



Role of Consumer Technology and Connected Electronic Devices on SCM: A Discussion on its Usages, Impact and Challenges

Aditya Anshul¹ and Anirban Sengupta^{1*}

¹Dept. of Computer Science and Engineering,
Indian Institute of Technology Indore, 453552, INDIA

*Corresponding Author

Abstract:

Consumer technology and connected electronic devices such as the Internet of Things (IoT) are ubiquitous in our everyday lives. These digital devices play an integral role in modernizing human society as well as creating a positive impact on human advancements. The increased trade demands of the rapidly developing modern society and the evolution of supply chain management (SCM) have provided the necessary and sufficient infrastructure for the proliferation of these intelligent consumer technology devices. This chapter presents a novel study on the role and impact of consumer technology and connected electronic devices in supply chain management. A novel perspective and analysis of the impact and usage of the Internet of Things and consumer technology digital devices in supply chain management, along with the agile nature of the supply chain management over the Internet of Things, is presented in this chapter. Moreover, details regarding the advantages of IoT integration with supply chain management, challenges in the deployment of IoT in supply chain management, and future use of IoT in SCM are also discussed in this chapter.

Keywords:

IoT · Consumer technology · SCM · Industry 4.0

1. Introduction

The development of modern society revolves around the enormous use of consumer technology and connected electronic devices (also known as the Internet of Things (IoT)). It is hard to imagine life without smartphones and smart devices such as tablets, laptops, smartwatches, etc. Besides making our daily life easier, they also provide crucial real-time information related to health, finance, management, etc. The involvement of multiple offshore (3rd -party intellectual property (IP) core vendors) entities in these semiconductor devices overall design and manufacturing process makes the process complex. It is because some places can afford cheap labor while some have reasonable technical costs. This introduces the supply chain management (SCM) in these smart semiconductor devices' overall design, manufacturing, and selling process. Besides these, SCM is the backbone of the current fast-developing society which involves massive trade worldwide daily. Nowadays, every person contributes to the SCM process, either as the supplier, end consumer, or intermediary. For example, delivery of products directly to the home via online booking, food delivery services, various other types of logistic services, etc., involves the SCM process at the root level. Earlier, SCM only used basic tools and technologies such as transport management systems (TMS), Enterprise Resource Planning (ERP), bar code scanners,

etc. But, industrial development 4.0 completely revolutionizes the supply chain industry by introducing the IoT and various smart consumer technology devices. Figure 1. illustrates the usages and impact of industry development 4.0 in detail. IoT is basically physical objects capable of sensing, processing, storing, and exchanging real-world data with other devices connected over any communicating network, such as the internet. Similarly, various smart devices, such as smartwatches, digital cameras, wristbands, tablets, etc., are consumer technology devices. Moreover, the different IoT devices contain various sensors to sense real-time information such as temperature, location, pressure, etc. These sensors are also part of consumer electronic devices. These IoT are used to collect important real-time information in context with the supply chain management, such as the real-time location of goods, preservation of goods, actual route plan, etc., to make SCM more transparent and interactive [1].

Let us consider an example of food delivery services. Nowadays, getting delicious food at the doorstep has become a common practice in metro cities, and it is just a matter of time before it will become popular in villages. IoT integration in SCM facilitates an easy, transparent, and reliable delivery in this case. Now, a person can keep track of the exact departure and arrival time of the parcel, storage temperature, the delivery route plan, and every necessary detail about that delivery. This also happens in the case of goods or logistic transport. Managers, as well as end consumers, can track the exact location of the product and can also make intermediate decisions based on that. Moreover, it becomes crucial in the case of high-value or sensitive goods that the complete transportation system remains transparent to both managers and end consumers for their respective satisfaction.

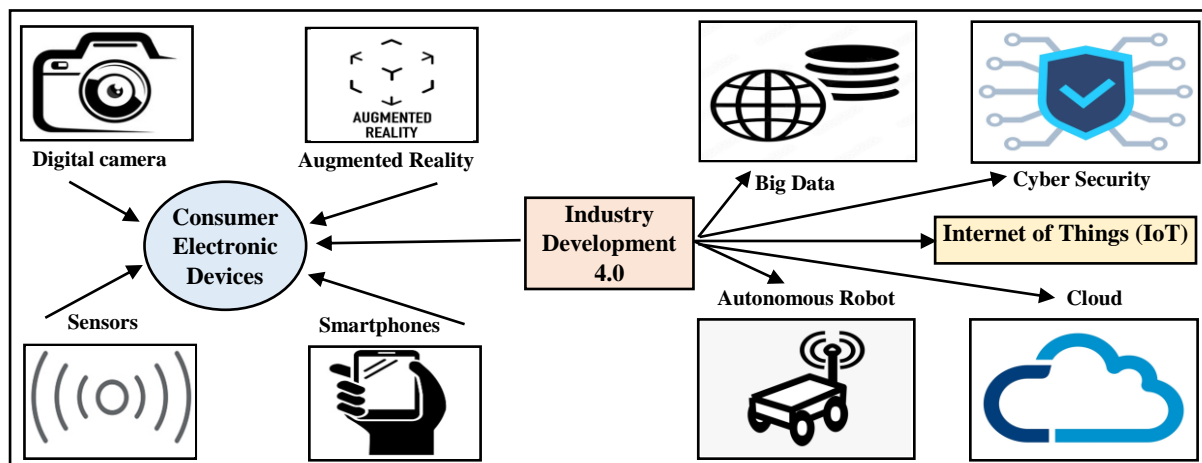


Figure 1: Thematic diagram representing the usage and impact of industry 4.0

Further, the designing and fabrication process of electronic devices also involves SCM up to a great extent. The meteoric growth of the digital and semiconductor industry, competitive rivalries, and time-to-market demands have compelled manufacturing companies to include multiple third-party IP core vendors for the fast development and launch of the final product into the market. This involves SCM at the international level as designing, fabrication, and assembly; all happen in different countries. The production of consumer technology or semiconductor devices involves multiple threats and concerns due to the involvement of third-party entities. Thus, providing a safe and transparent supply chain and management process to handle the needs of such semiconductor companies is crucial. IoTs with SCM are a perfect combination for it. IoTs help to keep track of the different components being transported globally with a more detailed transparency level, such as the involved intermediate warehouses, exact delivery route plan, storage environment conditions in case of sensitive goods, and all involved intermediary [2].

The rest of the chapter is as follows. Section 2 explains the impact and usage of IoT in SCM. Section 3 deals with the agile nature of the SCM over IoT. The importance of IoT integration into SCM is highlighted in section 4. Section 5 discusses the challenges during the deployment of IoT in SCM. Section 6 focuses on the future use of IoT devices in SCM. Finally, section 7 concludes the chapter with the usage and impact of IoT in SCM.

2. Consumer Technology and Internet of Things Usages and Impacts on Supply Chain Management

2.1 Background on Consumer Technology and IoT Usages in SCM

Industrial development 4.0 (Industry 4.0/I4.0) introduces the integration of newer technological development, such as the Internet of Things in Supply Chain Management, to improve the overall management performance and customer services experience and to realize the concept of a smart industry ecosystem [3], [4]. The integration of IoT in SCM automates the supply chain process more effectively by providing continuous traceability, transparency, innovative management, accuracy, and availability of information. Furthermore, it overcomes the incapability of previous management tools & technologies like Enterprise Resource Planning (ERP), Transport Management System (TMS), Advance Planning System (APS), and Warehouse Management System (WMS) [5]. The improvement required in the flow of information, cash, and material for developing an effective and efficient SCM encourages the shift from traditional Electronic Product Codes (EPC) to IoT in SCM [6].

Kevin Ashton first coined the term Internet of Things in 1999 to describe the concept of integration of Radio Frequency Identification (RFID) technology with the internet at the MIT AutoID lab [7]. The collection of connected physical objects that can sense, process, and exchange real-world data with other systems or devices over any communication network, such as the internet, is called IoT [8]. In the modern era, information means power, and these IoT devices generate a massive amount of information that is processed, analyzed, and stored for their respective use. IoT's omnipresent nature facilitates any functionality/process optimization by providing contextual information. We are on the verge of reaching 50 billion smart consumer technology devices, as Ericsson [9] predicted in 2011.

2.2 Impact of Consumer Technology Devices and IoT on SCM

Smart connected electronic devices such as IoT are crucial in enhancing and optimizing the supply chain management process. IoT in SCM supports industries in competing at the same pace as their surrounding environment and provides a better understanding of consumers. An organization's overall growth and development heavily depend upon the knowledge of the complete complex system. The information/statistics provided by IoT describe the complex system better. Some of the key characteristics of IoT adoption in SCM are:

- a) machine-generated information,
- b) real-time equipment monitoring,
- c) large-scale intelligent decisions,
- d) cost reduction and wastage minimization,
- e) integration between supply chain (SC) stages,
- f) delivery service improvement,
- g) seamless communication and transportation,
- h) faster response and increased profits,
- i) enhanced inventory control, and
- j) parts visibility.

Part visibility adds a competitive advantage to IoT adopted SCM compared to non-adopted ones by bringing more visibility and transparency to the individual items [10]. The IoT revolution in SCM has made it easier to authenticate the real-time location and track the speed of movement of goods, which helps in deciding an effective routing plan to minimize delivery delay [11].

Moreover, it also ensures maintaining the proper condition of stored raw materials and products with the help of continuous monitoring through IoT, capable of sensing light intensity, humidity, temperature, and other environmental factors. Further, due to the integration of IoT in SCM, the supply chain manager can easily verify the acknowledgment of the final delivery of the product to initiate administrative works like payment, return, or onward shipping requests. IoT has reduced the relationship gaps between industries and their consumers by giving a better consumer perspective to these industries with the help of stored and analyzed data.

There are two significant problems in the SCM process. First, each stockholder/entity of the supply chain exploits the process to promote their interest and achieve their own goals. The second problem is uncertainty in forecasting and planning, known as the "Bullwhip effect" [12] in the logistical management process. It is challenging to maintain a trade-off between the production and consumption rate of the products to cope with the overstocking problem and stock-outs. As mentioned earlier, a better understanding of the consumer and the entire market will help maintain the required trade-off. Therefore, decentralized monitoring with the IoT and consumer technology devices minimizes the first problem mentioned above. Different entities in the IoT ecosystem, such as devices, users, objects, services, and applications, play an essential role in encouraging machine efficiency improvement, maintenance cost saving, suggesting smart and self-controlling products, and strengthening buyer-seller relationships [4]. IoT implementation also addresses the changing needs of consumers/clients and encourages the optimization of shipments [4].

The most commonly used IoT and consumer technology in supply chain management are RFID chips and mobile sensors. These RFID chips identify, track, and maintain stock availability. It addresses the second problem of the "Bullwhip effect" mentioned above. There are two types of RFID tags named active and passive RFID tags. Active RFID tags have a power source and are coupled with humidity or temperature sensors. In contrast, passive RFID tags use EM (electromagnetic) waves as the power source for the electronic onboard circuit. RFID tags are different from barcodes. The barcode scanner needs a line of sight to the barcode, while the RFID scanner can communicate with RFID tags without coming in the line of sight. RFID technology supports SCM and offers exciting possibilities such as keeping labor costs low, optimizing operational costs, increasing inventory accuracy, mitigating security risks, diminishing error rates, adhering to regulatory and compliance standards, and increasing real-time tracking and visibility [11]. Decathlon uses RFID technology throughout its supply chain and has reported an 11% growth in its sales from July 2014 to July 2015 [13]. Figure 2. demonstrates the impact and usages of IoT in SCM.

IoT's benefits in SCM are highlighted using the Supply Chain Operations Reference (SCOR) model.

SCOR Model:

- *Plan:* IoT helps generate and share live data amongst involved entities that ultimately helps in the sales forecast. The movement is tracked using wireless scanners to manage and maintain

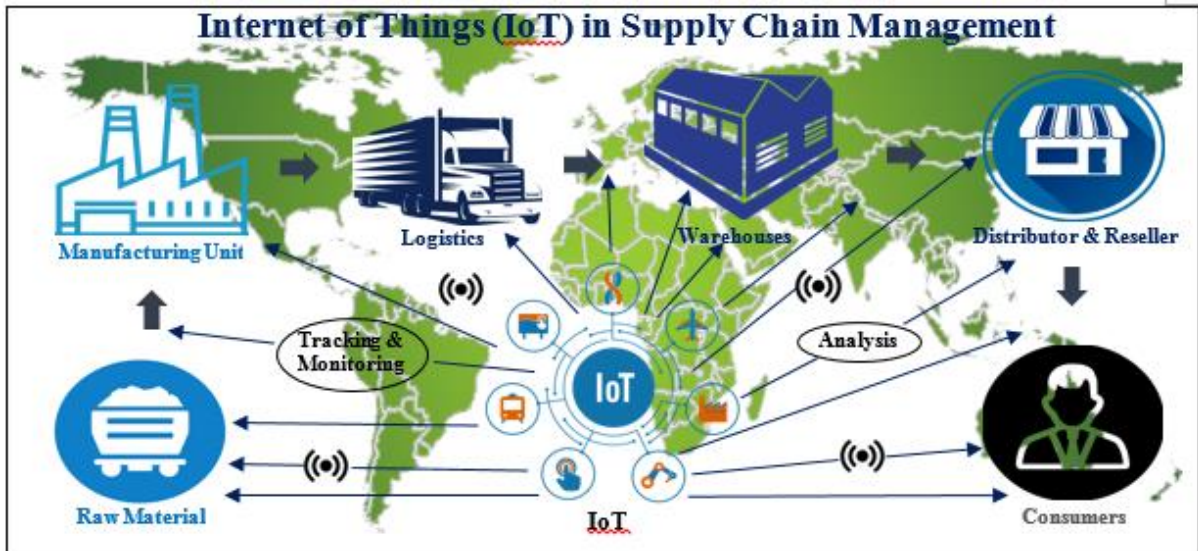


Figure 2: Figure demonstrating usage and impact of IoT in SCM

the live inventory stock. The downtime can be easily prevented using smart sensors and planned/predictive maintenance.

- *Source*: Producer/supplier can access even granular levels of data in the SCM process with the help of different sensors (new RFID & GPS sensors). Companies can have better product forecasting, on-time deliveries, and improved quality control with the help of these granular levels of data. According to IBM, the way suppliers handle the supplies contributes 65% to the company's product and service values.
- *Make*: IoT provides automation in SCM execution, resulting in optimal resource utilization [14] and making the finished product market available to meet the actual demand. Real-time information sharing, increased visibility, and sophisticated analysis enhance responses to changing demands and technological shifts.
- *Deliver*: IoT connects the massive environment of the SCM and provides detailed external or internal movements of information and materials within all participants in addition to inventory level visibility, which ultimately leads to on-time and accurate delivery to the right customer.
- *Return*: IoT provides a "closed-loop" SC model [14] with the help of enhanced visibility, interconnectivity, and traceability. Due to the involvement of the option of return delivery from the customer to the company, IoT helps in providing closed-loop SCM.

2.3 Impact of IoT on SCM involving International Boundaries

IoT also plays an important role in SCM, involving international production sharing, investment, and trade. A single production task is divided into various activities and carried out in different overseas countries. Advancement in information and communication technology, lower labor and transport cost, innovation in logistics, and liberalization of trade and investment has made cross-border production and trade easier. All the involved countries share profits from developing an individual product (such as SoC used in IoT and consumer technology devices) due to the involvement of various 3rd-party Intellectual Property (3-PIP) vendors. Some countries can afford cheaper raw materials, while some have lower labor costs and a skilled workforce. The dependency on the various countries (or 3-PIP vendors) is due to the time-to-market competition with rival companies. Maintaining a trade-off between mass production and a lesser price is also necessary. The different components required to produce an individual unit are transported to the final parent production company. It involves various threats such as a change in the genuine product with a duplicate one, loss of important design information, delay in

the delivery of the product such that the company does not meet the time-to-market requirement, and damaging the quality of the product. Therefore, it is essential to completely automate the transportation process to provide complete transparency and traceability, and IoT plays a vital role in this regard. With the help of various sensors and IoT devices, authorized personnel can have live tracking of their shipment worldwide. They can trace the route, time, and the different involved warehouses in the complete transportation process. Integrating IoT also ensures the integrity of each country involved, thus strengthening the global relationship between various countries.

3. Agile Supply Chain Management over the Internet of Things

The involvement of multiple activities, such as procurement of raw materials from suppliers, production of desired products at respective factories, storage of the produced products at warehouses, and final delivery of the products to end consumers, makes the supply chain process complex and agile. The generated gap between the information and material flow and the need for faster response w.r.t the volatility in the consumer's demand increases the agility and complexity of the SCM. The newer trends in the business have proved that a single enterprise cannot handle the financial market's customer demands and overall economic growth. Instead, it is the collaborative efforts of the entire network comprising various firms involved in the procurement, production, storage, and delivery of the final products. Thus, the integration of the information among multiple activities such as purchase, manufacture, transportation, stock & store, and the market is necessary to maintain the smooth functioning of the SCM, and IoT is playing a crucial role in this regard.

The emergence of the internet & WWW (World Wide Web) has created a revolution in information aggregation and flow, ultimately enhancing communication between different supply chain entities, reducing logistics costs, and improving service levels. The internet has reduced the relationship gaps between firms and their customers. IoT, being the next generation of the internet, can make pervasive connections between different entities of SCM. IoT helps accelerate the material and information flow with the help of integration and sharing of information, resulting in the prompt decision and an increase in the efficiency of supply chain execution. It guarantees the production and distribution of the right quantities of merchandise to the correct location and at the right time with minimal system cost. The addition of new forms of e-business, such as e-commerce, e-procurement, and e-collaboration, has only been realized due to the infusion of the internet/IoT in business operations. IoT facilitates the exchange of valuable and sensitive information safely and reliably. With the help of the IoT, any physical object/entity can be connected globally at any time and place. The more accurate and real-time information captured with the help of IoT helps in the overall execution of SCM. Continuous traceability makes the SCM more transparent and visible to the supplier and consumers, ultimately bridging the relationship gaps. IoT helps understand SCM's complexity and realize SCM's agility in a better way. With the help of RFID and different mobile sensors, real-world data (real-time information) is captured and sent to data agents for further processing & analysis and to make local decisions to improve the efficiency of the supply chain. The increased accuracy due to the provided real-time information in the supply chain adds a competitive advantage in process optimization [17].

4. Advantages of Internet of Things Integration into Supply Chain Management

A brief discussion on the benefits of the integration of IoT into supply chain management has been presented in the previous sections. However, this section explains the various advantages of IoT integration into SCM. The advantages of IoT and consumer technology integration into SCM are as follows [21], [22]:

- i. *Increased visibility:* The integration of IoT devices such as GPS devices into the SCM process has made it possible for the SCM managers to efficiently manage the goods supply management process and enables end consumers to get updates regarding the precise location of their products. The continuous and precise location update of goods in SCM facilitates effective and timely decision-making by managers in order to keep goods moving efficiently. Further, complete transparency ensures the presence of goods at their respective place from the stakeholder perspective.
- ii. *Maximum and efficient utilization of assets:* One of the key advantages of IoT integration into SCM is that it maximizes the efficient utilization of assets. For example, an effective real-time routing mechanism due to the integration of IoT in SCM can help to reduce driver hours by almost 25%. This helps in increasing the number of delivery in the same amount of time. Smarter IoT devices provide real-time weather and traffic data that helps the manager and logistic teams to optimize their fleet with efficient updated routing plans. Further, it also locates and points out the assets which are delayed.
- iii. *Improved collaboration:* Integrating intelligent IoTs and consumer technology devices provides a better collaborative platform for different entities in the SCM process, which is essential for a more complex value chain with increased transparency.
- iv. *Improved customer service:* Using IoT devices such as mobile phones in the SCM process helps provide better customer service. It provides real-time tracking of goods for both SCM managers as well as end consumers. Further, an estimate regarding delivery date and time can also be made using crucial data and mobile applications. With this, SCM managers can provide alternative arrangements in case of delayed deliveries to ensure the service level agreement is met.
- v. *Real-time tracking of sensitive goods:* It has now become easier to maintain the real-time tracking of high-value and temperature-sensitive goods using different types of sensing IoT devices such as temperature sensors, humidity sensors, pressure sensors, etc. Real-time tracking of sensitive goods also satisfies the end consumers as they are entirely aware of their product in transit. Further, it enables SCM managers to take necessary actions within a feasible time in case of a compromised delivery environment, such as delayed or lost goods.
- vi. *Forecasting accuracy:* IoT integration into the SCM process improves demand forecasting by eliminating human data collection and prediction errors. IoT/ smart consumer technology devices help to make demand-based predictions based on historical and real-time data. Further, it automates the data collection process and has made it possible to collect data that are impossible to collect manually.
- vii. *Improved inventory control:* Inventory control is one of the most important aspects of the SCM process as it helps to maintain the stock level as per demands and needs. The advanced IoT devices automatically track the stock level and inventory positions and provide a detailed analysis. IoT helps SCM managers develop an efficient, accurate, up-to-the-minute inventory tracking system. As explained previously, the use of RFID tags by Decathlon has completely revolutionized the automation of the inventory control system.
- viii. *Warehouse automation:* Integrating ubiquitous IoT devices has also revolutionized the warehouse automation system. Amazon has automated most of its warehouses. The exponential growth in the business facilitates the automation of the warehouse to provide an accurate and fast delivery of goods to end consumers.
- ix. *Paperless technology:* Paperwork is the most time-consuming and painful task in supply chain management. Some processes in SCM, such as processing a bill of landing or verification of a trucker's freight broker bond, etc., consume unnecessary time as the responsibility often rests with truckers. IoT introduces various innovative solutions to automate the SCM process towards

complete paperless technology, such as online verification of delivery process using digital signature, RFID technology for inventory update management, etc.

5. Challenges in the Deployment of Consumer Technology and IoT in SCM

Integrating IoT and consumer technology in supply chain management involves various challenges and security risks. Involved risks are classified into the following categories:

- a) *Poor security of IoT devices and low privacy level:* The increase in the number of IoT-based DDoS attacks shows the poor security of consumer technology devices connected to IoT systems. Further, IoT gathers and transfers sensitive data about its owner. Therefore, a robust data transfer security mechanism is required to prevent an adversary from unauthorized access [18].
- b) *Network risk:* It considers the risk associated with communication between different parties in the supply chain (SC). Maintaining trust within the SC network is challenging due to the exchange of sensitive data and increased collaborations [15]. Besides privacy and security, "poor internet connectivity" is a challenging factor in the global deployment of IoT in SCM.
- c) *Risks from the organizational perspective:* The risks associated with production, IT problem, and industrial actions are categorized as organizational risks. Smart manufacturing considers quicker production and delivery expectations and closer customer relationships. One major problem is the use of different operating systems and the collection of different (heterogeneous) types of data by different organizations. Dealing with heterogeneous data is not easy to extract meaningful information from it. It also makes data/ information exchange across different organizations very problematic. On the other hand, putting limitations/ restrictions on data access hinders the development of IoT in the SCM process [20].
- d) *Environmental risk:* The factors such as earthquakes or extreme weather, acts of God, and political, social, and economic aspects are environmental risks associated with IoT [16].
- e) *A large volume of data generation:* IoT generates, stores, and continuously transfers a huge amount of data. So, traditional methods are not reliable in this case. IoT technologies must be designed to handle massive data with newer technologies such as NoSQL solutions, highly scalable cloud services, and LPWA technology. Gathering and analyzing useless data is also not a solution in making an intelligent decision. Further, the tremendous rise of data in SCM has created data dependency and congestion problems. Congestion, measurement inaccuracy, misleading information, noise build-up, etc., are primary factors that induce blockage in scaling, extension, research, planning, and storing [20].
- f) *Energy consumption:* IoT devices are consumer technology devices connected and working continuously for an extended amount of time. They are responsible for continuously sensing, storing, and transferring sensitive data, and sometimes IoT devices with analytical capability perform computation on data also. Therefore, these IoT devices must be powered with extended battery life solutions to facilitate easy maintenance. Moreover, providing a longer battery life while maintaining low energy communication within the system and lower energy consumption is a challenging task to solve [18], [19].
- g) *Talent shortage:* Deployment of IoT in supply chain management systems at a massive scale and their maintenance requires a higher number of trained specialists. The rapid growth challenges educational institutes to adjust according to newer technological changes and trends to produce the required number of trained specialists.
- h) *Regulatory compliance:* The selection of the right IoT technology for the supply chain management process is always challenging when adopting a newer IoT technology. Standards and regulations for temperature-controlled logistics, privacy, data laws, etc., make it imperative to select and deploy the right IoT solution to ensure regulatory compliance.

6. Future Usage of Internet of Things in SCM

The prevalence of IoT devices will increase in the future due to a reduction in their cost, which will significantly impact the SCM process in various ways. Some of the examples of IoT prominence in the field of SCM are:

- IoT devices supporting augmented reality (AR) services can provide a new paradigm to the SCM process. AR services can improve worker's productivity and provide an improved safe environment. The workers can be able to complete their tasks in a more efficient and improved way by learning from their AR devices. The AR-based devices can be programmed to guide the workers step-by-step regarding handling complex machinery on the factory floor.
- The massive usage of IoT devices will improve safety standards in the working environment in various ways. For example, a truck driver can quickly get an alert message in case of signs of fatigue. Further, a worker can be alerted of an upcoming dangerous situation with increased usage of various alert sensors.
- In the coming future, the supply chain management process will greatly benefit from the introduction of advanced wearable technology, such as smartwatches with advanced machine learning computation complexity. AR technology is one example, as discussed in the previous point. Further, managers in the SCM process can make more accurate instant decisions based on previous and current data with the help of these intelligent wearables.

Apart from the above-discussed points, the increasing usage of IoT devices will greatly impact the SCM process by enabling safer, cheaper, faster, and more efficient ways of transporting goods from start to end [23].

7. Conclusion

This chapter presents a novel study on the impact and usage of IoT and consumer technology in supply chain management. Different consumer electronic devices have become an integral component of daily livelihood. The involvement of multiple 3rd- party IP core vendors in the design and manufacturing process of consumer technology devices, increased trade demands of a modern developing society, and industrial revolution 4.0 drives the introduction of IoT in the SCM. The introduction of IoT and consumer technology makes the complete supply chain process more accessible and interactive by providing crucial real-time information (such as real-time tracking information, preserving the condition of goods, actual route plan of the goods, etc.) to managers, suppliers, and end-user. This chapter presents a study on the importance of IoT concerning the agile (continuously changing) nature of the SCM. Further, a detailed explanation of the importance of IoT in the supply chain management process is discussed. This chapter also includes a brief discussion on the challenges and issues faced while integrating IoT in SCM.

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