How Can the Internet of Things Affect Global Supply Chain Management in the 21st Century: A Case Study Based on the Food Grocery Industry and the Manufacturing Industry

Yili Deng*

Penn State Smeal College of Business, Pennsylvania State University, University Park, State College, USA

*Corresponding author: yxd5155@psu.edu

Abstract. The global supply chain network in the 21st century is faced with increasing unprecedented uncertainty, such as the unpredictable rage of Covid-19 and the fierce international competition for more efficient and affordable supply chain management. For such reasons, the Internet of Things (IoT), a modern tool in supply chain management, has been used more often. This research examined the application of IoT in the food grocery and manufacturing industries, both of which sustained severe challenges during the rage of Covid-19 and are essential for social and economic development. The findings of this research suggest that IoT is a powerful tool to increase food safety and security in emergencies like Covid-19. IoT also enhances the supply network effectiveness of the food grocery industry by working with e-commerce. In the manufacturing industry, IoT reduces costs and avoids waste in goods transportation. IoT also increased supply chain reliability by tracking the movement of goods and more effective equipment maintenance. However, the findings also reveal that IoT is not flawless, as it bears more risks in terms of data breaches. This should be the future focus for improving IoT's application in supply chain management.

Keywords: Internet of Things; Supply Chain Management; Food Grocery Industry; Manufacturing Industry.

1. Introduction

Since the last few decades in the 20th century, innovations have flooded human society, reshaping and transforming different aspects of human civilization. One of such innovations is the Internet of Things (IoT), which usually refers to "a worldwide network of interconnected heterogeneous objects (sensors, actuators, smart devices, smart objects, RFID, embedded computers, etc.) uniquely addressable, based on standard communication protocols" [1]. As a matter of fact, it is not a recent development that IoT has been used widely for a long time in the transportation industry, the medical industry, the agriculture industry, the food grocery industry, and the manufacturing industry [2-4]. Particularly, in the 21st century, due to increasing globalization and changing customer demands, global supply chain management, especially for multinationals, is faced with growing demand for higher efficiency and lower costs[5]. These changes in the worldwide context of supply chain management then have made IoT one of the favorites for supply chain managers to enhance their supply chain management. By 2020, it is estimated that the number of connected devices and sensors in supply chain management will exceed 50 billion[5]. Hence, there is no doubt that IoT is significant for effective modern supply chain management practices. Specifically, the outbreak of Covid-19 has led to unprecedented challenges to the global value chain, particularly in the food grocery and manufacturing industries [6-9]. This research is deliberately designed to cast light on how IoT mat affect global supply chain management in critical industries in a post-pandemic world concerning both the food grocery industry and the manufacturing industry, which are either closely related to people's daily life or serve as a pillar for national economic developments in major countries. The significance of this research is that it can cast light on how supply chain managers can be better prepared for future similar uncertainties. It also highlights the improvements that should be made to the IoT application in supply chain management.

2. Literature Review

As a matter of fact, due to the importance of IoT in supply chain management, there has been a large body of literature exploring how IoT has been impacting supply chain management. For example, Sharma et al. (2020) studied how IoT has been used to check real-time storage conditions by monitoring different unit operations in the supply chain[2]. However, despite the growing interest in this field, a dispute is how effective IoT can be when applied to enhance supply chain management. On the one hand, many scholars believe that IoT is beneficial to help companies improve their supply chain management, particularly in the face of fast-changing customer demands and uncertainty in a post-pandemic world [9-11]. On the other hand, however, Yang (2020) noticed that not all scholars are so optimistic about IoT's application in supply chain management, as it can bring up new challenges and risks, such as the lack of knowledge to use IoT effectively and possible threats to data security[5]. Hence, it is evident that an existing gap in current literature is whether the advantages of IoT in supply chain management outweigh its disadvantages or not.

In the meantime, due to the importance of the food grocery industry and the manufacturing industry, many scholars and researchers have focused on the application of IoT in the supply chain management of the two industries, some of whom focused particularly on how IoT has been helping the two industries cope with new challenges and uncertainties posed by Covid-19 [4,7,12,13]. Although these studies have been illuminating, they have their limitations. For one thing, most studies tend to focus on one aspect of IoT and its applications in the supply chain of either industry. Ekren et al. (2021) focused on how IoT can help supply chains solve labor shortages during Covid-19[3]. Whereas Iftekhar and Cui (2021) focused on how traceability with IoT can ensure food security[8].

Similarly, Passlick et al. (2020) studied how IoT can help maintain equipment in a manufacturing supply chain network. In other words, there is a lack of overall assessment of the significant differences that IoT can make to supply chain management in the food grocery industry and the manufacturing industry[14]. For another, most of the existing studies on IoT applications in the manufacturing and food grocery industries tend to only focus on what has already been done, without any suggestions for future directions. This also reduced the value and meaningfulness of the existing literature. Hence, it is fair to say that the other two gaps in the existing literature about the application of IoT in the supply chain management of the food grocery industry and the manufacturing industry include a lack of an overall assessment and insufficient suggestions for future directions of IoT practice in the supply chain of the two sectors.

3. Case Studies

3.1 The application of IoT in the food grocery supply chain

The outbreak of Covid-19, its health risks, and the ensuing social lockdowns in several countries have made food grocery supply a vital issue. For one thing, in countries like China, the long-term social lockdowns led to crazy panic stockpile behavior among customers, hoarding food, and increasing the supply shortage[6]. For another, amid the rage of Covid-19, e-commerce for food groceries became increasingly popular among customers worldwide [3]. This poses new challenges to the supply chain management of food groceries, such as the need for real time tracking of information. After Covid-19, people, especially those who experienced social lockdown, are more concerned with food security than ever, which increased the use of IoT in the supply chain management of good groceries [15]. This then makes the food grocery a perfect example to look into how IoT can exert tremendous effects on establishing a safe and secure food supply for consumers worldwide.

Although the real cause of Covid 19 remains debatable, many people believe Covid-19 has close associations with what people choose to eat, such as wild animals like bats [16]. Hence, consumers today are more concerned with food safety than ever, which makes establishing a supply chain that offers safe food to customers essential. Given this, Iftekhar and Cui (2021) pointed out that from the

perspective of supply chain management, traceability has been crucial in that it can ensure sufficient information on environmental conditions and product quality, which are an essential reference to food safety and can profoundly alter food security[8]. After all, no consumer would like to buy unsafe food items. This concern then gives ample space for IoT to play its role in food grocery supply chain management. Perhaps the most significant return of investing in IoT in food groceries is that suppliers and food sellers can closely monitor key indicators of food safety. This can help reduce the likelihood of foodborne disease outbreaks, potentially paralyzing the supply chain for food and groceries. Particularly when it comes to the IoT tools to ensure food safety in food groceries, the most commonly used equipment is the real-time temperature tracking sensor, which can continuously monitor the product temperature from the moment the product leaves the farm until it is bought by the consumer [8]. This application of IoT can ensure the benefit of consumers, food suppliers, and grocery owners. In the United States, the Food Safety Modernization Act (FSMA) of 2011 imposes strict and specific restrictions on the temperature control and tracking of foot items [8]. IoT enables different links in the supply chain of good groceries to stick to these restrictions.

Moreover, IoT also ensures food safety by complying with the Hazard Analysis and Critical Control Point (HACCP), where more consistent data collection and information reporting under the HACCP checklist become available [8]. Different parties in the food grocery supply chain can check such information concurrently. From this perspective, it is evident that IoT tools can enhance food safety in a post-pandemic world.

In addition to food safety, IoT is also a massive contributor to food security in a post-pandemic world. In the food grocery sector, it is estimated that about 40% of fresh items go bad before they can reach consumers [13]. This is a lethal threat to food security in countries like China, where the so-called dynamic-zero policy has made social lockdowns in different cities commonplace. Given this, IoT can also be applied to avoid or eliminate such a colossal waste of fresh food in the supply chain network, contributing significantly to food security in today's world. Specifically, Rejeb et al. (2021) proposed that food businesses can establish an integrated cloud database to track the real-time control point of food for better management decisions[10]. For example, when a batch of broccoli produced in Mexico encounters a negative temperature factor during shipment, the suppliers can shorten the quality guarantee period and offer special prices not only to reduce the loss but also to ensure the broccoli will not be wasted. This is indeed in line with the proposal of Kayikci et al. (2022). They also proposed that IoT sensor data can show suppliers the freshness of the food items, based on which suppliers can use differentiated pricing strategies to ensure as many fresh items can be sold before they go rotten and end up as waste[13].

Particularly in the face of the rise of e-commerce in food grocery since the outbreak of Covid-19, IoT has also been playing a critical role in ensuring the supply network effectiveness in the e-commerce food grocery sector. Using IoT in the supply chain to track user behaviors, accurately predict market demand, control product quality, shorten the supply chain, and reduce operating costs by extending to the production end is essential to improve the supply chain management ability[3]. For example, when Covid-19 gives rise to exponentially rising orders online for fresh food items, e-commerce owners usually suffer labor shortage for sorting and distribution. With IoT, they may figure out service-oriented enterprises such as the catering industry and hotels in certain areas where parts of their supply chain network operations, then they could share employees with these enterprises so that employees of the catering industry who are temporarily out of business can come to the fresh e-commerce platform to work.

However, the application of IoT to ensure the safety, security, and effectiveness of food grocery supply is not flawless. Just like coins, there is also the other side of IoT in the food grocery supply chain network. For example, IoT may lead to privacy leakage in the supply chain network of food groceries, as the data and information generated by the sensors are usually digitalized, which can then be susceptible to hackers [11]. On the one hand, these data generally include large amounts of personal data of clients and consumers. On the other, privacy leakage can also expose business secrets of food suppliers, such as their future directions.

3.2 The application of IoT in the manufacturing industry supply chain

The manufacturing industry is an essential pillar of the economy in many developing and developed countries. According to Khan et al. (2021), the top ten manufacturing countries include China, the United States, Japan, Germany, South Korea, India, Italy, France, the United Kingdom, and Mexico[12]. Significantly, amid the rage of Covid-19, under the global value chain division of labor, supply and demand overlapped and impacted each other, which made the global supply chain face the risk of interruption and have significant global supply chain uncertainty [9]. Even in a post-pandemic world, many manufacturers face multiple difficulties, such as supply chain interruption, insufficient production material inventory, cash flow shortage, rising transportation and logistics costs, doubling epidemic prevention pressure, insufficient market grayscale, and declining customer demand. All these, then have allowed IoT to make a difference in the supply chain management of the manufacturing industry, one of the most critical industries in the world.

IoT can help manufacturers manage their supply chain by reducing costs and avoiding waste. An essential purpose of modern supply management is to maintain the best quantity of raw materials to implement lean manufacturing [2]. To this end, they need to keep sufficient supply to avoid depletion and operation pause and at the same time, ensure that there is no backlog. This further requires manufacturers to replenish raw materials according to various factors when the inventory exceeds a certain level. IoT sensors can monitor a manufacturer's inventory and notify relevant personnel when the quantity drops to a critical level, enabling manufacturers to order replenishment in time to ensure minimum cost, minimum waste, and uninterrupted operation [2]. In a post-pandemic world nowadays, clients of many manufacturers still face high uncertainty, which also increases the uncertainty facing manufacturers. This inventory monitoring function of IoT can at least reduce some degree of uncertainty facing global manufacturers today.

In the meantime, similar to food groceries, IoT can also be used to track the movement of goods in the manufacturing industry. Logistics is the key driver of any manufacturing supply chain, which is responsible for transferring goods and resources from one end of the supply chain to the other. A third-party service provider usually provides logistics in the manufacturing industry [9]. Although the transportation status of goods can be reported at a fixed time and regular distance intervals, the estimated arrival time of goods can often be misjudged, which may cause unnecessary trouble in the supply chain, such as deformation of compliments due to higher temperature or longer delivery time in the transportation process. With the IoT network, manufacturers can monitor the maintenance conditions of goods during transportation. When these conditions reach a non-optimal level, the storage conditions can be changed remotely, such as automatically adjusting the temperature in the transportation according to the situation [9]. The IoT sensors can also prevent theft and other loss of products in transportation based on the changes in the size and weight of the products, and essential stakeholders can use GPS and other tracking methods to find the location of goods at any time [9].

Moreover, IoT can help manufacturing supply chain networks with more effective equipment maintenance. The supply chain in the manufacturing industry is usually heftily reliant on multiple pieces of equipment, whether for production or transportation purposes. Such equipment must always be kept at the best functional and performing level to ensure the continuity of the manufacturing supply chain [14]. In other words, any shutdown due to equipment failure may trigger a chain reaction, affecting the entire supply chain of manufacturers and leading to serious financial losses. Given this, IoT sensors can continuously monitor equipment and its conditions in the manufacturing supply chain network, allowing maintenance personnel to check and fix any problems before they become serious [14]. Timely implementation of such maintenance operations will not only help prevent any unnecessary shutdown at the manufacturers due to mechanic failure but also prevent severe and irreparable equipment damage that may lead to considerable expenses in the future. IoT sensors can also be installed on vehicles to track their functions and performance [14]. This, then can minimize transportation and delivery delays of items such as materials, components, and finished products by triggering preventive maintenance when needed. In doing so, manufacturers can better meet client

needs and thus enhance their service quality, which can potentially make a massive difference to their sustainability in a post-pandemic world.

However, just like in the food grocery industry, the application of IoT in the supply chain management of the manufacturing industry may also lead to drawbacks. Significantly, the application of IoT may lead to severe security breaches in the supply chain manufacturer' supply chain network. When it comes to IoT devices, their components have intrinsic security attributes that depend on other members, and these components' attributes then also impact the security of other components as well: If any of these components is vulnerable, an attacker can destroy the entire supply chain of the manufacturer [4]. In addition, manufacturers using an IOT device to manage their supply chain do not always maintain an inventory of the number of IoT devices connected to the network [4]. Therefore, tracking the potentially vulnerable devices in the enterprise network will make security and risk management difficult, improving the probability of successful network attacks.

4. Conclusion

In light of what has been mentioned above, based on the food grocery industry and the manufacturing industry, it is evident that while IoT's applications have both pros and cons in supply chain management, its advantages far outweigh its disadvantages. This solves one of the disputes in current literature regarding how advantageous IoT is when applied to supply chain management. On top of this, by refereeing to different aspects of the food grocery industry and the manufacturing industry, this research developed relatively thorough insights into the functions of IoT in the supply chain management of the two sectors, including better food safety and security, solutions to labor shortage, reduced costs and waste, effective equipment maintenance, and eventually between communications between different links in a supply chain network. About the disadvantages, such as data security and privacy breach, it is the direction for the future development of IoT in supply chain management.

References

[1] Fortino, Giancarlo, and Paolo Trunfio, eds. Internet of things based on smart objects: Technology, middleware and applications. Springer Science & Business Media, 2014.

[2] Sharma A, Kaur J, Singh I. Internet of things (IoT) in pharmaceutical manufacturing, warehousing, and supply chain management. SN Computer Science, 2020, 1(4): 1-10.

[3] Ekren B Y, Mangla S K, Turhanlar E E, et al. Lateral inventory share-based models for IoT-enabled E-commerce sustainable food supply networks. Computers & Operations Research, 2021, 130: 105237.

[4] Alattas K A, Mardani A. A novel extended Internet of things (IoT) Cybersecurity protection based on adaptive deep learning prediction for industrial manufacturing applications. Environment, Development and Sustainability, 2022: 1-17.

[5] Fog and Fogonomics: Challenges and Practices of Fog Computing, Communication, Networking, Strategy, and Economics. 2020.

[6] Hao N, Wang H H, Zhou Q. The impact of online grocery shopping on stockpile behavior in Covid-19. China Agricultural Economic Review, 2020.

[7] Habib S, Hamadneh N N. Impact of perceived risk on consumers technology acceptance in online grocery adoption amid covid-19 pandemic. Sustainability, 2021, 13(18): 10221.

[8] Iftekhar A, Cui X. Blockchain-based traceability system that ensures food safety measures to protect consumer safety and COVID-19 free supply chains. Foods, 2021, 10(6): 1289.

[9] Ardolino M, Bacchetti A, Ivanov D. Analysis of the COVID-19 pandemic's impacts on manufacturing: a systematic literature review and future research agenda. Operations Management Research, 2022: 1-16.

[10] Rejeb A, Rejeb K, Abdollahi A, et al. Digitalization in food supply chains: A bibliometric review and key-route main path analysis. Sustainability, 2021, 14(1): 83.

[11] Lei M, Xu L, Liu T, et al. Integration of Privacy Protection and Blockchain-Based Food Safety Traceability: Potential and Challenges. Foods, 2022, 11(15): 2262.

[12] Khan I, Hou F, Le H P, et al. Do natural resources, urbanization, and value-adding manufacturing affect environmental quality? Evidence from the top ten manufacturing countries. Resources Policy, 2021, 72: 102109.

[13] Kayikci Y, Demir S, Mangla S K, et al. Data-driven optimal dynamic pricing strategy for reducing perishable food waste at retailers. Journal of Cleaner Production, 2022, 344: 131068.

[14] Passlick J, Dreyer S, Olivotti D, et al. Predictive maintenance as an internet of things enabled business model: A taxonomy. Electronic Markets, 2021, 31(1): 67-87.

[15] Hove-Sibanda P, Motshidisi M, Igwe P A. Supply chain risks, technological and digital challenges facing grocery retailers in South Africa. Journal of Enterprising Communities: People and Places in the Global Economy, 2021.

[16] Luo L, Ni J, Zhou M, et al. Food Safety Knowledge, Attitudes, and Self-Reported Practices Among Medical Staff in China Before, During and After the COVID-19 Pandemic. Risk Management and Healthcare Policy, 2021, 14: 5027.