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# EFFECT OF INTERNET OF THINGS (IOT) ON ENHANCING SUPPLY CHAIN MANAGEMENT (SCM):MEDIATING EFFECT OF TRACEABILITY,VISIBILITY AND FLEXIBILITY ON EFFECTIVE SCM

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***Abstract***
*This research aims to examine the impact of the use of IoT Technologies for SCM taking into account important aspects that include traceability, visibility and flexibility. The study uses a quantitative approach, with an emphasis on a survey to gather data from organizations with the implementation of IoT in their supply chain. A total of 430 responses were received from the SC managers and practitioners working in different industry sectors. Descriptive statistics of the results were also determined using correlation and regression analysis to establish the impact of IoTs on SCM with relation to its performance in the areas of traceability and visibility, and flexibility. The research results point towards a positive correlation between the IoT and SCM efficiency. IoT aids decision-making, improves track and trace of goods and materials, raises transparency of supply chain process flow and is a good fit in volatile chains. These findings support the previous literature, and attest to the capacity of IoT to effect change in SCM best practices. The study confirms the assertion that IoT enhances SCM effectiveness through increased traceability and visibility coupled with flexibility. However, the study can only be done within certain industries and regions only; thus, further research should consider the impact of IoT on SCM across different industries throughout the world.*

**Keywords:** SCM, IoT, flexibility, traceability, visibility

## 1. Introduction

The contemporary global economy is characterized by growing complexity and interdependence, with companies working toward ever-rising consumer demands, risks, and sustainable competitiveness (Sallam, 2023). The essential area of supply chain management (SCM), which is one of the key priorities in terms of organizational performance and effectiveness, is located in the center of this environment (Lee, 2022). As companies integrate their supply networks across geographies and get involved in multiple industries, the problems of coordinating, monitoring, and controlling the decisions have emerged as critical (Kumar, 2022). The more generic conventional supply chain management frameworks, which are highly centralized and possess disaggregate structures, often fail to adequately address these complex requirements. However, the introduction of IoT has revolutionized Supply Chain Management (SCM) and created opportunities to enhance existing supply chain tools, such as traceability, visibility, and flexibility (Nazari, 2021).

The technology concept known as the Internet of Things (IoT), which connects physical devices, sensors, and systems through the internet, has significantly changed the way supply chains operate (Thomas, 2021). Due to the constant transfer of data and tracking of events taking place in real-time, IoT is able to support the supply chain vision of a business organization (Tan, 2022). This connectivity translates into forward-looking information that enables an organization to manage its affairs with improved efficiency by reducing risk and reacting to changes in the market. The integration of IoT into Supply Chain Management (SCM) not only addresses the shortcomings and lack of transparency of existing models, but also establishes new standards for SCM that align with the demands of contemporary customers and investors (Birkel, 2020). IoT is offering a comprehensive solution to address the strategies of speed, accuracy, and adaptability in the business environment, thereby preparing organizations to embrace the policy of constant change (Rizwan, 2022).

As customer awareness, regulations, and sustainability aspects have grown in importance, so, too, has traceability, one of the most basic elements of SCM (Khan, 2022). For industries that have an essential focus on product quality, food and drug, electronics, etc., ethical sourcing, and product safety, the correct tracking of goods from their source to the end consumer is mandatory. Employing RFID tags, GPS devices, and smart sensors in the supply chain process enables end-to-end tracing through the use of IoT (Yadav, 2022). Product information capture technologies provide live tracking data on the location, condition, and movement of products throughout the supply chain (Brandin, 2024). For instance, we can monitor items equipped with temperature sensors during their movement, enabling instantaneous correction of any changes. Such high levels of food traceability provide not only compliance with the regulatory requirements regarding food safety but also establish consumer confidence based on credible information about food origin and quality (Bhutta, 2021).

Visibility, a broader concept of traceability, represents another potential area of transformation (Ahmed, 2021). In the traditional supply chain environment, a lack of data integration often leads to data isolation and system delays. IoT addresses this issue by interconnecting data from suppliers, manufacturers, distributors, and retailers, thereby facilitating seamless data flow (Udeh, 2024). This interconnectivity allows organizations to actually see the entire supply chain and can give an immediate indication of potential traffic jams, so to speak, and areas where resources could be better utilized (Roy, 2021). For instance, an IoT solution for inventory management can provide precise information about stock status, flow, and requirements, all of which are crucial to prevent overstocking and stock outs. Moreover, IoT-based analytics utilize both historical data and real-time information to identify future patterns on various aspects, thereby facilitating preventive decision-making and efficient resource utilization (Wagner, 2022). The increase in visibility due to IoT therefore transforms supply chains into dynamic, adaptive, and flexible supply networks that are capable of responding to and reacting to disruptions and uncertainties.

Supply chain (SCM) flexibility is the ability of a business to respond to changes in demand, market conditions, and disruption (Dolgul, 2021). It is one of the key characteristics of the modern supply chain. In the current world of unpredictable markets, supply shocks, and changing consumer trends, businesses would benefit from having much more agile and robust supply chains (Goli, 2023). Real-time IoT technologies help secure the flexibility of the supply chain, as they allow one to make immediate changes and respond to threats or opportunities instantly. For instance, the application of IoT to the transportation network incorporates vehicles equipped with internet connectivity, GPS tracking, and intelligent algorithms, enabling an efficient delivery framework that accounts for traffic conditions, weather patterns, and customer preferences (Shukor, 2021). Likewise, machine health prediction through IoT means that it has become simple to predict the efficiency of all the manufacturing equipment for optimal production without having to shut down. This flexibility also extends to areas such as demand forecasting, where IoT-driven analytics of real-time information, coupled with historical data, provide a precise forecast, enabling businesses to tailor production and distribution plans to consumers (Enrique, 2022). Through flexibility promotion, IoT does not just improve utilization effectiveness but also prepares organizations for contingencies and helps them seize new market opportunities.

The integration of IoT and SCM represents a crucial turning point in the evolution of supply chain management strategies. Engaging IoT to manage supply chains enables companies to

achieve extraordinary levels of tracing, visibility, and flexibility, transforming their supply chains into intelligent and adaptive systems (Razak, 2023). Amidst current technological innovation and evolving customer preferences, IoT-driven supply chain management (SCM) is considered a critical success factor for organizations to thrive in a complex and connected world. Such complexities may complicate the journey towards attaining the full potential of IoT in SCs; nonetheless, the destination is very appealing, as manifested by efficiency, transparency, and flexibility, which articulate an élite SC of the future (Sunny, 2020).
The research gap which has been identified in the field of Supply Chain Management (SCM) entails low incorporation of current technological solutions like the Internet of Things (IoT) within the critical areas like traceability, visibility, and flexibility. The problem is that global supply chains continue to become complex and linked together while the original principles of SCM are still most often centralized and fragmented frameworks that do not cover the decentralised real-time monitoring and decision-making across multiple industries and countries (Lee, 2022; Kumar, 2022). Current architectures cannot accommodate the dynamic behaviour required to adapt to disruptions and shift in customer expectations (Sallam, 2023). Therefore, the main aim of this study is to establish how IoT can help to close these gaps by availing real-time information, increasing the trackability of products and increasing the decisional freedom in supply chain. Thus, through the adoption of IoT in SCM, the study intends to address frameworks that will enhance the implementation of innovative and effective SCM strategies that are able to capture both the known and the unknown risks to supply chain. This research is valuable because greater efficiencies and supply chain robustness, or decreases in expenditure and customer dissatisfaction can pave the way for better sustainable practices in the field.

### 1.1 Research Questions

**1.1.** How does IoT improve traceability in supply chain management?

**1.2.** What role does IoT play in enhancing supply chain visibility?

**1.3.** How can IoT increase flexibility in responding to supply chain disruptions?

**1.4.** What are the challenges of implementing IoT for supply chain traceability and visibility?

**1.5.** How does IoT-based traceability affect the efficiency of supply chain operations?

## 2. Literature Review

**2.1. The impact of IoT on SCM** The Internet of Things is a global network of Internet-connected smart devices used by supply chain organizations in order to enhance their internal as well as external integration with both suppliers and consumers. With the aid of NVivo, twelve semi-structured interviews of retail managers from Australia had been taken for thematic analysis. The findings reflect that various kinds of IoT enhance information, visibility, data interchange, and data auto-capture capacity for the connected retail supply chain. Consequently, this has an upgrading impact on a supply chain in terms of cost, quality, delivery, and flexibility, further increasing the overall financial, social, and environmental sustainability of the company (De Vass, 2021).
Among the many advantages that IoT technologies bring to supply chain management are the following: inventory optimisation, predictive equipment maintenance, and real-time item monitoring and tracking. Ivanov and Dolgui (2020) state that customers may gather massive volumes of data from various supply chain processes using IoT sensors and devices. With more information readily available, proactive decisions may be made and issues like interruptions or inefficiencies can be addressed faster.

Udeh (2024) discovered that the IoT provides real-time tracking of product and data flow, thus greatly enhancing supply chain transparency. This increased transparency makes it easier to make proactive decisions, adhere to sustainability standards, and comply with regulations. Improving client happiness via more dependable and timely service delivery, streamlining operations, and saving money are all possible outcomes of integrating the IoT.

According to Hayhoe et al., (2019), any business which aims at retaining clients and anticipating future actions would do well to have the capability of forecasting delivery status. The term used to describe this improvement in performance within the framework of industry 4.0 is supply chain 4.0. This study used machine learning algorithms to predict if a customer's order will be delivered late. The results are shown as a contrast between three different Feature Selection scenarios and RFC approaches. The data-based model's accuracy went raised from 97.9% to 99.38% after feature selection.

The purpose of Rebelo (2022) is to investigate and analyse the effects of IoT technology on the efficiency of supply chain management (SCM). Analysis of the literature on the GSCF SCM framework processes revealed that most IoT-based research has concentrated on improving order fulfilment, production flow management, and demand management procedures. On the basis of above studies, we hypothesized;

*H1: There is significant positive relationship between implementation of IoT and SCM effectiveness.*

## 2.2. Traceability

A number of organisations specialising in supply chain management have started implementing supply chain monitoring systems and increasing transparency via the use of blockchain technology. When designing the distribution network, order visibility should be a top priority. A blockchain-based supply chain traceability system allows consumers to trace the origin and whole history of halal beef products. A blockchain-based tracking system was developed and used by Caro (2018) to oversee the agri-food supply chain.

According to Bradley et al. (2018), because traceability systems allow for better real-time asset monitoring, supply chain participants may find it easier to interchange and use resources and assets together. Traceability has been helpful in healthcare for properly tracking commodities such as blood supplies, wheelchairs, infusion pumps, medications, surgical trays, and supplies; these goods are costly, long-lasting, and mobile. Therefore, it helps keep healthcare at a high standard (Hald, 2019).

The application of IoT in order to enhance the efficiency and the supply chain chain operationalization on the Internet are dependent on traceability. Khan (2022) has pointed out that the process of DSC is quite complicated, as there are so many internal and external players involved The author has concluded that starting the process of digital supply chain transformation is a good strategy.

Accounting for the company's real stock can be aided by the precise point-of-sale data offered by traceability technology (Fatorachian, 2021). Thanks to this degree of traceability, inventory data can be quickly exchanged across the supply chain, which improves security and dependability and decreases inventory mistakes and the bullwhip effect (Punder et al. 2020). It also gives a trustworthy record of transactions, which is useful for audits of financial matters. Hence, we formulate;

*H2: There is significant positive relationship between traceability and implementation of IoT.*

H3: *There is significant positive relationship between traceability and SCM effectiveness*

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### 2.3. Visibility

Al-Khatib (2023) intends to examine the potential relationship between the IoT, BDA, and SCV. A positive and statistically significant relationship between SCV and the IoT and BDA was reported in the study. Supply chain visibility (SCV) can be helpful to reduce the cost of distribution and enhance the adaptability of the supply network toward unexpected changes and disruptions, according to Baah (2021). SCV can potentially make supply chain management more efficient by increasing the coordination and integration between the different parties involved in the supply chain.

Ljung (2020) aims to explore the impact of IoT on supply chain efficiency, transparency and connectivity . The authors and researchers employed document analyses and interviews with an automotive OEM and many third-party visibility providers to provide actual and qualitative data for the study in order to realize the proposed topics of the study. Thus, the analysis of the available data makes it possible to identify the informational requirements of a linked supply chain, the possibilities of improving the supply chain due to IoT, as well as the overall effect of improving the transparency of its processes. It can take information of where consumers and suppliers are to help decide when the most time and energy-efficient logistics mode may be (Sharma, 2022). Hence, we conclude;

*H4: There is significant positive relationship between visibility and implementation of IoT.*

*H5: There is significant positive relationship between visibility and SCM effectiveness.*

### 2.4. Flexibility

Enrique (2022) explores the potential for digital transformation to create a smarter supply chain, which would enhance supply chain efficiency, in situations when both suppliers and customers are hard to predict. They use organisational information-processing theory to clarify how the digital transformation strategy, digital base technologies, and digital front-end technologies—the three pillars of the Smart Supply Chain—align with the information demands, and so lessen these uncertainties by making the supply chain more flexible. Sourcing, shipping, and production are all part of this plan. Statistical analysis of the relationship between Smart Supply Chain and operational performance reveals a sequential mediating function for the three characteristics of supply chain flexibility.

Using the Organisation Information Processing Theory (OIPT), Gupta's (2019) research establishes a link between smart supply chains and adaptable information systems. This is good since supply chain can be made to be more flexible with this approach. In light of the above findings that drew from 150 participants, a high level of supply chain flexibility is therefore a resultant of a positive relationship between the characteristic features of smart supply chain management on one end, and the features of information system flexibility on the other. A survey confirms that IoT and AI can support the degree of integration between different tiers of supply chains by enabling the transmission of real-time information (Liu et al., 2022). These technologies might enhance transportation and distribution robots and make spare parts more accessible through 3D printing, just as it only takes one more step to automate and predict decision-making (Meindl et al., 2021). Such cases just illustrate the abundance of information available in the literature regarding the potential application of new technology by a smart supply chain to enhance operational flexibility. Thus, we formulate;

*H6: There is significant positive relationship between flexibility and implementation of IoT.*

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*H7: There is significant positive relationship between flexibility and SCM effectiveness.*

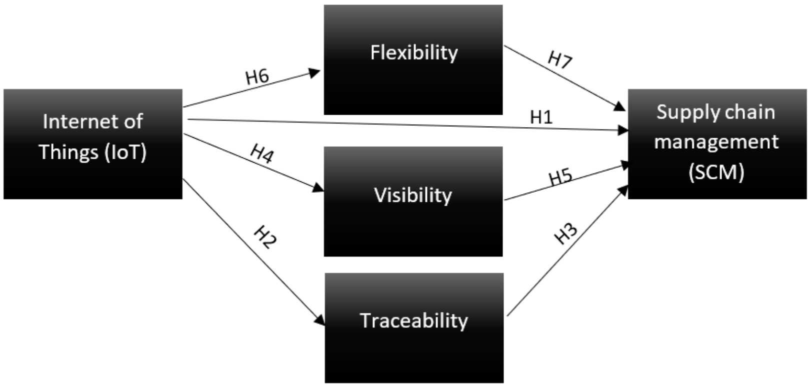


Figure 1

Conceptual framework

**Research Methodology:**

In this research, the quantitative research design was employed to determine the effect of IoT on SCM. The quantitative approach allowed for measuring the amount of quantity data and determining importance and relationship between one or more factors. This methodology was suitable for big data from supply chain systems and effectiveness of performance related to IoT integration.

**Research Design**

The descriptive correlational research design was used for the study in order to assess the relationship between IoT technologies and SCM KPI of flexibility, traceability and visibility of the supply chain. The study aim was, therefore, to determine by how much IoT has impacted SCM performance, and to validate the hypothesis that IoT affected high-growing supply chain activities.

**Population and Sample**

The target population was made of different firms operating in different industries that had integrated IoT technologies in their supply chain systems. Through purposive sampling, 432 participants were selected from different enterprises within miscellaneous industries ranging from manufacturing to retail to logistics. These individuals were purposively selected because of their expertise on the use of IoT in supply chains that should provide rich data to address the research goals.

**Data Collection**

Quantitative data were collected mode through questionnaires from the practicing SCM managers, logistics coordinators and IT specialists in the organizations under study. As part of the survey questionnaire, Likert type questions were used to establish IoT perceived impact on supply chain performance.

**Variables and Measurement**

In this research study, several variables were considered in order to analyse the effect of IoT on SCM. The assessment of these variables was done with the use of scales that have been developed and used in earlier studies. SCM was assessed using nine items adapted from De (2014). The extent of IoT integration was defined as the independent variable and was measured using twelve items from De (2014) The level of flexibility was

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measured using four items from Haddud (2018) The level of visibility was also measured using eight items adapted from Haddud (2018). This paper used the three-items measure of traceability originally from (Haddud, 2018). In order to measure these variables, each item was responded to on a 5 item Likert scale which ranged from Strongly Disagree=1 to Strongly Agree=5. This scale aided in the valid and reliable measurement of the various dimensions of SCM performance and IoT integration, as respondents self-ported on the level and impact of adjusted IoT technologies on their particular supply chain.

## 3. Data Analysis

*Table 1 Demographic Data Table*

| Variable | Value | Frequency |
|---|---|---|
| **Gender** | Male | 345 |
| | Female | 87 |
| **Age** | 18-27 years | 26 |
| | 28-37 years | 315 |
| | 38-47 years | 69 |
| | 47 years and above | 22 |
| **Industry Sector** | Manufacturing | 293 |
| | Retail | 36 |
| | Logistics | 27 |
| | Healthcare | 15 |
| | Other | 61 |
| **Job Role** | Supply Chain Manager | 68 |
| | Logistics Professional | 369 |
| | Operations Manager | 223 |
| | IT Specialist | 17 |
| | Other | 6 |

The **Demographic Data Table** reveals key insights about the survey participants. **Gender** distribution shows 345 males and 87 females, indicating a male-majority. In terms of **Age**, the largest group is in the **28-37 years** range (315 participants), smallest group by **47 and above years** (22 participants). Regarding **Industry Sector**, most respondents come from **Manufacturing** (293), followed by **Logistics** (27), with fewer from **Retail** (36), **Healthcare** (15). For **Job Role**, the majority are **Logistics Professionals** (369), with notable representation from **Operations Managers** (223) and **Supply Chain Managers** (68), while **IT Specialists** and **Other roles** have smaller representation.

### 3.1. Descriptive Statistics

The following table shows the descriptive statistics of the hypothetical data generated for this study. The data is structured to test the relationship between IoT Implementation, SCM Effectiveness, and the mediating factors: Traceability, Visibility, and Flexibility.

*Table 2 Descriptive Statistics*

| Variable | Mean | Standard Deviation | Min | Max |
|---|---|---|---|---|
| **IoT Implementation** | 3.98 | 0.8 | 3 | 5 |

| | | | | |
|---|---|---|---|---|
| **SCM Effectiveness** | 4.31 | 0.72 | 3 | 5 |
| **Traceability** | 4.31 | 0.73 | 3 | 5 |
| **Visibility** | 4.59 | 0.6 | 3 | 5 |
| **Flexibility** | 4.3 | 0.76 | 3 | 5 |

The matrix highlights the strong positive relationships among IoT Implementation, SCM Effectiveness, and the mediating variables (Traceability, Visibility, and Flexibility). All the variables show significant correlations, with IoT Implementation and SCM Effectiveness showing a correlation of 0.81, and other mediators such as Flexibility showing a similar strong relationship. These results support the hypotheses that the implementation of IoT positively influences SCM effectiveness, with mediating roles played by traceability, visibility, and flexibility.

### 3.2. Correlational Analysis

The following table presents the correlation matrix for the hypothetical data generated in this study. It highlights the relationships between IoT Implementation, SCM Effectiveness, and the mediating variables: Traceability, Visibility, and Flexibility. The correlations support the hypotheses that all these variables are positively correlated, indicating significant relationships.

*Table 3 Correlation Matrix*

| | **IoT Implementation** | **SCM Effectiveness** | **Traceability** | **Visibility** | **Flexibility** |
|---|---|---|---|---|---|
| **IoT Implementation** | 1.0 | 0.81 | 0.81 | 0.56 | 0.82 |
| **SCM Effectiveness** | 0.81 | 1.0 | 0.68 | 0.78 | 0.68 |
| **Traceability** | 0.81 | 0.68 | 1.0 | 0.43 | 0.67 |
| **Visibility** | 0.56 | 0.78 | 0.43 | 1.0 | 0.54 |
| **Flexibility** | 0.82 | 0.68 | 0.67 | 0.54 | 1.0 |

The correlation matrix reveals strong positive relationships among the study variables, with IoT Implementation showing a high correlation of 0.81 with SCM Effectiveness, indicating that increased IoT implementation significantly improves SCM outcomes. Mediators such as Traceability, with correlations of 0.81 and 0.68 with IoT Implementation and SCM Effectiveness, respectively, suggest that IoT enhances traceability, positively influencing SCM. Visibility (0.56 with IoT, 0.78 with SCM) and Flexibility (0.82 with IoT, 0.68 with SCM) further support the positive mediation role of these factors in improving SCM effectiveness through IoT.

### 3.3. Internal consistency

Composite reliability was utilized to assess the internal consistency of the model, as it offers a more accurate estimate compared to Cronbach's Alpha (Peterson & Kim, 2013). This study applied the Dillon-Goldstein rho composite reliability coefficient (Tenenhaus et al., 2005).

The composite reliability (ρa) values observed were: IoT (0.97), Flexibility (0.984), Traceability (0.963), Visibility (0.961), and Supply Chain Management (0.978). All these values exceed the recommended threshold of 0.7 (Fornell & Larcker, 1981). Additionally, the Dillon-Goldstein rho (ρc) values were: IoT (0.975), Flexibility (0.986), Traceability (0.972), Visibility (0.974), and Supply Chain Management (0.979) (Table 4).

*Table 4 Composite Reliability*

| | Cronbach's alpha | Composite reliability (rho_a) | Composite reliability (rho_c) |
|---|---|---|---|
| **FLEX** | 0.983 | 0.984 | 0.986 |
| **IOT** | 0.971 | 0.976 | 0.975 |
| **SCM** | 0.975 | 0.978 | 0.979 |
| **TRAC** | 0.962 | 0.963 | 0.972 |
| **VIS** | 0.960 | 0.961 | 0.974 |

### 3.4. Convergent validity

Discriminant validity evaluation combined tests of Fornell-Larcker Criterion with Heterotrait-Monotrait Ratio of Correlations (HTMT) and Cross Loading assessment. A research-focused model generated through square root evaluation (0.88) analyzed IoT together with Flexibility (0.95), Traceability (0.95) and Visibility (0.96) and Supply Chain Management (0.91) (Table 7).

The HTMT correlations were as follows: Flexibility and IoT (0.931), Flexibility and Visibility (0.915), Flexibility and Supply Chain Management (0.912), and Flexibility and Traceability (0.983). Financial discriminant validity analyses based on HTMT produced data below 1 (Henseler et al., 2016) across the entire research study which confirmed valid discriminant measurement (Table 8).

Every model indicator revealed outer loadings which surpassed its intervening construct relationships therefore reinforcing discriminant validity proofs (Table 8). A PLS-SEM model attains good fit when its value for Standardized Root Mean Square Residual stays under 0.08 according to Hu & Bentler (1999) and Ringle et al. (2015). The research analyses showed an SRMR value at 0.059 which stayed within acceptable thresholds.

Unweighted Least Square Discrepancy (d_ULS) and Geodesic discrepancy (d_G) prove useful indicators in research because their measures should remain below 0.05 according to Henseler et al. (2016). The assessment of model fit revealed both Unweighted Least Square Discrepancy (d_ULS) and Geodesic discrepancy (d_G) produced results below 0.01 which confirmed a successful fit of our model. Model achievement assessment data at the aggregate level produces acceptable outcomes.

*Table 5 Average Variance Extracted (AVE)*

| | Average variance extracted (AVE) |
|---|---|
| **FLEX** | 0.896 |
| **IOT** | 0.782 |
| **SCM** | 0.836 |
| **TRAC** | 0.898 |
| **VIS** | 0.926 |

*Table 6 Outer Loadings of indicators*

| | | Outer Loadings |
|---|---|---|
| **Flexibility** | FLEX1 | 0.909 |
| | FLEX2 | 0.951 |
| | FLEX3 | 0.917 |

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|---|---|---|
| | FLEX4 | 0.976 |
| | FLEX5 | 0.962 |
| | FLEX6 | 0.957 |
| | FLEX7 | 0.961 |
| | FLEX8 | 0.936 |
| **IOT** | IOT1 | 0.830 |
| | IOT10 | 0.904 |
| | IOT11 | 0.916 |
| | IOT2 | 0.965 |
| | IOT3 | 0.781 |
| | IOT4 | 0.939 |
| | IOT5 | 0.917 |
| | IOT6 | 0.677 |
| | IOT7 | 0.907 |
| | IOT8 | 0.963 |
| | IOT9 | 0.887 |
| **SCM** | SCM1 | 0.879 |
| | SCM2 | 0.960 |
| | SCM3 | 0.910 |
| | SCM4 | 0.929 |
| | SCM5 | 0.913 |
| | SCM6 | 0.909 |
| | SCM7 | 0.898 |
| | SCM8 | 0.896 |
| | SCM9 | 0.930 |
| **Traceability** | TRAC1 | 0.966 |
| | TRAC2 | 0.962 |
| | TRAC3 | 0.932 |
| | TRAC4 | 0.929 |
| **Visibility** | VIS1 | 0.962 |
| | VIS2 | 0.974 |
| | VIS3 | 0.951 |

### 3.5. **Discriminant validity**

Discriminant validity evaluation entailed several tests including the Fornell-Larcker Criterion and Heterotrait-Monotrait Ratio of Correlations (HTMT) and Cross Loading evaluation. Semantically a research-oriented model using the largest square root (0.88) examined IoT alongside Flexibility (0.95), Traceability (0.95) and Visibility (0.96), Supply Chain Management (0.91) (Table 7).

The HTMT correlations were as follows: Flexibility and IoT (0.931), Flexibility and Visibility (0.915), Flexibility and Supply Chain Management (0.912), and Flexibility and Traceability (0.983). All discriminant validity tests based on HTMT produced values below 1 (Henseler et al., 2016) in this research (Table 8) to establish the validity of discriminant measures.

Any single indicator in this model presented outer loadings exceeding its values for cross-construct relationships thereby strengthening discriminant validity proof (Table 8). A successful PLS-SEM model demonstrates good fit when Standardized Root Mean Square Residual (SRMR) remains below 0.08 as identified by both Hu & Bentler (1999) and Ringle et al. (2015). The research generated an SRMR value of 0.059 that remained underneath the defined threshold.

The research finds significance in Unweighted Least Square Discrepancy (d_ULS) and Geodesic discrepancy (d_G) when these indicators produce values below 0.05 (Henseler et al., 2016). Model fit assessment showed both d_ULS and d_G recorded values of less than 0.01 thus indicating successful model fit. The model achievement assessment data demonstrates satisfactory results as an aggregate.

***Table 7 Fornell Larker Criterion***

| | FLEX | IOT | SCM | TRAC | VIS |
|---|---|---|---|---|---|
| **FLEX** | 0.946 | | | | |
| **IOT** | 0.931 | 0.884 | | | |
| **SCM** | 0.912 | 0.885 | 0.914 | | |
| **TRAC** | 0.983 | 0.913 | 0.930 | 0.947 | |
| **VIS** | 0.915 | 0.887 | 0.811 | 0.892 | 0.962 |

***Table 8 Heterotrait-Monotrait ratio (HTMT) – Matrix***

| | FLEX | IOT | SCM | TRAC | VIS |
|---|---|---|---|---|---|
| **FLEX** | | | | | |
| **IOT** | 0.951 | | | | |
| **SCM** | 0.925 | 0.903 | | | |
| **TRAC** | 1.011 | 0.942 | 0.957 | | |
| **VIS** | 0.942 | 0.916 | 0.830 | 0.927 | |

***Table 9 Cross Loadings***

| | FLEX | IOT | SCM | TRAC | VIS |
|---|---|---|---|---|---|
| **FLEX1** | 0.909 | 0.817 | 0.810 | 0.892 | 0.932 |
| **FLEX2** | 0.951 | 0.869 | 0.848 | 0.929 | 0.873 |
| **FLEX3** | 0.917 | 0.901 | 0.818 | 0.879 | 0.874 |
| **FLEX4** | 0.976 | 0.919 | 0.899 | 0.963 | 0.865 |
| **FLEX5** | 0.962 | 0.900 | 0.882 | 0.941 | 0.852 |
| **FLEX6** | 0.957 | 0.878 | 0.872 | 0.948 | 0.861 |
| **FLEX7** | 0.961 | 0.891 | 0.863 | 0.937 | 0.850 |

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|---|---|---|---|---|---|
| **FLEX8** | 0.936 | 0.870 | 0.908 | 0.952 | 0.827 |
| **IOT1** | 0.748 | 0.830 | 0.659 | 0.724 | 0.702 |
| **IOT10** | 0.811 | 0.904 | 0.876 | 0.810 | 0.779 |
| **IOT11** | 0.940 | 0.916 | 0.916 | 0.944 | 0.834 |
| **IOT2** | 0.881 | 0.965 | 0.808 | 0.852 | 0.842 |
| **IOT3** | 0.719 | 0.781 | 0.599 | 0.690 | 0.800 |
| **IOT4** | 0.887 | 0.939 | 0.825 | 0.875 | 0.807 |
| **IOT5** | 0.893 | 0.917 | 0.846 | 0.878 | 0.824 |
| **IOT6** | 0.630 | 0.677 | 0.679 | 0.632 | 0.518 |
| **IOT7** | 0.806 | 0.907 | 0.730 | 0.768 | 0.812 |
| **IOT8** | 0.892 | 0.963 | 0.840 | 0.865 | 0.865 |
| **IOT9** | 0.796 | 0.887 | 0.775 | 0.786 | 0.799 |
| **SCM1** | 0.741 | 0.678 | 0.879 | 0.779 | 0.636 |
| **SCM2** | 0.917 | 0.861 | 0.960 | 0.932 | 0.825 |
| **SCM3** | 0.852 | 0.790 | 0.910 | 0.869 | 0.744 |
| **SCM4** | 0.890 | 0.823 | 0.929 | 0.903 | 0.792 |
| **SCM5** | 0.815 | 0.773 | 0.913 | 0.846 | 0.704 |
| **SCM6** | 0.865 | 0.863 | 0.909 | 0.861 | 0.773 |
| **SCM7** | 0.807 | 0.853 | 0.898 | 0.816 | 0.706 |
| **SCM8** | 0.685 | 0.710 | 0.896 | 0.734 | 0.573 |
| **SCM9** | 0.887 | 0.892 | 0.930 | 0.882 | 0.862 |
| **TRAC1** | 0.971 | 0.912 | 0.903 | 0.966 | 0.876 |
| **TRAC2** | 0.953 | 0.885 | 0.883 | 0.962 | 0.854 |
| **TRAC3** | 0.908 | 0.842 | 0.856 | 0.932 | 0.864 |
| **TRAC4** | 0.891 | 0.819 | 0.883 | 0.929 | 0.783 |
| **VIS1** | 0.897 | 0.905 | 0.792 | 0.869 | 0.962 |
| **VIS2** | 0.856 | 0.824 | 0.740 | 0.827 | 0.974 |
| **VIS3** | 0.886 | 0.828 | 0.805 | 0.876 | 0.951 |

### 3.6. Data normality

We assessed the normality of the data using Skewness and Kurtosis. Skewness measures the degree and direction of asymmetry in the distribution, while Kurtosis evaluates tail extremity, indicating either the presence of outliers or the distribution's tendency to produce outliers.
The responses for all items were found to be normally distributed, with Skewness values ranging between −1 and +1 (SE = 0.16) (Hair, Black, Babin, & Anderson, 2013) and Kurtosis values ranging between −3 and +3 (SE = 0.33) (George & Mallery, 2012; Hair, Hult, Ringle, & Sarstedt, 2017).

### 4.7 Results of PLS-SEM (Structural model)

Table 10 presents the results of the PLS-SEM analysis. In Hypothesis 1, we proposed that the implementation of IoT within an organization would positively influence supply chain management. The findings support this hypothesis, revealing a significant positive relationship between IoT implementation and effective supply chain management ($\beta = 0.332$, $p < 0.01$).These empirical results demonstrate that organizations implementing IoT have successfully maintained an effective supply chain, highlighting the value of IoT integration in achieving supply chain efficiency.

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*Table 10 Direct path coefficient of hypothesized model*.

| Hypothesis | Paths | Path coefficients | *p* value |
|---|---|---|---|
| **H1** | IOT -> SCM | 0.332 | |
| **H2** | IOT -> TRAC | 0.913 | |
| **H3** | TRAC -> SCM | 1.001 | |
| **H4** | IOT -> VIS | 0.887 | |
| **H5** | VIS -> SCM | -0.167 | |
| **H6** | IOT -> FLEX | 0.931 | |
| **H7** | FLEX -> SCM | -0.229 | |

In Hypotheses 2 and 3, we proposed that the implementation of IoT enhances traceability in supply chain transactions and that increased traceability leads to effective supply chain management. Our findings support both hypotheses, demonstrating that IoT implementation has a significant positive relationship with traceability, which in turn contributes to effective supply chain management (H2: $\beta = 0.931$, $p < 0.01$; H3: $\beta = 1.001$, $p < 0.01$).The empirical results indicate that employees perceive improved traceability of orders and transactions with the integration of IoT, which ultimately leads to enhanced supply chain management effectiveness.

In Hypotheses 4 and 5, we hypothesized that the implementation of IoT is strongly related to increased visibility of transactions, and that enhanced visibility would lead to effective supply chain management. Our results reveal an interesting finding: while the implementation of IoT significantly improves the visibility of orders and transactions related to supply chain management ($\beta = 0.887$, $p < 0.01$), employees do not perceive visibility as a critical factor in achieving an effective supply chain ($\beta = -0.167$, $p < 0.01$).Thus, only Hypothesis 4 is supported, while Hypothesis 5 shows a negative relationship. These findings provide empirical evidence of the significant role IoT plays in enhancing visibility within supply chains.

In Hypothesis 6 and Hypothesis 7, we reasoned that implementation of IOT has a strong relation with the flexibility of the transactions and thereby increase in flexibility can lead to effective supply chain management. Our result shows and interesting findings that implementation of IOT in an organization can increase flexibility of orders and transactions related to supply chain management ($\beta$=0.931, p <. 01), but mostly employee do not relate flexibility as an important factor considered for having an effective supply chain ($\beta$=0.-0.229, p <. 01). Hence, only Hypothesis 6 is supported where as in hypothesis 7 we can see a negative relationship. Our study provides empirical support for the important role played by IOT on flexibility.

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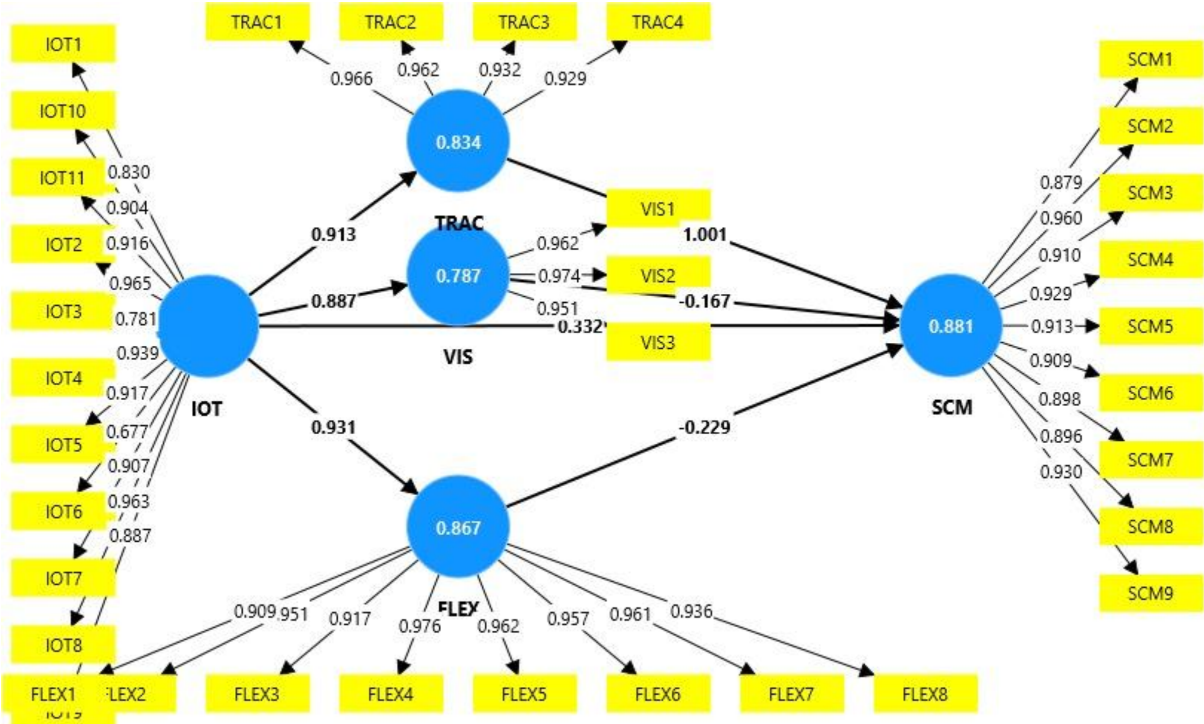


*Figure 2 Smart PLS-SEM analysis*

**The coefficient of determination ($R^2$) for SCM and other three mediating variables i.e. traceability, visibility and flexibility were 0.881, 0.834, 0.787 and 0.867 respectively.**

***Table 11 Specific indirect effects***

| | |
|---|---|
| **IOT -> FLEX -> SCM** | -0.213 |
| **IOT -> VIS -> SCM** | -0.149 |
| **IOT -> TRAC -> SCM** | 0.915 |

To test the mediating paths, we used the bias-corrected confidence interval and applied the bootstrapping method, which is recognized as a robust technique for mediation analysis (Shrout & Bolger, 2002). With 1,000 bootstrap samples, a 97.5% confidence interval was calculated.In Hypothesis 1, we proposed that the implementation of IoT would have a significant positive impact on overall supply chain management. Our results indicate that the indirect effect of traceability, visibility, and flexibility on effective supply chain management, with traceability as a mediating variable, was significant and positive ($\beta = 0.915$, $p < 0.01$, BC CI = 0.02–0.13).

(Table 11 and Figure 2)

## 4. Discussion

### 5.1 Theoretical Implications:

This research provides significant contributions to the theory of Supply Chain Management (SCM) and the role of the Internet of Things (IoT) in enhancing SCM effectiveness. By demonstrating the positive impact of IoT on traceability, visibility, and flexibility, this study deepens our understanding of how IoT technologies influence supply chain operations.

1. **IoT and SCM Integration**: The study reinforces the theoretical perspective that IoT is a critical enabler in modernizing and revitalizing supply chain systems. The findings support the notion that IoT serves as a key factor in enhancing SCM effectiveness by providing real-time data that facilitates better decision-making, reduces risks, and improves overall performance. This expands on the work of

scholars like Birkel (2020) and Tan (2022), who argue that IoT's role is essential in today's rapidly evolving supply chains.

2. **Traceability and SCM Effectiveness**: The research further solidifies the theoretical understanding that traceability is a crucial component in effective SCM. By showing that IoT enhances traceability and enables the real-time tracking of goods and materials, this study contributes to the growing body of knowledge that views traceability as integral to achieving transparency, improving quality, and maintaining customer satisfaction. This aligns with previous studies by Thomas (2021) and Nazari (2021) on the importance of real-time product identification in modern supply chains.
3. **Visibility as a Mediator**: The study's findings about the mediating role of visibility in IoT implementation offer new insights into SCM theory. By highlighting that enhanced visibility enables quicker decision-making and better risk management, this research contributes to the theoretical discourse on the increasing importance of transparency in supply chains. As noted by Tan (2022), the ability to measure and respond to disruptions in real-time is a crucial aspect of modern SCM, and this study affirms its significance.
4. **Flexibility and IoT Adoption**: The study also advances theoretical understanding of flexibility in the context of IoT adoption. By linking flexibility with IoT technologies, it provides theoretical support for the notion that flexibility enables organizations to adapt to dynamic business environments. This aligns with Nazari's (2021) argument that flexibility is vital for organizational resilience in rapidly changing supply chain landscapes.

**5.2 Practical Implications:**

The findings of this study have several important practical implications for organizations seeking to improve their supply chain performance through IoT implementation:

1. **Enhancing SCM through IoT Integration**: Organizations can benefit from understanding that IoT implementation is a powerful tool for improving SCM effectiveness. By adopting IoT technologies, firms can achieve real-time insights, improve decision-making, reduce risks, and enhance operational transparency. This can lead to more responsive and efficient supply chains, enabling companies to better meet customer demands and navigate market changes.
2. **Improving Traceability for Operational Transparency**: The study emphasizes the practical importance of traceability in supply chains. By integrating IoT systems that provide real-time tracking of products and materials, organizations can increase transparency, reduce the risk of errors, and improve product quality. This is especially critical in industries where compliance, quality control, and customer satisfaction are paramount. Businesses should prioritize implementing IoT systems that offer real-time tracking capabilities to enhance operational efficiency and mitigate risks.
3. **Leveraging Visibility for Better Decision-Making**: The research highlights the role of visibility in improving SCM effectiveness. Practically, organizations should focus on integrating IoT technologies that enhance the visibility of supply chain processes. Real-time data allows managers to monitor inventory levels, assess potential risks, and make informed decisions quickly. Businesses that improve visibility in their supply chains will be better equipped to handle disruptions, optimize logistics, and enhance overall performance.
4. **Utilizing Flexibility to Adapt to Changing Environments**: The study also reveals that flexibility is an essential factor in successfully adopting IoT for SCM. In practice, businesses should recognize the importance of flexible IoT solutions that can be

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adapted to meet the evolving needs of the supply chain. By leveraging IoT systems that offer customizable and adaptable features, organizations can respond more effectively to disruptions, market shifts, and emerging trends, thereby maintaining a competitive edge.

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These theoretical and practical implications underscore the significant role IoT plays in optimizing supply chain performance, offering both academic insight and actionable strategies for businesses aiming to improve their SCM capabilities.

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**5.3 Conclusion**

This research aims to find out the correlation between the adoption of IoT technologies in SCM and the results of these technologies on SCM performance with special emphasis on facets like traceability, flexibility, and visibility. The analysis demonstrates that IoT has the potential to increase substantially the performance of SCM by addressing some of the most crucial issues that can influence a decision of supply chain managers in an increasingly globalized and integrated market environment. More particularly, the research evidence indicates that IoT enhances SCM effectiveness in a direct manner by enabling organisations to provide market change responses faster and to mitigate operational risks, as well as by providing better, more timely data support to decision-making. This study also gives a positive effect on the traceability by using IoT. With the help of IoT innovations, enterprises can obtain and monitor the geographical position of products and materials during their shipment and distribution, thus improving their quality and conformity to the standards as well as satisfying the customers' requirements. The ability to track products at every step from procurement of raw material to distribution of the final product enhances the supply chain transparency which is highly required by the buyers as well as authorities. This improvement in traceability results to enhanced SCM practices because firms can be in a position to look for solutions on possible possible bottlenecks, minimizes loss, and guarantee even the products' quality.

As with the visibility case, the connection between IoT and the concept is core to the contributions. Since the flow of real-time data from different segments of supply chain can be viewed, organizations receive the enhanced awareness of activity, which leads to improved decision-making. Through visibility, managers are able to notice areas which requires improvement, determine the right stock holding and minimise on risks. These improvements in transparency allows businesses to minimize lead time, enhance client satisfaction, and more effectively synchronise manufacturing and supply chain with consumer requirements.

Another interesting point is that flexibility is a critical aspect for IoT adoption based on the research done by the authors. The general supply chain needs some flexibility to cope with the market swings, shocks, or shifts in consumer preference. IoT technologies allow the introduction of more dynamic systems to the business thus making it easier to change operations when the need arises. This flexibility is crucial in withstanding the rates of change that characterize today's business world. Specifically, the research establishes that companies with more flexibility can reverse unfavourable conditions and benefit from opportunities more successfully, enhancing the SCM success.

Therefore, the results of this study prove that the introduction of IoT leads to the improvement of SCM effectiveness in terms of traceability, visibility, and flexibility. These findings support prior research that highlights the role of digital technologies in remodelling existing traditional SCM models into improved, more open, and efficient systems. However, the study is not without limitations; the study samples only industries of interest examined in the literature and only certain regions, thus may not fully provide a global picture of how IoT affects SCM. Subsequent research could look into the universality of the application of IoT in other industries and countries; and research the impact of IoT in the long run towards sustainably and resilience in the supply chain. Moreover, the study could focus on other IoT areas of study to place the technology in a better perspective, such as IoT AI and IoT blockchain.

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