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Examining the effect of Internet of Things (IoT) adoption on supply chain performance

Fahad Zafar [1*]

[*1] *Faculty of Business Administration, Iqra University, Karachi, Pakistan*

**Corresponding email: Zafar12201@iqra.edu.pk*

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ABSTRACT

Data is the heart of the Fourth Industrial Revolution. The growth of the Internet of Things is one of the main reasons behind this (IoT). The Internet of Things (IoT) is a network of interconnected physical items (sometimes known as "things") that are implanted with sensors, software, and other technologies to communicate and share data with other devices and systems over the Internet. However, research on IoT adoption in the supply chain domain is scarce, and its acceptance in industries is also very limited due to the various challenges that come with it. The objective of this study is to gain an understanding of the impact that IoT has on supply chain performance through its integration or adoption. A quantitative approach was pursued in this study, and a questionnaire survey of 200 respondents from the supply chain domain with managerial experience was collected and analyzed using the SPSS tool. The results indicate that IoT positively and significantly affects supply chain performance. Theoretically, this study contributes to the literature about supply chain integration and technologies. This research can help those who want to specialize in IoT and its applications in supply chain management. Organizationally, the research findings tell managers about the potential IoT investment that will lead to a positive supply chain performance outcome.

Keywords: *Internet of things, IoT, Supply chain performance, SPSS, Quantitative Research*

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1. Introduction

Industry 4.0 is currently underway worldwide, building upon previous industrial revolutions. The first industrial revolution introduced steam engines, while the second revolutionized electricity generation and mass production through assembly lines. Industry 4.0 aims to revolutionize computer systems and robotics, introduced in the third industrial revolution, by making them intelligent and autonomous through machine learning and artificial intelligence. These autonomous systems rely on collected, processed, and utilized data or information to generate and execute results. This data flows between systems or devices in a network, leading to increased efficiency, productivity, and reduced waste with the timely availability of accurate data (Baloch & Rashid, 2022).

As mentioned in the introduction above, IoT is the concept and technology of a network of systems, machines, or devices that communicate with each other by sharing data, and it is at the heart of the Industry 4.0 transformation. One of the core technologies that supports or enables communication between the devices, for example, is radio frequency identification (RFID). An RFID system, in its basic form, consists of RFID tags with a unique identification code that transmits signals through built-in antennas that portable or stationary receivers or readers receive. When IoT is complimented by RFID technology and integrated with the supply chain, its benefits are limited to organization-wide information sharing. However, it also assists in reducing the bullwhip effect through the involvement of various stakeholders in the supply chain. IoT adoption can improve operational processes, save costs, and reduce risks due to its transparency, traceability, adaptability, scalability, and flexibility (Chong et al., 2015).

1.2 Problem Statement

Much of the previous research has focused on IOT's impact through adoption on different organizations from various industries and the entire supply chain (Haddud et al., 2017). Those researchers identified the potential benefits or challenges of IOT integration with the supply chain. Other studies examined the aspects influencing an organization's decision to use IOT in supply chain management through perceived benefits and risks (Tu, 2018). There have also been a lot of studies and practices on using IOT technologies, such as QR codes and RFID technology, to accomplish food traceability and ensure food safety in supply chain management (Li et al., 2017). Rejeb et al. (2019) state that supply chain competitiveness can be improved through IOT by allowing for accurate tracking of material movement, resulting in increased effectiveness and efficiency of essential processes and timelines. IOT's impact has also been observed in SCRM through research. Experts have also pointed out that the IOT has excellent scalability, and the ease with which devices can be integrated into its network will help with risk identification (Birkel & Hartmann, 2020). Although most of these studies have been performed in first-world countries with top infrastructure and labour skills, more research is yet to be performed in countries with poor infrastructure and literacy regarding technological advancements, and the impact of IOT on supply chain performance must be examined.

The objective of this study was to help organizations understand the impact that IoT has on supply chain performance through its benefits. Currently, organizations, in general, are hesitant to adopt new technologies due to various challenges. Certainly, IoT has yet to convince many organizations from various industries due to its challenges. However, now that more research is being done to understand its nature and impact, organizations are beginning to realize its long-term potential as a technology driver. Therefore, IoT has become an emerging technology that needs to be pursued. The principal objective of this study was to demonstrate to organizations, especially those in Pakistan, that IOT positively impacts supply chain performance. This study's primary goal was to provide answers to the following questions:

RQ: Does IoT have an impact on supply chain performance?

1.3 Significance of Study

Industries are transitioning to Industry 4.0 solutions to prepare for current and future challenges and meet customer demands in a competitive environment while maximizing profits. These industries are continuously finding solutions to achieve the goals mentioned above. This has resulted in the implementation of IOT technology in the supply chain as a means to boost productivity, efficiency and performance. Regarding past research regarding IOT and its relationship with supply chains, as well as resulting productivity, the focus of this research was an extension of understanding the subject by focusing on different regions, as every region has its socio-economic dynamic. Furthermore, the outcomes of this study contribute to the confirmation of the relationship that IOT has with supply chain performance.

1.4 Purpose of the Research

The main focus of the research was to identify the connection that IOT has with supply chain performance. IoT is an emerging technology that must be widely adopted worldwide due to its challenges and other factors. Most companies that have adopted the IoT technology are located in countries that use modern technologies and have the best infrastructure compared to countries with poor infrastructure. This study has provided an understanding for industries about the overall benefits to the Supply Chain by increased performance when IoT is integrated. The primary purpose of the research was to determine the effect of IOT on supply chain performance.

2. Literature Review

This section seeks to discuss important literature on the research subject. The main objective was to provide an analysis of the existing knowledge related to the research topic by highlighting what has already been done in the field, the new trend, and what the future will be. The existing knowledge can be backed up with citations from other research sources. Owing to its continued expansion across multiple industries and domains, IOT is expected to grow even more and will significantly impact consumers, businesses and societies (Haddud et al., 2017). As a result, this section begins with a brief overview of IOT technology, followed by an explanation of the relationship between IOT and supply-chain through integration or adoption and, ultimately, how that relationship affects overall supply-chain performance. Finally, the Conceptual Framework, along with the hypothesis, is provided.

2.1 Overview of the IOT

Kevin-Ashton introduced the word "Internet-of-Things" 1999 to define the interactions between various electronic gadgets implanted into objects without human input, gathering and saving data (Birkel & Hartmann, 2020). With the emergence and advancement of wireless technologies, sensor equipment and the Internet, IoT has become a robust and intelligent network of systems and devices that can communicate in real-time. As Manavalan and Jayakrishna (2019) stated, a unique aspect of IOT technology is the ability to communicate through a remote location in real-time data. There are four levels to the IOT system architecture. The sensing layer comes first, and its purpose is to configure and calibrate devices to acquire real-time data. This is basically called sensing from the real world. The networking layer is the backbone of the IoT system, and it connects the devices over wireless or wired networks and transmits and receives the data using the Internet. The next is the service layer, a middleware that provides data storage, advanced computing, and analytical capabilities for the data (Rasheed et al., 2024). Lastly, the interface layer is mainly used to display the data in a meaningful form to the users, which then uses the information from the data to make decisions and interact with the system. Radio Frequency Identification (RFID) technology is at the heart of IOT systems. RFID is a non-contact automated recognition system that identifies items or persons in a static or dynamic environment (Yan & Huang, 2008). Tags, antennae, and readers are the components of RFID technology. A unique identification for a product or person bearing the tag is an Electronic Product Code (EPC). Antennas transmit radio-frequency signals between tags and readers,

while readers are electronic devices that accept data from tags.

2.2 IoT Integration with Supply-Chain

Digitalizing the traditional supply chain is referred to as a digital supply chain, also known as supply chain-4.0, and at its core, electronics and sensors power it. Various technologies are utilized in digital supply chains, such as IoT, blockchain, machine learning, and artificial intelligence, and their ultimate goal is to have time tracking, movement, and information sharing throughout the supply chain cycle. Tracking the movement of goods is essential to logistics; therefore, IoT, through RFIDs, plays a vital part. There has been much progress in using IOT across supply chains in recent years. (Abderahman et al., 2019) Stated that IOT has now become widely used as machine automation and Information-and-Communication-Technologies-(ICT) have merged, particularly in logistics and supply chain. With IOT's help, businesses can track their items in real-time and oversee their logistical operations (Sun, 2012). The whole end-to-end process, whether it is an upward or downward stream in the supply chain, is supported by logistics. From procurement of raw materials to its manufacturing to finished goods and then its packaging and shipment to customers, all require adequate planning and management through coordination (Rashid et al., 2024d). The goal of logistics in the supply chain is allocating the correct quantity of resources for manufacturing at the right time and then ensuring that they are delivered to the right customer/consumer at the acceptable price at the correct location at the intended time. This overall efficiency and effectiveness are achieved with proper tracking and information sharing. IOT may aid in transferring more reliable information about quality control, delivery, logistics and manufacturing across multiple supply chain stakeholders (Abderahman et al., 2019).

2.3 IoT Relation with Supply Chain Performance

Despite the numerous obstacles to IOT adoption in the Supply Chain, it is seeing growth as its benefits outweigh its risks, and IOT technology has seen advancement in recent years. IoT can enhance Supply Chain competitiveness by allowing for more accurate monitoring of materials movement, resulting in increased efficiency and effectiveness of critical processes and timetables (Shrouf et al., 2014). IoT can track Supply Chain operations, enhancing visibility, uniformity, detectability, coordination, and shared governance (Reaidy et al., 2015). IoT brings several benefits to supply chain management, according to Ben-Daya et al. (2019), including cost reductions, stock-on-hand accuracy, and tracking of products and shipments. Nevertheless, the level at which IOT impacts supply chain operations is still unknown, and additional studies are being conducted. These researchers have also mainly used the RFID technology, especially in warehouse management and inventory control areas. Mostafa et al. (2019) proposed a framework for order fulfilment in their research through the implementation of IOT in warehouses, which resulted in an increase in efficiency and accuracy while preventing any chances of counterfeiting.

2.4 Conceptual Framework

Based on the above literature review outlining IOT technology and its integration with the supply chain, a theoretical framework was designed, as can be seen in Figure 1, to demonstrate supply chain performance influenced by IOT (Haddud et al., 2017). Because integrating IOT affects the supply-chain performance, the independent variable of the theoretical model is IOT and the dependent variable is supply-chain performance.

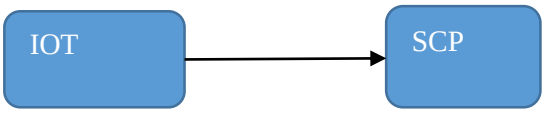

Figure 1: Conceptual model (Source: Author's creation with the support of literature)

2.5 Hypothesis

H 1: IOT has a positive effect on Supply Chain Performance

3. Methodology

This section discusses the research methods used in this study, providing valuable information on participant eligibility requirements, participant demographics, and the data collection techniques employed. The researcher also explains the rationale for choosing the study's research strategy and provides detailed descriptions of the data collection instrument and procedures used. Additionally, the statistical techniques used to interpret the results are discussed. Numerous studies have already documented the influence of IoT on supply chain performance. However, further research is needed to expand on existing knowledge and understanding. Therefore, the nature of this research is explanatory, aiming to explain an existing theory or phenomenon. This type of study helps gather new perspectives on a problem to construct, elaborate, extend, or test a hypothesis (Rashid et al., 2021; Amirah et al., 2024). This study employs an explanatory research technique to understand the relationship between IOT and the supply chain, specifically focusing on whether IOT impacts supply chain performance. The study utilizes a Deductive Approach, which involves formulating a hypothesis based on existing theory and testing it using a research strategy (Rashid et al., 2022a). The Deductive method helps explain causal relationships between variables under study and allows for generalization of research results to some extent (Rashid et al., 2024a; 2024b). Although many studies have explored this topic across various industries and aspects, research has yet to be conducted in Pakistan. This research also considers obtaining the perceptions and observations of industry professionals, which was a limitation in prior research (Rashid et al., 2024d; Rashid & Rasheed, 2023). The insights gained from this research contribute to a better understanding of the advantages and relevance of IOT in supply chain performance. Besides, qualitative research poses a trustworthiness issue (Haq et al., 2023). There, a deductive followed by a quantitative research method is deemed adequate. A causal research approach was chosen to explore the influence of IOT on supply chain performance, as a cause-and-effect relationship exists between IOT and supply chain performance. The study is based on a survey and utilizes data collection through questionnaires (Rashid & Rasheed, 2023). Previous research employed a deductive approach to acquire primary data through an online questionnaire survey. The questionnaire in this study utilizes a five-point Likert scale, a standard method to assess perceptions, views, and attitudes (Rashid et al., 2023; Rasheed & Rashid, 2023).

3.1 Sampling Design

The target population for this research comprises various industrial sectors in Karachi, Pakistan. The research uses simple random sampling, a part of probability sampling where everyone is equally likely to be selected. Simple random sampling ensures a fair representation of the target population (Rasheed et al., 2023). A 202 supply chain managers from different industries were randomly selected for the survey.

3.2 Instrument and Procedure of Data Collection

Previous research has collected data through online sources and questionnaire surveys (Rashid et al., 2022b; Hashmi et al., 2021a; 2021b). Similarly, this research gathers data using structured questionnaires to capture participants' opinions, thoughts, perceptions, and observations. Selected participants were contacted and provided a brief overview of the research objectives. Their consent was obtained before participating, ensuring their personal information and data remained confidential and used solely for academic purposes. Participants were then sent a questionnaire, which they filled out and returned within two weeks (Hashmi et al., 2020a; 2020b).

3.2 Statistical Technique

Regression analysis was used in this study to evaluate the stated hypotheses (Rashid et al., 2020; Khan et al., 2023a). Regression analysis helps determine the correlation between multiple variables and how much an independent variable influences a dependent variable. The specific analysis used in this study was simple linear regression, as the research question involved one independent and one dependent variable (Khan et al., 2023b; Rashid & Rasheed, 2022; Hashmi & Mohd, 2020).

4. Finding and Analysis

4.1 Descriptive Profile of the Data

The demographics of the survey participants are shown in table 1. Males account for 84.7% of participants, while females account for 15.3%. Age group-wise, the majority of respondents aged between 31-40 years is 46.5%, while 40.6% of respondents fall between 41-50 years and only 12.4% are between 18-30 years. Table 1 shows that 73.3% of respondents hold master's degrees, 26.2% are bachelor's, and 1% choose another. From an occupational point of view, the majority of respondents in this study are from a supply chain background and serve in different managerial positions. Many responders (69.8%) had fewer than ten years of professional experience. In contrast, only 2.5 per cent had more than twenty years of experience, compared to 27.7%, who had ten to twenty years of experience.

Table 1: Demographic-Items

Demographic-Items	Frequency	Percentile-%
-Gender		
-Male	171	84.7
-Female	31	15.3
Other	0	0.0
	202	100%
Age		
18-30	82	40.6
31-40	94	46.5
41-50	25	12.4
Other	1	0.5
	202	100%
Education		
Bachelor's degree	53	26.2
Master's degree	148	73.3
Other	1	0.5
	202	100%
Professional Experience		
0-10 Years	141	69.8
10-20 Years	56	27.7
20 and above	5	2.5
	202	100%

Source: SPSS output

4.2 Validation of Model

The IBM SPSS tool was used to analyze the collected data to ensure the model is consistent and reliable. The reliability of the scale used in the survey was determined using Cronbach's Alpha. As per Rashid (2016) and Rashid et al. (2019), for the scale to be considered reliable, Cronbach's Alpha must be greater than 0.7.

4.2.1 Reliability analysis

Table 2: Reliability-Statistics

Cronbach's-Alpha	Cronbach's- Alpha-Based-on-Standardized-Items	N-of-Items
.770	.769	6

Table 2 shows that Cronbach's is 0.77, higher than 0.7; hence, all the items in the independent variable, i.e., Internet of Things (IoT), are reliable (Rashid & Amirah, 2017).

Table 3: Reliability-Statistics

Cronbach's- Alpha	Cronbach's- Alpha-Based-on-Standardized- Items	N-of-Items
.853	.852	6

Table 3 shows that the dependent variable Supply Chain Performance has Cronbach's at 0.853, more significant than 0.7. Therefore, all the items in the dependent variable are reliable.

4.3 Hypothesis Testing

The validity of the hypothesis was examined by applying a linear regression model through the IBM SPSS tool.

4.3.1 R, R-square, and adjusted R- square

Table 4: Model-Summary

Model	R	R-Square	Adjusted-R-Square	-Std.-Error-of-the-Estimate	Change-Statistics					Durbin--Watson
					R-Square-Change	-F-Change	-df1	-df2	-Sig. -F -Change	
1	.630[a]	.397	.394	.45829	.397	130.211	1	198	.000	1.749

a. -Predictors-: (Constant), IoT
b. -Dependent-Variable-: Supply-Chain-Performance

The R and R2 values are shown in the table 4 above. The correlation between the dependent and independent variables is represented by the R-value, which has a high value, suggesting a strong association. According to Hashmi (2022; 2023), correlation coefficients between 0.6 and 0. have a moderate positive relationship. In the above model summary table shown in Table 4, the R-value is 0.630, showing both independent and dependent variables having a moderately positive association. R square reflects how much an independent variable can be explained regarding the dependent variable's fluctuation. It is suggested that R2 values be equivalent to or more than 0.10 to be considered satisfactory (Khan et al., 2022; Khan et al., 2021). Table 4 yields an adequate R2 value of 0.397. Adjusted R square in multiple regressions depicts whether or not extra independent variables influence the model. A minor difference between the R and adjusted R square is feasible. Table 4 shows a value of 0.394, close to 0.397 and thus acceptable.

Table 5: ANOVA-[a]

Model		Sum-of-Squares	-df	Mean-Square	-F	-Sig.
1-	Regression-	27.348	1	27.348	130.211	.000[b]
	Residual-	41.586	198	.210		
	Total-	68.934	199			

a.- Dependent-Variable-: Supply-Chain-Performance
b.- Predictors-: (Constant), IoT

Source: SPSS output

The study is typically conducted with a 95 per cent confidence interval or a significance level of 5%. As a result, for the null hypothesis to be rejected, the p-value must be less than 0.05 (Agha et al., 2021; Das et al., 2021; Haque et al., 2021). The Sig value from Table 5 above is 0.00, which is less than 0.05; hence, the model's result is significant.

Table 6: Coefficients-[a]

Model		Unstandardized-Coefficients		Standardized-Coefficients	-t	-Sig.	95.0%-Confidence-Interval-for-B		Collinearity-Statistics	
		-B	Std.-Error	-Beta			Lower-Bound	Upper-Bound	Tolerance-	-VIF
1-	(Constant)	.887	.307		2.886	.004	.281	1.493		
	IOT	.780	.068	.630	11.411	.000	.645	.914	1.000	1.000

a. Dependent Variable: Supply Chain Performance

Source: SPSS output

The correlation strength is represented in Table 6, i.e., the independent variable's importance and the degree by which the dependent variable is influenced. Overall, this study contributes to the validation of the research hypothesis. As per Alrazehi et al. (2021), the acceptance and rejection of the null hypothesis depend on the significance value being below 0.05 and vice versa. When a hypothesis is accepted, it can be deduced that the independent variable influences the dependent variable. If a hypothesis is rejected, however, no effect occurs. Table 6 shows that the Sig value of independent variable IOT is 0.00, which is less than 0.05. Hence, the independent variable, IOT, significantly impacts the dependent variable, supply chain performance.

Table 7: Hypothesis Assessment Summary

Hypothesis	Result
H1: IOT has a positive effect on Supply-Chain-Performance	Accepted

Source: Based on SPSS output

Because the Sig value of the independent variable Internet of Things (IOT) in Table 7 is 0.00, which is less than 0.05, it can be concluded that there is a significant change in the dependent variable supply chain performance as a result of a change in the independent variable Internet of Things (IOT). With a 1% increase in IoT adoption, supply chain performance will increase by 78%, the B value from Table 6. In conclusion, the hypothesis is accepted, implying that supply chain performance is positively affected by IoT.

5. Discussion, Implications, Limitations, Recommendations and Conclusion

5.1 Discussion

A hypothesis was formed based on the research above, with IOT and supply chain performance being the independent and dependent variables, respectively. After collecting data from respondents through a questionnaire survey, the data was subjected to reliability and regression analysis using the IBM SPSS tool. The degree to which the independent variable impacts the dependent variable is measured, and the extent to which the two are related. Our findings confirm our hypothesis that IOT significantly impacts supply chain performance. This finding supports prior research suggesting IOT may help supply chain processes throughout the supply chain, resulting in increased visibility, uniformity, collaborative decision-making, interoperability and traceability (Reaidy et al., 2015). Prior studies on this topic reported that IoT can improve supply chain competitiveness by monitoring more precise material movement, improving efficiency and effectiveness of essential operations and timelines (Shrouf et al., 2014). The results also suggest that respondents are open to adopting IoT in their industries. Therefore, IoT will expand, substantially impacting consumers, businesses, and societies.

5.2 Implications

5.2.1 Theoretical implications

This study contributes theoretically to works of literature regarding supply chain integration as well as technical literature. The focus of literature regarding supply chain integration is mainly on the practical application of technologies around various supply chain entities, such as procurement, logistics, customer, supplier, and inter-organizational. On the other hand, the technological literature

focuses on new technologies such as AI, machine learning, IoT, and so on. From the academic point of view of students who want to specialize in IOT and its application in the supply chain, this study provides the basics of understanding the relationship between IOT and the supply chain. It helps them do further research in this area. Furthermore, while this study reveals the influence of IoT on supply chain performance using existing technology such as RFID, academics in the future who wish to do research in this field employing future technologies may find this helpful study.

5.2.2 Organizational implications

From the perspective of an organization or industry, this research contributes to making us better understand IOT and its association with the supply chain, and also resulting in an increase in productivity. Those managers who want to transition to IOT adoption in their organizations will find this study beneficial, especially in Pakistan, where the concept and application of IOT are relatively new. This study will encourage future investors or government agencies to invest further in IOT technology. While most organizations already employ technologies such as bar code, EDI, and WMS, upgrading to the new IOT technologies, e.g., smartphones, sensors and RFID, will require them to procure, integrate, reconfigure, and release resources. Numerous IT companies and software houses are working on IOT applications, most of which are small-scale or not fully needed to bend to the supply chain. Therefore, this study also works as a catalyst for these IT firms to pursue integrating and implementing IOT in broader scenarios in organizations that have been encouraged to adopt this technology.

5.3 Limitations

IoT is a cutting-edge technology driving the fourth industrial revolution and can enhance information flow in the supply chain. Nevertheless, the adoption of IoT in the supply chain and its influence on supply-chain performance have yet to be thoroughly examined in practice. There is also a geographical limitation, as this study was conducted in Karachi, Pakistan. It might hold well in Karachi, but results might vary in other cities or remote locations, needing more proper infrastructure and human skills. Due to time restrictions, the study's sample size was also limited to 200 participants.

5.4 Recommendations

Most of the research related to IoT and its integration into the supply chain has been conducted in first-world countries or with the best infrastructure. It has shown good practical results, but the same cannot be valid for third-world or developing countries where the overall infrastructure is not on par with that of developed countries. So, the infrastructure factor needs to be considered for future studies on this topic. The sample is also restricted to 200 respondents due to time and budget constraints, so future research with a large sample size can be undertaken to get more refined results. Future studies may also include other supply chain members or stakeholders to understand IoT's role in improving organizational performance. Organizational resistance can also impact the relationship between IoT and supply chain performance, which can be tested for future studies. According to Teo and Pok (2003), stakeholders of an organization, such as vendors, clients, and government entities, hinder the adoption of new and emerging technologies by applying pressure.

5.5 Conclusion

This research aimed to determine the impact of IOT on supply chain performance. It has been observed that there is resistance and hesitance from industries to the implementation of new technologies due to various challenges, and indeed, IOT, due to its complexity, offers its own sets of challenges, and that is why it has not been easy to convince many organizations to adopt it. However, as time passes and more research and study into this technology is conducted, corporations are becoming more willing to accept its long-term benefits. As a result, IoT has grown in popularity as an emerging technology in first-world countries. As a result, this study aims to highlight the positive and beneficial effects of IOT on supply chain performance, particularly in Pakistan, where there is a lack

of knowledge and acceptance owing to the factors above. This study utilized a reliable questionnaire construct containing 12 questions. These questions were divided into two variables, i.e., one independent variable called the Internet of Things and the other dependent variable called supply chain performance. These two variables are part of the theoretical model, which shows IoT's impact on Supply Chain Performance. A total sample of 200 respondents from a population of various industries from Karachi, Pakistan, who had professional managerial experience and a background in the supply chain were selected. The result of the study highlighted the positive impact of IOT on supply chain performance; thus, the overall benefits of implementing IOT technology in organizations to improve productivity, efficiency, and performance are emphasized.

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