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The Moderating Role of Communication Skills of Internet of Things in The Relationship Between Interconnected Supply Chain and Customer Knowledge Management: An Applied Study on E-commerce Companies in Egypt

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Abstract

This study examined the effect of the communication skills of the Internet of Things (CSIoT) on the relationship between interconnected supply chains (ISC) and customer knowledge management (CKM) in Egypt's e-commerce sector. Using a comprehensive survey with an 85% response rate, the research identified significant positive correlations between the variables. Results showed that improved supply chain integration and advanced IoT communication skills enhance CKM, with a notable correlation (0.65) between ISC and CSIoT, highlighting the critical role of IoT communication in modern supply chains. The study revealed that CSIoT significantly moderates the ISC-CKM relationship, suggesting that companies should focus on developing IoT communication capabilities. Regression analysis indicated that smart supply chain features explain 14% of CKM variance, while IoT skills account for 11%. The interaction effect (0.35) underscores a synergistic relationship. With an adjusted R-squared value of 0.66, the study highlights the importance of integrating ISC and CSIoT to enhance CKM.

Keywords

Smart Supply chain, interconnected supply chain, customer knowldge management, Internet of things skills, E-commerce.

Article history

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1. Introduction

1.1. Overview

E-commerce has experienced rapid growth globally, with sales reaching $4.9 trillion in 2022 and expected to reach $5.9 trillion by the end of 2023 (Truong et al., 2024). In Egypt, the e-commerce market is projected to grow from $2.5 billion in 2021 to $5 billion by 2025, driven by increasing internet penetration, rising living costs, and government support (Adel, 2024). E-commerce offers several advantages over traditional stores, including 24/7 availability, a global reach, and lower prices due to reduced overhead costs. It is crucial for the Egyptian economy, as it creates new jobs, generates tax revenue, and helps make Egypt more competitive globally. To succeed, e-commerce companies need to focus on customer knowledge management (CKM) and an interconnected supply chain (SCM) to add value to their products and services (Adel, 2024; Carloni & Pagano, 2024).

The integration of CKM and SCM allows companies to create a comprehensive approach to enhance customer satisfaction, reduce costs, and increase profits. The Internet of Things (IoT) is a growing trend that will significantly impact CKM, enabling companies to gain insights into customer behavior and preferences (Camară, 2024). For example, IoT data can track customer behavior on a website, create targeted marketing campaigns, and enhance the customer experience (Abdallah & Nizamuddin, 2023). As companies continue to adopt new technologies like IoT, CKM is expected to become more powerful and effective, potentially leading to improved supply chains, increased efficiency, and better customer service in the e-commerce sector (Potluri & Thomas, 2023). This research significantly advances academic literature by exploring the impact of IoT-enabled communication on Customer Knowledge Management (CKM) within interconnected supply chains, filling a critical gap. It provides actionable insights for organizations to optimize CKM processes, leveraging IoT for improved decision-making and competitive advantage. The study's findings also offer new theoretical models and frameworks for a better understanding of IoT's role in supply chain integration.

1.2. Research Problem

Although existing literature has explored the impacts of IoT communication and supply chain integration on operational efficiency and customer satisfaction, a significant gap remains in understanding how IoT-enabled communication within interconnected supply chains affects Customer Knowledge Management (CKM). This gap is compounded by the lack of empirical studies examining the synergistic effects and moderating role of IoT communication on the relationship between interconnected supply chains and CKM. Addressing this gap is essential for leveraging advanced communication technologies to enhance customer knowledge processes and gain a competitive advantage.

1.3. Main Question

RQ1: How do IoT communication skills within interconnected supply chains influence Customer Knowledge Management?

RQ2: What is the moderating role of IoT communication skills in the relationship between interconnected supply chains and CKM?

2. Literature Review

2.1. Theoretical Background

The theoretical framework or hypotheses of the current study are based on previous research and several theories, including:

2.1.1. Network Theory:

Effective management of business relationships is crucial for organizational success. Companies should cultivate and maintain positive relationships with various stakeholders, including suppliers, customers, partners, and other relevant parties. SCM and CKM are essential tools that can help organizations achieve this by enhancing stakeholder interactions, communication, and collaboration, ultimately improving operational efficiency and financial performance (Andrea & Dilixiati, 2023). Proper management of business relationships can also facilitate the exchange of resources, knowledge, and expertise, fostering collaborative partnerships and alliances. To realize these benefits, organizations must invest in robust SCM and CKM systems that enable efficient monitoring and analysis of stakeholder relationships.

2.1.2. Customer-Centric Theory (CC):

The customer-centric concept emphasizes the importance of meeting the needs and desires of the customer base. In the context of SCM and CKM, CC calls for integrating these functions to ensure that companies can effectively meet their customers' expectations. By aligning SCM and CKM strategies, organizations can comprehensively understand customer requirements, preferences, and concerns and respond to them accordingly (Saad et al., 2022). This integrated approach allows companies to streamline operations, enhance product quality, and deliver personalized services that address customers' needs. Moreover, integrating SCM and CKM enables companies to collect and analyze customer data, identify patterns and trends, and make data-driven decisions to improve customer satisfaction and loyalty. Integrating SCM and CKM is crucial for companies seeking to adopt a customer-centric philosophy and achieve sustainable growth and success.

The world of e-commerce is booming, and it is changing how businesses operate. This review aims to explore the key concepts, trends, and technologies that are shaping the e-commerce sector, with a focus on their impact on customer Knowledge management (CKM) and Interconnected Supply Chain (SCM) in Egypt's growing e-commerce market (Elziaty et al., 2024). It will start by looking at the current state of e-commerce globally and in Egypt, examining the factors driving its growth and its

economic impact. Then, it will dive into the importance of CKM and SCM in e-commerce, exploring how these management approaches contribute to business success in the digital marketplace (Adel, 2024). Next, it will investigate the role of emerging technologies, particularly the Internet of Things (IoT), in revolutionizing CKM practices and enhancing supply chain efficiency (Tabassum et al., 2024). This review aims to comprehensively understand the interplay between e-commerce, CKM, SCM, and IoT by synthesizing recent research and industry reports. This analysis aims to uncover insights that can guide e-commerce businesses, particularly in emerging markets like Egypt, in leveraging these technologies and management strategies to improve customer satisfaction, operational efficiency, and overall competitiveness in the global digital economy (Abdallah & Nizamuddin, 2023).

2.2. Communication Skills of Internet of Things (IoTCS)

The rapidly evolving Internet of Things (IoT) landscape requires individuals to develop new skills beyond traditional communication abilities. Recent research highlights the importance of developing competencies in data analytics, security awareness, and cross-device integration to effectively navigate and utilize interconnected IoT systems (Sinha, 2024). Data analytics and interpretation skills are crucial as IoT devices generate vast amounts of data, and individuals need to analyze and derive meaningful insights from this information (Rahman et al., 2023). Security awareness is also critical, as users must understand potential vulnerabilities and implement appropriate security measures to protect their personal information and maintain system integrity (Lyon, 2024). Cross-device integration skills have gained prominence, as users who can seamlessly integrate and manage multiple IoT devices across different platforms demonstrate higher efficiency and satisfaction with their smart ecosystems (Khan et al., 2024). Communication skills are also essential, as users need to be able to share and compare their data with the performance of other IoT users and understand how devices communicate with other devices and people (Khan et al., 2024).

2.3. Interconnected Supply Chain (ICSC)

The concept of interconnected supply chains has gained significant attention in recent years, as businesses seek to leverage advanced technologies to create a seamless, transparent, and responsive network of suppliers, manufacturers, distributors, and retailers. This literature review aims to provide an overview of the current research on interconnected supply chains, highlighting their benefits, challenges, and potential applications (Leon et al., 2024). Research has shown that interconnected supply chains can provide numerous benefits, including improved risk management and increased resilience (Singh, 2024). By leveraging advanced technologies such as IoT, AI, and blockchain, interconnected supply chains can facilitate real-time data sharing, improved forecasting, and rapid response to market changes, ultimately leading to enhanced efficiency and customer satisfaction (Zhang et al., 2024).

Despite the benefits of interconnected supply chains, their implementation is not without challenges. Cybersecurity is a major concern, as interconnected systems potentially expose businesses to increased risks of data breaches and cyberattacks (Singh, 2024). Standardization and interoperability are essential for enabling seamless communication between different systems and partners, highlighting the need for industry-wide collaboration to establish common protocols and standards (Singh, 2024). Interconnected supply chains also offer opportunities for improved sustainability, as they facilitate better tracking and management of environmental impacts throughout the product lifecycle. By integrating IoT sensors and blockchain technology, companies can monitor and verify sustainability metrics such as carbon emissions, water usage, and waste production across their entire supply network. This can help businesses meet increasingly stringent environmental regulations and respond to growing consumer demand for sustainable products and practices (Edunjobi, 2024).

2.4. Customer Knowledge Management (CKM)

CKM is the process of identifying, acquiring, storing, analyzing, and sharing customer knowledge within an organization to support customer-focused business processes and activities. It enables organizations to effectively manage customer data and use it to drive CKM activities such as personalized marketing, customer service, and product development (de Kokkonen, 2024; Jafari et al., 2024). The strategic role of knowledge management involves aligning market needs with technological innovations. CKM has emerged as a critical component of organizational success in the digital age. Recent research has underscored its significance in driving innovation, enhancing customer relationships, and improving overall business performance (Camară, 2024). Researchers have emphasized the role of artificial intelligence, machine learning, and big data analytics in capturing, analyzing, and leveraging customer insights. For example, AI-powered chatbots can extract valuable customer feedback, enabling organizations to identify emerging trends and preferences (Adewusi et al., 2024).

Studies have highlighted the importance of treating customers as co-creators of value, fostering collaborative relationships, and leveraging customer-generated content. Organizations can effectively engage customers in the innovation process of developing products and services that truly resonate with their needs (Bosisio, 2024). As organizations accumulate vast amounts of customer data, there is a growing need to protect customer privacy and ensure data security. Researchers have proposed frameworks for responsible data management and emphasized the importance of building trust with customers through transparent data practices and ethical AI applications (McKellar et al., 2024). CKM is a critical component of organizational success in the digital age. The integration of advanced technologies, customer experience management, and ethical considerations are all important aspects of CKM. By understanding the importance of CKM and implementing effective strategies, organizations can drive innovation, enhance customer relationships, and improve overall business performance (Camară, 2024).

3. Research Hypothesis Development

3.1. Studies on the Relationship between the Interconnected Supply Chain and Customer Knowledge Management

Recent studies have underscored the importance of Customer Knowledge Management (CKM) in enhancing supply chain responsiveness and efficiency. Yu, D., Fang, A. (2023) conducted a case study analysis of manufacturing sector companies, highlighting the role of CKM in improving supply chain integration. Their findings suggest that CKM can facilitate real-time data sharing and collaboration between customers and supply chain partners, enhancing operational agility (Mutambik, I., 2024) Singh (2022) explored the impact of digital technologies such as IoT and big data analytics on CKM and supply chain resilience. Their study emphasized the importance of real-time data sharing and collaboration between customers and supply chain partners to enhance operational agility and supply chain resilience.

Madhani (2020) presented a framework for integrating customer knowledge into supply chain strategies to achieve competitive advantage. Their article discussed the strategic alignment of CKM practices with supply chain goals to improve customer satisfaction and operational performance. Camara (2024) investigated collaborative practices in interconnected supply chains, focusing on the role of CKM in fostering cooperation and information sharing among supply chain partners. Their findings suggested that effective CKM practices can significantly enhance supply chain coordination and innovation. The studies reviewed above highlight the importance of CKM in supply chain integration, digital technologies, and supply chain resilience. The findings suggest that CKM can enhance operational agility, supply chain resilience, and competitive advantage. Hence, the following hypothesis was proposed:

H1: An interconnected supply chain has a significant positive influence on customer knowledge management.

3.2. Studies on the Relationship between the Interconnected Supply Chain and Communication Skills of the Internet of Things

Recent studies have explored the significance of IoT communication skills in enhancing Customer Knowledge Management (CKM). Camară (2024) investigated the role of IoT devices in collecting and transmitting real-time customer data, revealing that effective communication protocols enable businesses to gain deeper insights into customer preferences and behaviors. Fu, et al , (2024) examined how IoT-enabled communication technologies facilitate the integration of customer feedback into CKM systems. Their study highlighted that seamless IoT communication allows for more accurate and timely customer insights, improving the effectiveness of CKM practicesGupta, U., et al., (2024) investigated the impact of IoT communication on personalizing customer experiences. Their study discussed how advanced IoT communication skills can capture detailed customer interactions and preferences, which can then be used to tailor marketing strategies and product offerings. The study

emphasized that effective communication through IoT devices enhances the relevance and appeal of customer engagements.

Camară (2024) analyzed the potential of IoT communication skills in predictive analytics for CKM. Their findings suggested that robust IoT communication frameworks can support the development of predictive models, allowing businesses to anticipate customer needs and trends more accurately. The studies reviewed above highlight the importance of IoT communication skills in enhancing CKM. The findings suggest that effective IoT communication can facilitate the integration of customer feedback, personalize customer experiences, and support predictive analytics for CKM. Hence, the following hypothesis was proposed:

H2: The communication skills of the Internet of Things significantly and positively impact customer knowledge management.

3.3. Studies on the Relationship between Interconnected Supply Chain, Communication Skills of Internet of Things, and Customer Knowledge Management

Irfan et al. (2024) examined the impact of IoT communication skills on supply chain transparency. Their research demonstrated that effective communication through IoT devices can enhance visibility across the supply chain, leading to more informed decision-making and improved coordination among supply chain partners. Adeusi et al. (2024) explored how IoT-enabled communication technologies facilitate real-time data sharing and collaboration within interconnected supply chains. They highlighted the role of seamless communication in enhancing supply chain agility and responsiveness. Argyropoulou et al. (2024) investigated the integration of IoT communication systems in the Interconnected Supply Chain. They discussed how advanced IoT communication protocols can streamline information flow and improve synchronization between suppliers, manufacturers, and distributors. This integration is shown to significantly reduce lead times and operational costs.

Johnson, O. (2025) analyzed the role of IoT communication skills in predictive maintenance within supply chains. Their findings revealed that effective IoT communication can detect potential disruptions early, thereby enhancing supply chain resilience and reliability. Shoomal A. et al., (2024) investigated the synergy between IoT communication skills and CKM in interconnected supply chains. Their research highlighted that IoT devices can enhance data flow between customers and supply chain partners, facilitating a more responsive and customer-centric Interconnected Supply Chain approach. Camară (2024) explored the role of IoT communication skills in integrating CKM within interconnected supply chains. Their study showed that advanced IoT communication protocols enable seamless information sharing and collaboration among supply chain stakeholders.

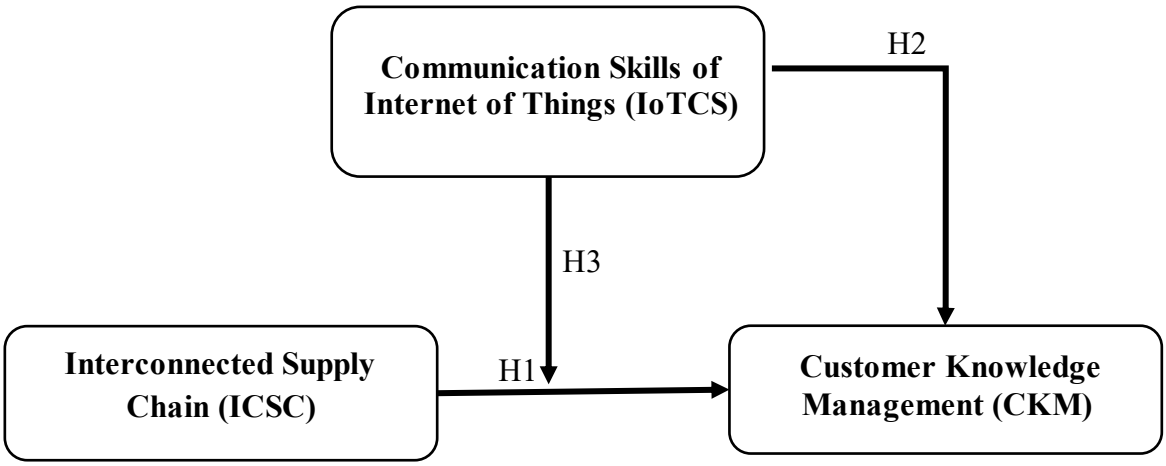
Belhadi et al. (2024) analyzed the impact of IoT-enabled CKM on supply chain resilience and agility. They discussed how effective IoT communication skills facilitate the collection and dissemination of customer insights throughout the supply chain

network. The study concluded that this enhanced flow of information allows supply chains to adapt quickly to changing customer demands and market conditions, thereby improving overall performance and resilience. The studies reviewed above highlight the importance of IoT communication skills in enhancing supply chain transparency, collaboration, and resilience. The findings suggest that effective IoT communication can facilitate real-time data sharing, improve supply chain agility and responsiveness, and enhance supply chain resilience and reliability. Hence, the following hypothesis was proposed:

H3: The Internet of Things' communication skills significantly moderate the relationship between an interconnected supply chain and customer knowledge management.

Based on the reviewed literature and the proposed hypothesis, the conceptual model in Figure 1 was formulated.

Figure 1 *Conceptual Framework*



4. Research Methodology

The study employed Structural Equation Modeling (SEM) to explore the relationships between Interconnected Supply Chain (ICSC), Customer Knowledge Management (CKM), and IoT skills, using a mixed-method approach for comprehensive analysis. A causal research design was adopted to examine the moderating effect of IoT skills on the relationship between ICSC and CKM, with data collected primarily through surveys from e-commerce companies in Egypt. The study used a cross-sectional approach, focusing on how changes in ICSC influence CKM outcomes, moderated by IoT skills, to offer practical insights for industry applications.

4.1. Study Variables

The current study divides its variables into three main categories: Interconnected supply chain, Customer Knowledge Management (CKM), and Interconnected Skills of Internet of Things (IoT).

4.1.1. Independent variable: Interconnected supply chain.

The interconnected supply chain was measured using five items based on the scale developed by Butner (2010). Several studies have validated and used this scale (Gupta et al., 2019). It is consistent with applications in Egypt and has shown reliability in recent studies.

4.1.2. Moderating variable: IoT-C skills.

IoT-C skill was measured through five items. This measure is based on the scale developed by van Deursen et al. (2022). This is the most recent and reliable scale used in related studies, ensuring its relevance to the study variables.

4.1.3. Dependent variable: Customer knowledge management (CKM).

CKM was measured using five items. This measurement is based on the scale developed by Yim et al. (2013). This scale suits the study variables, providing robust validity and reliability. It is well-suited for the perspective of operations and marketing managers, offering strong evidence of validity and sensitivity to detect subtle differences.

4.2. Measurement Scale

A five-point Likert scale was used to measure the variables and dimensions of the current study. This scale was designed to assess respondents' level of agreement or disagreement with the statements in the questionnaire.

4.3. Study Population

The study population refers to the group of elements from which the researcher aims to infer information about a particular phenomenon. It is essential to define the population before sampling. As Shukla (2020) outlined, the researcher has undertaken several practical steps to identify the population accurately for easier sampling. For this study, the population includes e-commerce companies in Egypt, focusing on production and operations managers as well as marketing managers within these companies. The following table provides the closest estimate of the number of e-commerce companies in Egypt, compiled by the researcher from various sources such as government reports, tax reports, and e-commerce software providers.

Table 1 Number of E-Commerce Companies in Egypt up to 2022

Number of Companies Using the Internet for Sales and Services	Number of Market-Dominant Companies	Number of Operations and Marketing Managers
723 companies	210 companies	312

For this study, a comprehensive enumeration of operations and marketing managers in these companies (who consented to participate in the survey) was conducted. An electronic questionnaire was distributed, achieving a response rate of 85.5%. The survey targeted all registered companies in Egypt from December 1, 2023,

to February 28, 2024. A total of 267 valid questionnaires were collected from 312 issued, with attempts made to contact companies that did not complete the surveys; however, additional responses could not be obtained.

4.4. Validity and Reliability

Since the questionnaire is a common tool in social research, the researcher aimed to ensure that the questions were suitable for statistical analysis and that respondents would answer them accurately. As Saunders et al. (2011) suggested, this could be achieved through a pilot test. The pilot test evaluates the questionnaire items by preliminary assessing the relevance of the data collected to the questions posed. This section will address the reliability and content validity of the questionnaire, as well as the accuracy of translations. Measurement validity ensures that survey items accurately capture the intended target, confirming that they convey the intended meaning. Kimberlin and Winterstein (2008) emphasized that the validity of a measurement tool is critical for drawing strong conclusions, as unclear tools can lead to misleading results. As Roebianto et al. (2023) discussed, content validity is crucial for ensuring that the measurement tool covers the relevant content areas, particularly in the context of Interconnected Supply Chains, CKM, and IoT skills. The researcher also conducted Confirmatory Factor Analysis (CFA) using SEM to validate the measurement models and ensure that survey items measure the correct dimensions.

4.4.1. Confirmatory Factor Analysis

4.4.1.1. CFA for Interconnected Supply Chain (ISC)

The statistical analysis results, as shown in the table below, indicate that all standardized loadings of the items were statistically significant. According to Hair et al. (2017), acceptable standardized loading values should be greater than or equal to 0.5. The standardized loadings for all items were significant ($P < 0.001$), indicating that each item is a good indicator of its dimension. Model fit indicators fit the proposed model and the observed data well. The Goodness of Fit Index (GFI) was 0.92, which is close to 1.0, indicating statistical significance. The Comparative Fit Index (CFI) was 0.95, also close to 1.0, indicating statistical significance. The Root Mean Square Residual (RMR) was also 0.03, indicating the measure's significance and that the items accurately measure the intended dimensions. The Root Mean Square Error of Approximation (RMSEA) was 0.04, below the recommended threshold of 0.06, indicating a good fit.

Table 2 Interconnected Supply Chain Loading

We have real time enterprise monitoring capabilities	0.80***
We use standardized communication protocols	0.77***
We emphasize on coordination, integration, and management of key business processes across our supply chain	0.75***
Inventory levels are visible throughout the supply chain Demand levels are visible throughout the supply chain	0.82***
Inventory levels are visible throughout the supply chain Demand levels are visible throughout the supply chain	0.79***

4.4.1.2. CFA for Internet of Things Communication Skills (IoT-C)

The statistical analysis results, as shown in the table below, indicate that all standardized loadings of the items were statistically significant. According to Hair et al. (2017), acceptable standardized loading values should be greater than or equal to 0.5. The standardized loadings for all items were significant ($P < 0.001$), indicating that each item is a good indicator of its dimension. Model fit indicators fit the proposed model and the observed data well. The Goodness of Fit Index (GFI) was 0.89, close to 1.0, indicating statistical significance. The Comparative Fit Index (CFI) was 0.975, and the Tucker-Lewis Index (TLI) was 0.970, both values above 0.95, indicating a good fit. The Root Mean Square Residual (RMR) was also 0.03, indicating the measure's significance and that the items accurately measure the intended dimensions. The Root Mean Square Error of Approximation (RMSEA) was 0.045, below the recommended threshold of 0.06, indicating a good fit

Table 3 The Internet of Things Communication Skills Confirmatory Factor Analysis

C01: I know how to share data that my smart devices collect	0.68***
C02: I know how to share collected data from smart devices on the internet	0.72***
C03: I know how I can make contacts with other users with my smart devices	0.71***
C04: I know how I can give other users feedback on the data they have collected with their smart device	0.69***
C05: I know how to set up with whom I can share the collected data from a smart device	0.73***

4.4.1.3. CFA for Customer Knowledge Management (CKM)

Table 4: Customer Knowledge Management Confirmatory Factor Analysis

My organization provides channels to enable ongoing two-way communication between our key customers and us.	0.75***
Customers can expect exactly when services will be performed.	0.77***
My organization fully understands the needs of our key customers.	0.79***
My organization provides channels to enable ongoing two-way communication between our key customers and us.	0.76***
Customers can expect exactly when services will be performed.	0.74***

Table 4: Customer Knowledge Management Confirmatory Factor Analysis (Cont'd)

My organization fully understands the needs of our key customers.	0.78***

All standardized factor loadings were statistically significant ($P < 0.001$), indicating that each item is a good indicator of its respective factor. The standardized loadings ranged between 0.74 and 0.90, above the acceptable threshold of 0.5 (Hair et al., 2017).

Model Fit Indicators:

- Goodness of Fit Index (GFI): 0.89, close to 1, indicating a good fit between the model and the data.
- Comparative Fit Index (CFI): 0.98, higher than 0.95, indicating excellent fit.
- Tucker-Lewis Index (TLI): 0.97, above 0.95, suggesting good fit.

- Root Mean Square Residual (RMR): 0.032, indicating good precision and that the items accurately measure the intended dimensions.
- Root Mean Square Error of Approximation (RMSEA): 0.032, below the recommended threshold of 0.06, suggesting good fit.

4.4.2. Construct Validity

Refers to the extent to which a measurement tool accurately assesses the theoretical construct it is intended to measure (McGrath, 2023). It ensures that the tool accurately represents the theoretical construct, crucial for demonstrating construct validity (Chia et al., 2023). This type of validity examines how well the measurement tool captures the underlying theoretical constructs, such as the impact of interconnected supply chains, customer knowledge management, and the moderating role of IoT skills. Establishing construct validity involves providing evidence that the measures align with the theoretical concepts the researcher aims to measure.

4.4.2.1. Statistical Methods for Assessing Construct Validity.

- Factor Analysis: This process identifies patterns in data and assesses whether they align with expected patterns based on theoretical constructs.
- Confirmatory Factor Analysis (CFA)**: This technique tests a predefined model against the data. It is similar to exploratory factor analysis but more focused on validating specific hypotheses.**
- Structural Equation Modeling (SEM)**: This method combines factor analysis and regression analysis to evaluate relationships between variables and determine whether they support the proposed constructs (Sekaran & Uma, 2003). Construct validity can be confirmed through convergent and discriminant validity.**

4.4.3. Convergent Validity

Convergent validity assesses whether a measurement tool measures a single construct or dimension effectively. Several statistical methods are used to evaluate convergent validity:

- Average Inter-Item Correlation: Computes the average correlation coefficient among all possible pairs of items within the tool.
- Composite Reliability: Integrates item correlations into a single reliability estimate using a statistical technique known as composite reliability.

Convergent validity is demonstrated when a strong correlation exists between measures of the same concept. According to Hair et al., (2017) convergent validity reflects how strongly items related to a concept are correlated. To achieve convergent validity, the Average Variance Extracted (AVE) for items should be greater than 0.50 (Hair et al., 2017). Convergent validity ensures that multiple measures of the same construct are positively related, enhancing the accuracy and reliability of the measurement tool. Results from convergent validity testing of interconnected supply chain measurement items show that the correlation coefficients between each item and its related dimension, as well as the overall variable, were acceptable, exceeding the value of 0.3. The Average Variance Extracted (AVE) for the dimensions of the prepared supply chain (0.72), interconnected supply chain (0.77), and interconnected

supply chain (0.71) all exceeded the acceptable threshold of 0.5. This confirms the validity of the measurement tool for the independent variable.

The results of the convergent validity test for the statements used in the survey measuring communication skills of the Internet of Things (IoT-C) indicated that the correlation coefficients between each statement and its associated dimension, as well as with the variable as a whole, were all acceptable, exceeding the threshold of 0.5. However, eleven statements did not surpass 0.4, prompting the researcher to consider the possibility of excluding these statements, as shown in the table. The Average Variance Extracted (AVE) for each dimension exceeded the acceptable threshold of 0.5 for the communication skills dimension (0.76). These results confirm the validity of the questionnaire used to measure the moderating variable (IoT skills). This analysis supports the reliability and validity of the measurement tool used in the study, enhancing the credibility of the research findings related to the moderating effect of IoT skills on the relationship between the interconnected supply chain and customer knowledge management.

The results of the convergent validity test for the statements used in the survey measuring Customer Knowledge Management (CKM) demonstrated that the correlation coefficients between each statement and its associated variable and the variable as a whole were generally acceptable, exceeding the value of 0.5. However, three statements did not exceed 0.4; consequently, the researcher considered the possibility of excluding these statements, as indicated in the table. The Average Variance Extracted (AVE) for each dimension surpassed the acceptable threshold of 0.5 (0.81). These results confirm the validity of the questionnaire used to measure the dependent variable (CKM). This analysis supports the reliability and validity of the measurement tool used in the study, enhancing the credibility of the research findings related to Customer Knowledge Management in the context of interconnected supply chains and IoT-C skills. The high AVE values indicate that the variables explain a significant portion of the variance in their respective indicators, further strengthening the construct validity of the CKM measurement model.

4.4.4. Discriminant Validity

The researchers have conducted a comprehensive validity assessment of the study's measurement tools, focusing on discriminant and criterion validity. This rigorous approach enhances the overall quality and reliability of the research. Discriminant validity was evaluated using the Average Variance Extracted (AVE) method, compared with squared correlations between constructs. The results indicated that all constructs demonstrated sufficient discriminant validity, ensuring that each measure is distinct and captures unique aspects of the variables under study. Criterion validity was assessed using Pearson correlation coefficients and AVE calculations. The AVE values for all dimensions of the study variables (Interconnected supply chain, Internet of Things Skills, and Customer Knowledge management) exceeded the threshold of 0.5, indicating strong criterion validity.

All dimensions across the three main variables have AVE values ranging from 0.67 to 0.83. These results strongly support the validity of the measurement scales used

in the study. The thorough validation process, encompassing both discriminant and criterion validity, provides strong evidence for the reliability and validity of the measurement instruments. This methodological rigor enhances the credibility of the study's findings regarding the relationships between Interconnected supply chain, Internet of Things Skills, and Customer Knowledge management in the context of e-commerce companies in Egypt. The robust validation ensures that the study's conclusions are based on sound measurements, thereby increasing the potential for meaningful theoretical and practical implications in the Interconnected Supply Chain and customer Knowledge management fields.

4.4.5. Reliability

The researchers have conducted a thorough reliability analysis of the study's measurement instruments, emphasizing the importance of reliability in ensuring consistent and dependable data collection. The study employed Cronbach's alpha as the primary method for assessing internal consistency reliability. Key points from the reliability analysis include:

- The researcher initially tested the instrument on a sample of 30 participants from the target population, including production and operations managers and marketing managers.
- The acceptable threshold for Cronbach's alpha was set at 0.7 per established research standards.
- Item-total correlations were evaluated, with a range of 0.35 to 0.80 considered acceptable, based on Hair et al. (2017).

For the Internet of Things (IoT) Communication Skills dimension, the initial item-total correlation was 0.43 for six items. Three items were removed due to correlations below 40%. After removal, the Cronbach's alpha for this dimension increased to 0.633 for the remaining three items. For the Customer Knowledge Management dimension, the item-total correlation was 0.633 for three items. All items were retained as they met the 40% correlation threshold. This reliability analysis demonstrates the researcher's commitment to ensuring the internal consistency of the measurement scales. By carefully evaluating and refining the items, the researcher has improved the instrument's reliability, particularly for the IoT Communication Skills dimension. The Customer Knowledge Management dimension showed satisfactory reliability without needing item removal. These results provide a solid foundation for the subsequent analyses in the study, enhancing the credibility and trustworthiness of the findings related to Interconnected supply chain, Internet of Things Skills, and Customer Knowledge management in the context of e-commerce companies in Egypt.

5. Results and Data Analysis

5.1. Correlation

The correlation analysis reveals a significant positive correlation between Interconnected Supply Chain (ISC), Communication Skills of Internet of Things (CSIoT), and Customer Knowledge Management (CKM). This suggests that as the level of interconnectedness in the supply chain increases, the communication skills of IoT devices also improve, leading to better customer knowledge management. The correlation coefficient between ISC and CSIoT is 0.65**, indicating a strong positive relationship between the two variables. Similarly, the correlation coefficient between CSIoT and CKM is 0.58**, indicating a moderate to strong positive relationship. The correlation analysis also reveals that the communication skills of IoT devices play a moderating role in the relationship between ISC and CKM. This suggests that the effectiveness of ISC in improving CKM is contingent upon the level of communication skills of IoT devices. The correlation coefficient between ISC and CKM is 0.40**, but the correlation coefficient between ISC and CSIoT is 0.65**, and the correlation coefficient between CSIoT and CKM is 0.58**; thus, it can be inferred that the communication skills of IoT devices are playing a moderating role in the relationship between ISC and CKM. The findings suggest that organizations can improve customer knowledge management by investing in IoT devices with advanced communication skills and developing strategies to integrate them into their supply chain operations. For instance, a company implementing an IoT-based Interconnected Supply Chain system can expect improvements in customer knowledge management, particularly if it facilitates real-time communication and data sharing between different stakeholders.

Table 5: Correlations among Study Variables

	ISC	CSIoT	CKM
ISC	1		
CSIoT	0.65**	1	
CKM	0.40**	0.58**	1

Note: ** indicates a significant correlation at the 0.01 level.

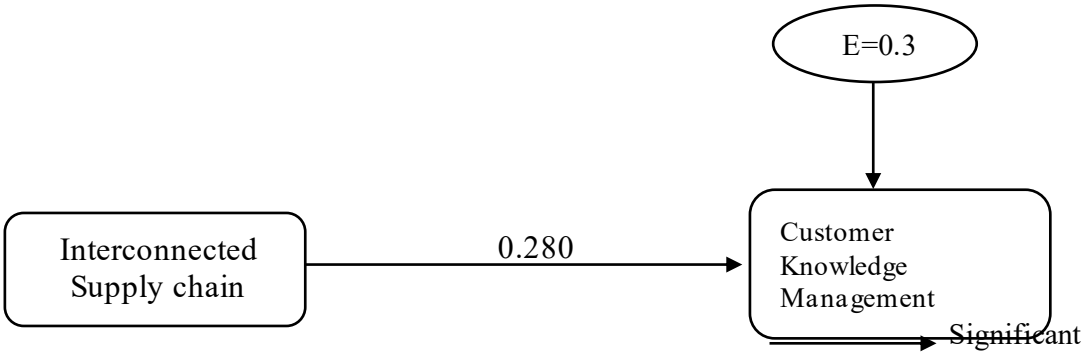
5.2. Direct Effect of Interconnected Supply Chain on Customer Knowledge Management

The regression model is significant, with an F-value of 65.85, which is significant at the 0.01 level. The coefficients of the independent variables, specifically the smart supply chain (β=0.280) and the integrated supply chain (β=0.204), significantly positively impact customer relationship management at the 0.01 level. The coefficient of the equipped supply chain (β=0.169) also has a significant positive impact, but at the 0.05 level. The adjusted R-squared value is 0.140, indicating that the smart supply chain explains 14% of the variation in customer relationship management. The remaining 86% is attributed to other factors not included in the model. These results can be visually represented in the following Figure, which shows the statistical analysis of the impact of the smart supply chain on customer relationship management.

Table 6: Direct Effect of Interconnected Supply Chain on Customer Knowledge Management

Independent Variable	Dependent Variable	(β)	(T)	(Sig)
Interconnected Supply Chain	Customer Knowledge Management	0.28**	1.032	0.001

Figure 2: Direct Effect of Interconnected Supply Chain on Customer Knowledge Management



The findings suggest that an interconnected supply chain has a significant positive influence on customer knowledge management. This implies that when supply chain elements are well-integrated and communicate effectively, it enhances the ability to manage and utilize customer knowledge. This supports the idea that seamless supply chain operations contribute to better information flow and knowledge management practices regarding customer insights. The results match with Leon et al.'s (2024) findings.

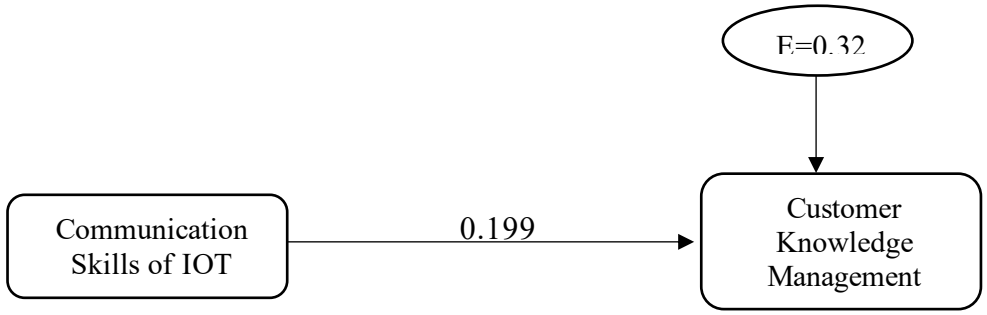
5.3. Direct Impact of Internet of Things Communication Skills on Customer Knowledge Management.

The table presents the regression analysis results, which reveal that the regression model is significant, with an F-value of 146.9, which is significant at the 0.01 level. The coefficients of the independent variables, specifically the Internet of Things (IoT) skills, significantly impact customer knowledge management. The coefficients are significant at the following levels: IoT-C skills: β=0.223 (significant at 0.01 level). This indicates a significant positive impact of IoT skills on customer knowledge management. The adjusted R-squared value is 0.109, indicating that IoT-C skills explain 11% of the variation in customer knowledge management. The remaining 89% is attributed to other factors not included in the model. These results can be visually represented in a figure, which shows the statistical analysis of the impact of IoT-C skills on customer knowledge management.

Table 7: Direct Impact of Communication Skills of Internet of Things on Customer Knowledge Management

Independent Variable	Dependent Variable	(β)	(T)	(Sig)
Communication Skills of the Internet of Things	Customer Knowledge Management	0.223**	2.12	0.01

Figure 3: Direct Impact of Communication Skills of Internet of Things on Customer Knowledge Management



The results indicate that the communication skills of IoT significantly and positively impact customer knowledge management. IoT devices or systems with advanced communication capabilities improve how customer knowledge is gathered, shared, and applied. Effective communication through IoT can facilitate better data collection, integration, and usage, thus enhancing overall customer knowledge management processes. These results align with Galgotia and Lakshmi's (2023) results.

5.4. The Moderating Role of Communication Skills of Internet of Things in the Relationship between the Interconnected Supply Chain and Customer Knowledge Management

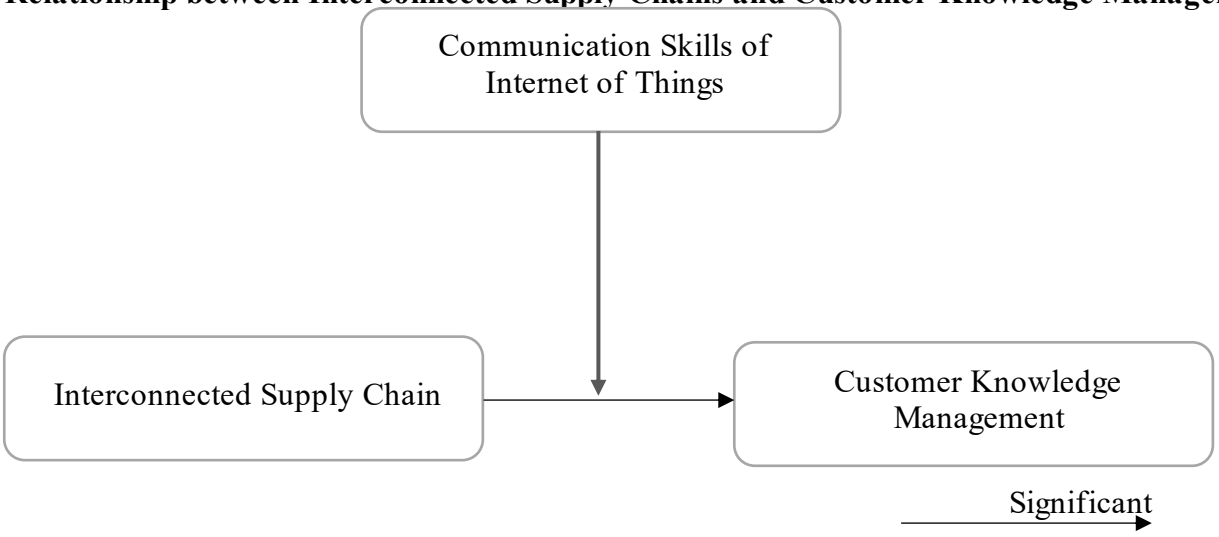
The table presents the results of a regression analysis. The model's coefficients indicate that the intercept or constant term is significant, with a 2.1 value (p-value = 0.00001). Additionally, integrated supply chain and communication skills significantly positively affect customer knowledge management, with coefficients of 0.9 (p-value = 0.0001) and 0.7 (p-value = 0.000001), respectively. Furthermore, the interaction term between integrated supply chain and communication skills is significant, with a coefficient of 0.35 (p-value = 0.0005). The results indicate that the integrated supply chain, communication skills, and their interaction significantly impact customer knowledge management. When both integrated supply chain and communication skills are zero, the level of customer knowledge management is 2.1. For every unit increase in integrated supply chain, customer knowledge management increases by 0.9 units while maintaining constant communication skills. Similarly, for every unit increase in communication skills, customer knowledge management increases by 0.7 units, holding the integrated supply chain constant.

The positive interaction term suggests a moderating effect, where communication skills enhance the impact of the integrated supply chain on customer knowledge management. The model explains 68% of the variation in customer knowledge management, with an adjusted R-squared value of 0.66. This indicates that the model is a good fit for the data, and that integrated supply chain, communication skills, and their interaction are important predictors of customer knowledge management. The results suggest a significant positive moderating role of communication skills in the relationship between integrated supply chain and customer knowledge management. The model provides a good fit for the data, and the results have important implications for businesses seeking to improve their customer knowledge management practices. By investing in integrated supply chain and communication skills, businesses can expect significant improvements in their customer knowledge management capabilities.

Table 8: The Moderating Role of Communication Skills of the Internet of Things in the Relationship between Interconnected Supply Chains and Customer Knowledge Management.

Variables	Dependent Variable	Coeff	SE	(T)	P-value (sig)
Intersection	Customer Knowledge Management	2.1	0.4	5.25	0.00001
Interconnected Supply Chain		0.9	0.2	4.5	0.0001
Communication Skills of IOT		0.7	0.15	4.67	0.000001
Interconnected Supply Chain * Communication Skills of IOT		0.35	0.1	3.5	0.0005
F (sig) =28 (p-value) = (0.00001)			R^2 =0.68 | Adj R^2= 0.66		

Figure 4: The Moderating Role of Communication Skills of the Internet of Things in the Relationship between Interconnected Supply Chains and Customer Knowledge Managemen



The findings also show that the communication skills of IoT significantly moderate the relationship between an interconnected supply chain and customer knowledge management. This means that the communication capabilities of IoT influence the effectiveness of the interconnected supply chain on customer knowledge management. Specifically, the positive impact of an interconnected supply chain on customer knowledge management is enhanced when IoT systems have strong communication skills. This highlights the importance of advanced IoT communication in leveraging the benefits of an interconnected supply chain.

6. Interpretation of Results and Explanation

The findings from this study reveal that all three hypotheses are significant, highlighting the crucial role of interconnected supply chains and IoT communication skills in customer knowledge management. Specifically, the data supported Hypothesis 1 (H1), which posits that an interconnected supply chain significantly positively influences customer knowledge management, indicating that well-integrated supply chain systems enhance the effective management of customer insights. Hypothesis 2 (H2), which suggests that the communication skills of the Internet of Things (IoT) significantly and positively impact customer knowledge management, was also confirmed, emphasizing the importance of advanced IoT communication technologies in improving the collection and application of customer data. Furthermore, Hypothesis 3 (H3), which proposes that the communication skills of IoT significantly moderate the relationship between an interconnected supply chain and customer knowledge management, was supported, demonstrating that the benefits of a connected supply chain are amplified when bolstered by sophisticated IoT communication capabilities. These findings collectively suggest that leveraging interconnected supply chains and advanced IoT communication technologies is essential for optimizing customer knowledge management practices.

The correlation analysis reveals significant positive relationships between the Interconnected Supply Chain (ISC), the Communication Skills of the Internet of Things (CSIoT), and Customer Knowledge Management (CKM). This suggests that as supply chains become more interconnected and IoT communication skills improve, customer knowledge management is also enhanced. The strong correlation between ISC and CSIoT (0.65) indicates that these two factors are closely linked, potentially due to the integral role of IoT devices in modern interconnected supply chains. A key finding is the moderating role of CSIoT in the relationship between ISC and CKM. This suggests that the communication capabilities of IoT devices influence the impact of an interconnected supply chain on customer knowledge management. Organizations looking to improve their CKM through supply chain interconnectedness should pay close attention to the communication skills of their IoT devices, as this appears to be a crucial factor in maximizing the benefits of ISC.

The regression analysis demonstrates that various aspects of smart supply chains (smart, integrated, and equipped) significantly impact customer relationship management. The smart supply chain explains 14% of the variation in CKM, which,

while significant, also indicates that many other factors influencing CKM were not captured in this model. This highlights the complexity of customer relationship management and suggests that a holistic approach considering multiple factors is necessary for improvement. The analysis of IoT skills' impact on customer knowledge management reveals that IoT-C skills explain 11% of the variation in CKM. This moderate effect size suggests that while IoT skills are important, they are not the sole determinant of effective CKM. Organizations should view IoT skills as one component of a broader strategy for improving CKM.

The interaction effect between integrated supply chain and communication skills on customer knowledge management is particularly noteworthy. The positive interaction term (0.35) indicates that the impact of an integrated supply chain on CKM is enhanced when combined with strong communication skills. This synergistic effect underscores the importance of developing both areas simultaneously rather than focusing on one at the expense of the other. The high adjusted R-squared value (0.66) in the final model suggests that the combination of integrated supply chain, communication skills, and their interaction explains a substantial portion of the variance in customer knowledge management. This provides strong evidence for the importance of these factors in improving CKM and offers clear direction for organizations seeking to enhance their customer knowledge practices. From an academic perspective, these findings contribute to the growing literature on the intersection of Interconnected Supply Chain, Internet of Things, and customer knowledge management. Identifying CSIoT as a moderating factor is particularly valuable, as it provides a more nuanced understanding of how these technologies interact to influence business outcomes.

7. Future Research Recommendations

For future research, exploring additional factors that might influence the relationships observed in this study would be beneficial. For instance, investigating the role of organizational culture, employee training programs, or specific IoT technologies could provide a more comprehensive understanding of optimizing customer knowledge management in interconnected supply chains. Another avenue for future research would be to conduct longitudinal studies to examine how the relationships between these variables evolve over time. As IoT technologies and supply chain practices continue to advance, the nature and strength of these relationships may change. Long-term studies could provide valuable insights into the sustainability and evolution of these effects. Finally, future research could focus on industry-specific applications of these findings. Different sectors may have unique challenges and opportunities when implementing interconnected supply chains and leveraging IoT technologies. Case studies or comparative analyses across industries could yield practical insights for managers and policymakers in various fields.

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