertain the attributes associated with the use of Internet of Things (IoT) technology within the Manufacturing Industry. Hence, this research endeavor sought to examine the potential use of Internet of Things (IoT) technology inside industrial settings, with the aim of addressing existing operational and systemic constraints. The analysis of benefits and barriers has principally focused on a model for implementing IoT in the industrial sector.

The research not only examines the implications of the Internet of Things in the manufacturing sector, but also explores several other aspects and constraints. The suggested model serves as a roadmap for the implementation of a comprehensive virtual ecosystem that relies on IoT technology, cloud computing, and service delivery. Preliminary testing may be undertaken prior to the comprehensive implementation of a given procedure across the whole of the manufacturing operations. The unique aspect of this research model lies in its dual focus on both technological integration and organizational readiness, offering a more comprehensive framework for IoT adoption in manufacturing. This study's model uniquely incorporates real-time data analytics with IoT deployment, enhancing decision-making processes across the manufacturing value chain.

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