

Application of Internet of Things (IoT) on Improving Performance within Global Manufacturing Supply Chains

HENIL SAVALIYA, SATYA R SHAH*
Engineering Management,
Royal Holloway University of London,
UNITED KINGDOM

**Corresponding Author*

Abstract: - Internet of Things (IoT) in the context of supply chains (SC) is mainly observed with integration to build resilience. It has discussed the rationale in terms of disruptions caused by the pandemic, the economic and political situation. It has elaborated on the issues such as labor and material shortages affecting demand and supply sides. IoT impacts greatly on the manufacturing SC to enhance efficiency and transparency. Besides this, the implementation of IoT technology has monitored manufacturing procedures and enhanced productivity to deliver a safer working space. In addition to this, this technology has improved supply chain performance to resolve the operational bottleneck and use OTA methods. The study has discussed the factors related to the vulnerabilities of IoT systems, and it has mainly focused on security issues leading to increased concerns. In the context of a SC system, organization and supplier networks are required to work together to get optimal performance. The study explores different methodologies for collecting data. Interpretivism philosophy, exploratory design, inductive approach, and secondary data collection methods have been chosen in this study. Data has been provided in support of the findings in linking them with objectives. It includes that IoT can use different techniques to improve the SC performance and advance the production process.

Key-Words: - Internet of Things (IoT), Technology Management, Digitalisation, Globalisation, Supply Chain Management (SCM), Engineering Supply Chains, Logistics, Supply Chain Performance, Circular Economy (CE).

Received: July 26, 2026. Revised: August 19, 2026. Accepted: September 11, 2026. Published: October 26, 2026.

1 Introduction

In the present day, IoT technologies play an important role in the performance improvement of the global supply chain (SC) in the manufacturing sector. Manufacturing companies focused on implementing IoT technologies for the development of the supply chain. The main aim of this section is to highlight the aim and objectives of the research study with a discussion of the study's background. The study has highlighted and analysed issues presented in the IoT technology implementation that affected the manufacturing SC, with a discussion of the study's importance.

IoT has been a very effective technology as it helped in the business development of the company, as it tracks business and monitors business activities, and has been responsible for giving accurate data for supply chain managers and distribution and transportation companies to get accurate data. As per the statistics manufacturing sector in the UK has benefited largely from the IoT, as it has received 4042 billion British pounds in

benefits from 2015 to 2020 [1]. IoT has been responsible for enabling predictive maintenance and giving real-time visibility into stock levels, which helped in the improvement of the supply chain of the companies. IoT devices are used in all industry verticals and consumer markets, accounting for 60% of all IoT devices connected. Studies have shown that most manufacturing firms get benefits from the IoT, and after that telecom industry gets major benefits. Along with other key areas of telecoms, retail, energy and utilities, and banking & insurance sectors. In the manufacturing sector, robots have been designed to work alongside humans and have been used in warehouses and Amazon packing centres, and auto manufacturers also used it [2]. The pandemic has created disruptions in global SCs by affecting the flow of consumer goods into the key markets, including US, Europe, and Southeast Asia. It has become important for the global SCM to build resilience for a fundamental shift, such as shifting from procuring for cost to procuring for resilience. In the context of SCM, innovation and data-driven

insights are important as advanced analytics allow forecasting the constraints related to SC and products.

1.1 Research Rationale

The problems that have occurred in the global SCs include the ongoing logistics disruptions caused by the global pandemic. The problem has turned into a major concern after the pandemic as the SC lack global resilience and operations of SC are becoming more costly and often represent the highest cost. It has been identified that multiple disruptions cause instability in supply chain operations and put pressure on SCs. Apart from the pandemic, geopolitical risks may cause disruptions in SCs including economic instability and cyber threats [3]. The economic turmoil caused by the pandemic has exposed the vulnerabilities of global supply chains. Labour shortages in the manufacturing sector are a critical issue as the employment rate has decreased by 400000 from the pre-pandemic period [4]. SCs have been disrupted across the world affecting different dimensions which are not limited to demand and supply, production performance, lead time and finance. 35% of people associated with SC operations have agreed that delays in cross-border transportation had a limited impact on business [1]. The most common SC challenges in 2021 and 2022 include manufacturing delays, port congestion and extreme weather conditions as shown in Figure 1 [1].

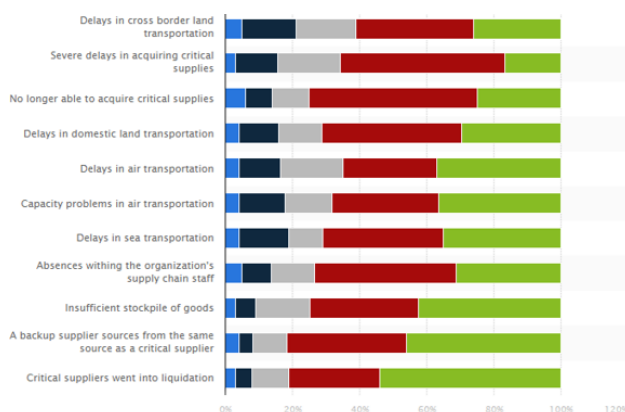


Fig. 1: Supply Chain Issues
Source: [1]

It is expected that the manufacturing sector would likely receive the largest benefit while integrating IoT in SCs. The rate of SC disruptions has increased since 2020 and caused an increase from 6000 SC disruptions to 11642 in 2021. North America is the region that had the highest number of disruptions [1]. In the global context, disruptions in the SC stem from pandemics, natural disasters,

economic downturns and political instability. It has been identified that 41% of decision-makers related to the automotive and transportation industry have lost 50-100 million USD due to disruptive issues during the pandemic [1]. The pandemic situation upended each aspect of SCs ranging from customer needs, material availability and digital capabilities. The gaps that have been developed in a global context include panic buying, factory shutdowns and a homebound workforce. Due to a lack of contingency plans, executives have struggled to respond to such large-scale disruptive events. It has been identified that 71% of the companies did not have a contingency plan beyond three weeks of the outbreak [2].

It has become important to transform SC with innovation to meet the goal of keeping up with shifting business and consumer priorities. SCM is concerned with making the SCs more integrated than ever before and improving overall performance. The issues related to SCM that became apparent in 2021 include unprecedented pressures on global SC caused by the pandemic. The series of lockdowns and restrictions caused severe challenges from country to country. SC trends and practices are driven by cost optimisation and lean strategy [5]. It has created disruptions along with poor continuity plans, and a lack of risk management initiatives. The current challenges that are related to global SCM include a lack of equipment, the impact of global bottlenecks and labour shortages. The issues that have been cited among the difficult hurdles for SC include demand-side issues such as fast response time. Disruptive SCs are a result of a combination of factors, and the pandemic has exposed the vulnerabilities as industries were forced to hold production due to restrictions. Apart from this, supply problems have occurred by the power outages in manufacturing plants in China and shortages of materials including semiconductor chips [1]. Supply problems have led to inflated shipping costs inventory challenges.

1.2 Research Objectives

The main aim of the study is to highlight the use of IoT technology and analyse its role in the improvement of the supply chain performance of the global manufacturing sector. The **research objectives** are described below in Figure 2.

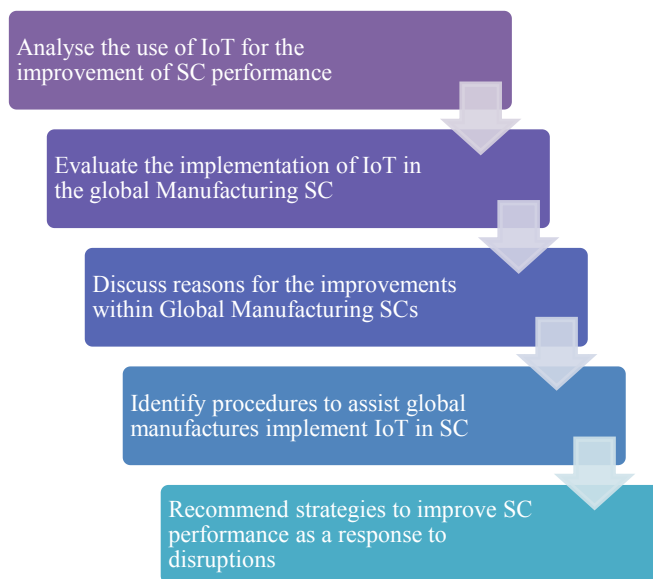


Fig. 2: Research Objectives

Source: Created by Authors

Key **research questions** of the study are:

- RQ1. What is the use of IoT in SC performance improvement worldwide?
- RQ2. How is IoT implemented in the supply chain of the global manufacturing sector?
- RQ3. What are the reasons for the need for improvement in the performance of the global SC?
- RQ4. What ways can the manufacturing sector follow for implementing IoT in supply chains?
- RQ5. What are the key strategies that need to be followed for the improvement in the performance of the SC for responding to disruptions?

The study is significant in terms of discussing the current situation of global SCs and future operations with IoT. The significance of the study can be discussed in terms of relevance and the impact of the findings. The study has outlined the factors related to SCs and discussed the rationale behind the use of IoT for SC operations which contributes added information to the existing body of knowledge. The findings of the study are effective in understanding the future operations with IoT technology and how it needs to be integrated with the manufacturing sector. It has provided a detailed description of SC disruptions, which have exposed the loopholes. The findings of the research provide a detailed description of the use of IoT for developing manufacturing SCs.

2 Literature Review

The Internet of Things (IoT) refers to the physical objects connected with processing ability, sensors, software and technologies for exchanging data with other systems and devices. Hence, IoT has various importance on the supply chain to improve the operational efficiency of the manufacturing sector. In this case, the study is going to mention the usage of IoT to improve the performance of the Manufacturing SCs to collect information from relevant sources related to the main topic. Therefore, the issues and factors of IoT are going to be addressed to provide proper strategies for the mitigation of the issues. Besides this, significant theories and gaps are going to highlight in this section for more improvement of the impact of the supply chain in the manufacturing sector.

2.1 Impact of IoT Technology on SC

The IoT greatly impacts the SCM system to improve operational processes. Hence, it has been found that it has combined with the power of cloud, analytics and mobile computing which has changed how the organisation can manage the logistics and SC. The adoption of IoT technology has enhanced the efficiency and visibility of the supply chain management system shown in Figure 3 [6]. In addition to this, IoT has identified one of the innovations which have improved the integration of the SC to make it simpler and more transparent. The infrastructure of the IoT has streamlined and benefits the SC for the improvement of the value chain networks [7]. Apart from this, it has connected significant objects of the SC to allow the management, to access the data and data mining [8].

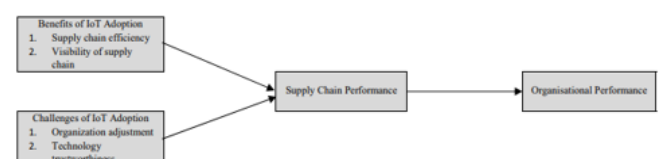


Fig. 3: IoT on Supply Chains

Source: [6]

IoT devices have included computer systems and sensors which has been helpful for tracking products and deliveries related to SCs. The IoT has been helpful in developing higher visibility in the supply chain to decrease any complexity to improve accuracy [9]. Therefore, it has been able to restructure the supply chain to decrease operational costs by providing proper storage facilities and transition. IoT emerged as a growing, evolving technology through which more industry has adopted and improved the efficiency related to the

SC [10]. The real-time visibility of stock levels and demanding patterns included in the SC has improved due to IoT technology.

2.2 Implementation of IoT Technology in Manufacturing Supply Chains

The IoT has been considered a recent development of digital technologies and information to deliver immense opportunities in the manufacturing sector to restructure the entire SCs.

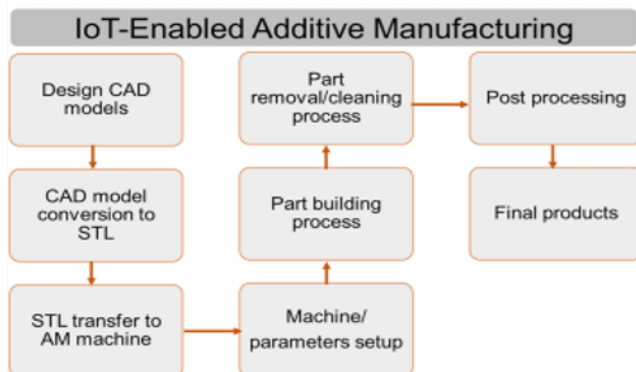


Fig. 4: Implementation of IoT Technology in Manufacturing
Source: [11]

The IoT has empowered various advantages of the machinery developed in the manufacturing sector to deliver opportunities for pattern modification, as shown in Figure 4 [11]. Hence, monitoring remote manufacturing operations is one of the implementations of technology in the sector. The implementation of IoT has been effective in making proper decisions and to make it more scientific and effective [12]. Therefore, IoT solutions have optimised everything from monitoring to the maintenance of machinery with efficiency metrics of real-time equipment. Intelligent machine interconnectivity and remote data collection have been regarded as the implementation of IoT technology to control production and latest growing technology. Studies state that IoT has the ability to capture real-time information from the various parts of the clothing and textile manufacturing value chains [13]. The application of this technology has brought distributed data management for providing support to the transaction services to improve the business management and SC network. Studies argue that IoT approaches have focused on the innovation process of the manufacturing to provide a safer and productive working space [14]. In addition to this, it has been important for the identification of the manufacturing SCs disruption and mitigated several threats related to the production process.

2.3 IoT Adoption to improve SC Performance

The manufacturing sector can implement IoT to improve SC performance based on the various stages, such as measuring and optimising inventory levels. The manufacturing sector should be able to reduce stock-outs, meet orders of customers, and mitigate other operational bottlenecks to improve supply chain performance [15]. Besides this, it is needed for the manufacturing sector to use encrypted protocols to enhance the end-to-end visibility of the SC as well as ensure route optimisation. Innovation is another important factor to improve the SC efficiency to gain competitive edge, as shown in Figure 5 [16].

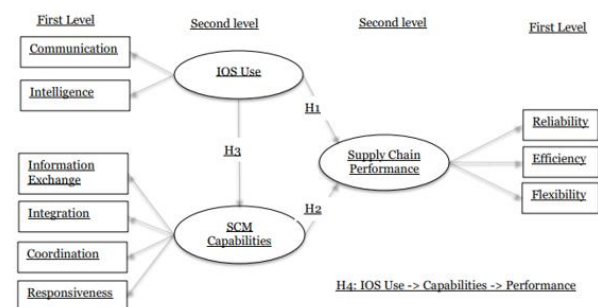


Fig. 5: IoT Methods to Improve SC Performance
Source: [16]

Apart from this, using OTA methods related to IoT can enhance the collaboration process with the stakeholders to the improvement of the performance relied on the SC. Enhancing forecasting accuracy and automation of data in real-time are considered other important ways through which the flow of the supply chain has been enhanced. Managing strategic resources and positive consumer relationships and expectations have been important ways to the improvement of the internal operation related to the SC [17]. Moreover, the manufacturing sector should focus on computation and intelligence-based data storage systems for enhancing information sharing and visibility of the SCM. It is essential to defend against IoT identity spoofing which can be effective in increasing the viability of the SC to partner with the current suppliers [18]. Apart from this, the manufacturing sector can change default passwords related to IoT to increase transparency in the SCs.

2.4 IoT Key Factors

The key factors that must be considered while designing the IoT infrastructure include scalability, security, connectivity management, data aggregation and management, integration, and usability. Scalability refers to the system's capacity to handle

increasing workloads [19]. The scalability of the custom IoT system is one thing that requires consideration while selecting a partner. It is also important to endow the IoT system with AI. Though it can raise the issue of its location in the IoT architecture [20]. Data found in major IoT systems should be interpreted properly and shared with IoT devices for better responses. Figure 6. shows the key applications of IoT system. Usability is another feature that should be added to IoT platforms to increase the ease of use. The safety and security of IoT devices are critical while SCs extended over wide geographical areas and are vulnerable to risks.

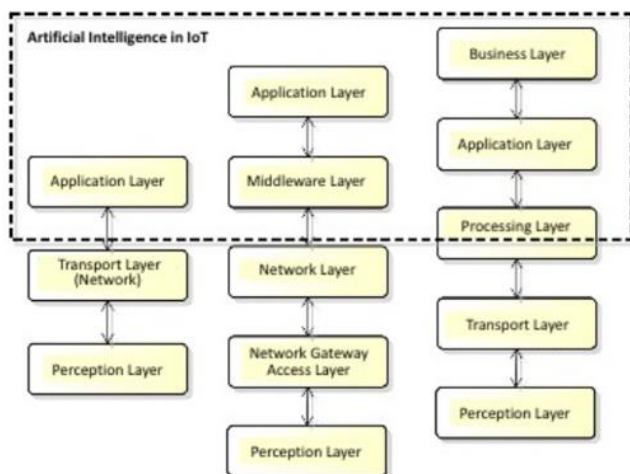


Fig. 6: Application of IoT System
Source: [19]

Product complexity is also increasing with the rapid changes in technology. The external environment is dynamic, and structural flexibility can increase the adaptability of SCs in the business environment. Information technology is critical to balance the required level of resilience and flexibility in supply chains. It can be considered an efficient enabler for an effective supply chain management system [21]. It provides the association for dealing with the challenges of an ever-changing environment and many risks at all stages of the SC system. The industrial revolution enabled technologies by integrating information and communication technologies [22]. Communication technologies have enabled dynamic manufacturing systems and autonomous systems. Moreover, it has been identified that technological innovations enable the use of resources to achieve sustainable performance in supply chain systems [23].

2.5 Analysis of IoT Challenges on SC

The issues that are related to IoT network systems include the fact that the devices rely too much on networks. Unsecured data is another issue that can

occur during the transmission, and it refers to the transfer of data over a network or the internet without protection. IoT in the merging industry increases the capability of enabling autonomous data collection. Data provenance and integrity are the major issues related to IoT-run environments, and these are the concerning areas surrounding IoT [24]. The issues occur regarding the availability, confidentiality and integrity of IoT ecosystems as shown in Figure 7 [25].

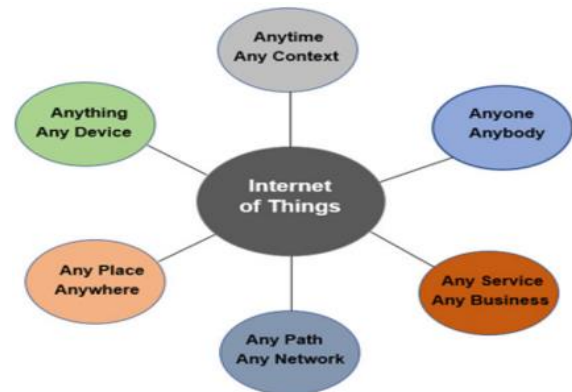


Fig. 7: IoT System Issues
Source: [25]

Data provenance involves the method of generation, storage and transmission that can be utilised to detect the origin of a piece of information. The data security issues that can occur include lack of visibility, open-source vulnerabilities, overwhelming data volume and limited security integration [26]. IoT security is the term that is used to cover the issues of protection, application and data and network connections. IoT security issues range from malicious or defective insiders to the vulnerability of divides and the scale of deployment. It has been identified that the IoT security challenge is critical due to the attack surface of threats that have already been destroying the networks [27]. The threats have increased due to the insecure and vulnerable practices of users and enterprises. The factor that works behind the increasing vulnerability of IoT devices is that they lack computational capacity for built-in security. The reason why the vulnerabilities can be pervasive is the limited budget for developing the framework of devices and the short development cycle. IoT provides numerous applications and services, it also faces security issues and vulnerabilities, including sinkhole attacks, denial of service attacks, eaves dropping [28]. Therefore, it can be stated that hijacked or attacked devices can infect the machines, thus reducing the efficiency of the devices and the SC system. The challenges created

by IoT vulnerabilities are the lack of standardisation across manufacturing, on-demand integration with the system and the need for a secure and easy-to-use solution.

2.6 SC Transformation in Manufacturing

SC transformation has involved existing process review and system implementation for SC demand management. Business goals of the SC and its demands have been changed and there have been transformations of the SC in the manufacturing sector. In the present day, transformation in the SC has mainly been towards a circular economy (CE) transformation in SCM mainly referred to the innovation in technology and digitalisation of a company which has been responsible for increasing growth [29]. In the manufacturing sector, SC transformation has been responsible for bringing innovation and risks have been easily mitigated. The digital supply chain (DSC) has mainly been built on digital transformation and smart technologies shown in Figure 8 [30]. In manufacturing firms, capabilities and environment have become two key enablers which helped in the transformation of the SC.



Fig. 8: Circular Supply Chain (CSC)
Source: [30]

The transformation has been responsible for making the SC faster and cost-effective for business [31]. In the manufacturing sector, there has been current use of new technologies for producing various products. In the industry, digitalisation has been responsible for developing the SC as transportation has been developed so the suppliers are easily able to deliver the products to the company. SC transformation has been a complex and strategic activity which has been responsible for encompassing the entire organisation [32]. The SC in has been responsible for facilitating transfer and raw material transformation which resulted positively in the company's business. SC related business operations have transformed from manual operations into electronic communication and processing [33]. Transformation has been

responsible for the effectiveness of transport that's responsible for fastening the product distribution to a consumer [34].

2.7 Improvement of SC Performance

In the present time, the SC in manufacturing has been improved which has become responsible for developing the overall business of the companies. Firms have focused on good relationships with the supplier and innovative technologies, and digitalisation have been responsible for developing relationships with them. SC structures in the present day have developed in the manufacturing sector which becomes responsible for improving SC performance. Information sharing and various inventory control policies have become responsible for giving chances to the manufacturing sector to improve the performance of the SC. The incorporation of the CE in SCM has been referred to as **C-SCM** [35]. Lead time and developed forecasting methods are important reasons as firms through this have developed the performance of the SC.

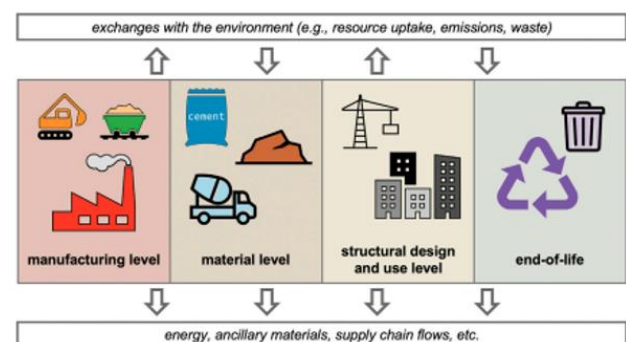


Fig. 9: Cement Life-Cycle
Source: [36]

Selection of review period length on time and offering good product supply by suppliers has helped to develop the performance of the SC. Water supply, new transportation demand, SC and cement use complexity have been helpful for net zero emissions which Figure 9 [36]. Customer demand in the manufacturing sector has increased so companies need more suppliers for raw material supply. It has become an important reason that has become responsible for developing the overall SC process of the manufacturing firms. Route optimisation ensures, and forecasting accuracy has been increased in the manufacturing firms which became responsible for developing the SC. The quality and safety of products and SC profit can be improved through centralised control decisions [37].

Stakeholder collaboration has been enhanced in the current time in the manufacturing sector, which

has become helpful for companies to improve their supply chains. Technology enhancement and digitalisation in the industry have been responsible for the improvement in the performance of the supply chain. A green SC has been responsible for improving the reputation of the corporate sectors [38]. Customers have been satisfied with the SC, and product quality has improved which has become responsible for developing the performance. In addition to this, utilisation of the resource and flexibility enhancement in the manufacturing sector have been responsible for developing the SC process.

2.8 Strategies for Improving SC Performance

Supply chain performance and efficiency need to be better so that it can be able to develop the business. Manufacturing companies nowadays have focused on automation adoption and ensure route optimisation for developing the overall SC. Stakeholder collaboration enhancement has been responsible for developing the performance, and companies need to also focus on measuring and optimising inventory levels. Global SCM improvement has been a contribution of sustainable transformation process strengthening [39]. Communication efficiency and internal operations collaboration can be important for manufacturing business owners to develop the SC performance. Big data analytics adoption has been responsible for improving the visibility and transparency of the SC [40]. Manufacturing companies need to focus more on measuring, reviewing and revising processes as these can be helpful for ensuring better supply chain improvement. Recently, manufacturing firms have focused on partnering with their current suppliers and increased information sharing and visibility which have responsibility for developing the performance. IoT and I4.0 (industry 4.0) sustainable solutions have been implemented to redesign the strategy of the SC in a more sustainable way [41]. Organisation and supplier networks need to be better as they can be responsible for maximising the value of the SC. In manufacturing firms, there has been development of circular strategies framework to support circular economy based innovation [42]. Planning, sourcing, developing, making and returning all need to be focused on by the manufacturing companies as this has a positive impact on the SC process. Distribution network improvement and SC council have been responsible for improving the efficiency of the SC.

2.9 Theories

Systems Theory (ST)

Systems theory explains the integration of different segments of a system to act as an entire system to produce a certain result. The theory mainly explains how theories are being integrated and managed to produce certain results. Studies [43] shown tools and methods are incorporated into a technological system to ensure that they achieve accurate results, and control ensures that all parts work together continuously. The main concept of systems theory is that the entire system is comprised of multiple smaller systems and the interactions between the segments is made up to create a complex system. The system concept explains that an organisation is made up of certain elements including raw materials, human resources, information, technology and capital. To create and integrate the entire system, it is important to integrate the different systems to manage the performance. Systems theory has been identified as ineffective for larger or more complex organisational contexts. It is effective in smaller contexts as elements can be identified easily [44].

Resource Based Theory of Supply Chain

Resource based theory of SC helps to identify the resources that are valuable, difficult to imitate, and non-substitutable. The strategic resources have been identified as effective in getting the best position by developing the capabilities leading the superior position [45]. Resource-based view in the context of SCM develops agility, adaptability, and alignment. It has been identified that the resources are required to be imitable to stand out in the creation of separate capabilities to increase performance. The concept mainly addresses the way through which the competitive edge in SCs can be increased. The firms mainly set the internal resources to excel in the performance of the SCs and provide a theoretical context to achieve sustainable performance. It is sometimes difficult to analyse the resource-based view due to broad explanations of resources [46]. Hence, resources can create value for a firm by reducing the cost of inputs and influencing the overall cost of manufacturing.

2.10 Conceptual Framework

The gap has occurred due to the lack of focus on the measures that can be used to mitigate the issues of security. A conceptual framework to support the study has been developed and as shown in Figure 10.

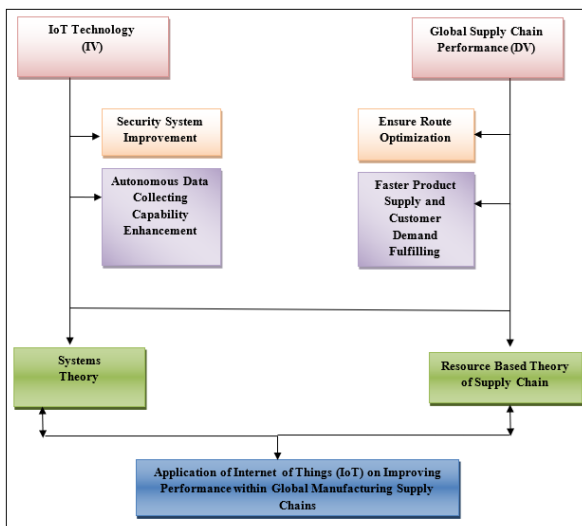


Fig. 10: Conceptual Framework

Source: Created by Authors

The major focus of the literature is on the implementation of IoT in the SCM. The literature does not completely discuss the measures to reduce the impact of security as well as the improvements in the control system. Literature gaps has occurred due to the lack of proper information regarding the use of IoT in SCs. Based on the discussion, it has been identified that security issues are critical, and the issues have been identified as the increased vulnerabilities and the built-in security system. The section has discussed the issues of security and the implementation of IoT for improving the SC performance. The study has discussed the resource-based view of SCM and systems theory to discuss the variables and how these variables can be managed.

3 Research Methodology

IoT's importance in the manufacturing sector is the focus of this study and the data collected from resources and manufacturing sector-related. The section aims to highlight the methodologies adopted for data collection, with appropriate philosophy, design, approach and data collection methods discussed. In addition, a description of the data analysis method and the reason for choosing the data collection method and why other methods have been avoided in this study. The primary purpose of research methodology is to improve theoretical strategic discussion on techniques and tools. The researcher is collecting all the information related to technology to improve the performance of the manufacturing sector. The study is also aiming to choose an appropriate data collection and data

analysis process to gather data and analyse it according to the respective topic of the research.

3.1 Research Philosophy and Approach

Philosophy has been helpful in guiding people properly and they are able to conduct research without any difficulty. Interpretivism has been more concerned with factors and variables in depth related to a context and considered as different from physical phenomena [47]. It has also been referred to as the belief about how data has been collected and analysed, and there have been various philosophies such as positivism, interpretivism, realism and others. In this study, there has been a focus on interpretivism philosophy as it is relevant, as it gives theoretical constructs and analytical focus. Positivism has been accurate for primary research and over-emphasis on universalism, so it has been avoided. Research philosophy is shown in Figure 11.

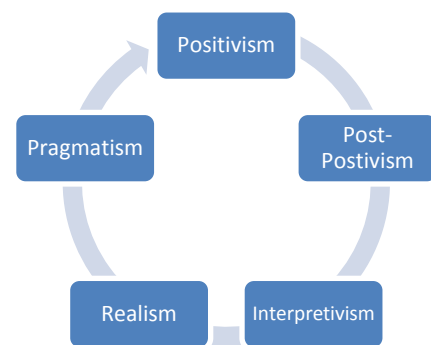


Fig. 11: Research Philosophy

Source: Created by Authors

Research Approaches have been helpful for drawing conclusions by going from specific to general. Inductive, deductive and abductive are the most used research methods by researchers to complete the research. In this study, there has been an inductive approach which is responsible for giving flexibility and attending closely to the IoT impact on the SC performance of the manufacturing sector. The deductive research method has been avoided as research outcomes sometimes become inaccurate and this approach is mainly used in qualitative studies. A research approach can be defined as a procedure or plan consisting of multiple steps of broad assumption associated with the detailed purpose of analysing, gathering and interpreting information. The notion of research approach is based on the essence of research issues that have been directed. The study has selected an appropriate approach that helps the researcher to pursue the research authentically by accumulating data and analysing it properly [6]. In this study,

there are three main kinds of research approaches that have been used in this research such as inductive, abductive and deductive. A deductive approach has been chosen in this study for research progress and to complete the research respectively. It has been seen that the research has chosen an Inductive approach to enable the researcher to analyse causal links among variable concepts [7].

3.2 Research Design and Research Method

There have been mainly three types of research design such as exploratory, explanatory and descriptive which have been used in the research studies. The exploratory design has been chosen in this study as previously unresearched things have been easily understood as uncovers facts have been covered and new issues of IoT implementation have been gathered. Research design has been serving as a significant element for well-defined design which has helped in the research to select suitable methods for fulfilling research objectives and aims. In this research, the researcher has chosen an exploratory design for gathering authentic data related to the use of technology for improving performance in the manufacturing sector [7]. The study has chosen a descriptive research design which can help the research observer to give vivid information according to this topic as well as other phenomena that have been chosen logically.

The **research method** is understood by its term as the simplest method in which the research work needs to be done. The easiest way in which the data related to the study area can be collected has been termed the method of research [48]. There have been three methods of research such as Quantitative, Qualitative and Mixed. In the context of collecting data in this study qualitative research method has been used. Thus, has been proven to be useful as the method has been useful in addressing the research question to its best. This method promotes the understanding of deep knowledge regarding the study area. This knowledge has been supported by the phenomenon, experiences and context regarding the research topic [49].

3.3 Research Strategy

The qualitative method has been chosen as the strategy for this research work. This strategy has been chosen as it helps the research worker to get the authentic and appropriate data regarding the research area [50]. The data that has been collected have been found to be much reliable and valid as the previous research world has conducted detailed research before preparing the work. The data have been analysed and evaluated by the previous authors

and experts. The strategy that has been used in this research has been proven to be helpful for the researcher to develop the correct understanding about the authenticity of qualitative research strategy [51]. The findings of this strategy have been found with very less cost involved in the process. The data of previous research works have been collected from reliable sources as Google scholar and ProQuest.

3.4 Data Collection and Analysis Method

In this study, there has been a focus on a secondary qualitative data collection method for understanding the use of IoT technology for improving SC performance in the manufacturing sector. Qualitative secondary analysis has been an experiment conducted by the re-use of the data which has been existing [52]. Manufacturing sector and IoT technology data have been collected from books, journals, reports and other secondary resources and Google Scholar has been used for collecting resources. In its simplest of definitions, **data analysis** has been defined as the most effective and appropriate way in which the logical and scientific techniques to illustrate, describe, recap, condense and evaluate data. In the context of this work of research, the research worker has been involved in collecting the secondary data related to the study area [53]. The secondary data have been developed by analysing the themes from different previous research works [54].

4 Results and Analysis

Data findings and analysis is going to be in this section to present information regarding the research topic. Information has been collected from secondary qualitative sources which has been analysed efficiently. To do this research has been collecting all the data from different books, journals, articles, and websites and government reports. The chapter is going to analyse the information which has been gathered through secondary sources and present by making themes. The secondary data collection method has shown several pieces of information about use of technologies in the manufacturing sector for developing business performance.

4.1 Technology Implementation for Supply Chain Performance

In the modern days technology has played an important role in the global business world specially in the manufacturing sector. Technology has been

helped to improve the SC performance in organisations. IOT technologies have played a significant role in the global SC helping to improve business performance [55]. It has been seen that IOT is an effective technology as it helps in the business for improvement of the organisational performance as it tracks business activities. The IoT has been impacted in the SCM system to develop business operational processes.

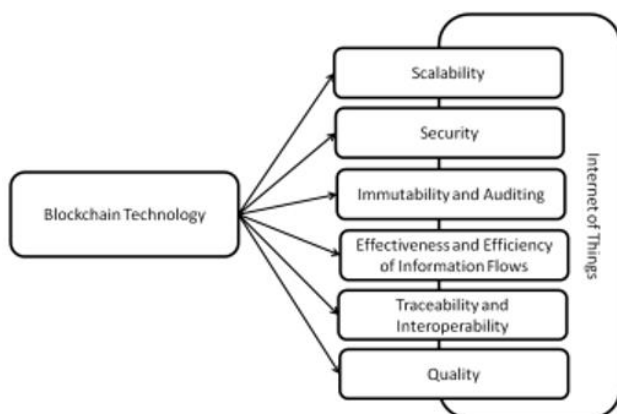


Fig. 12: The impact of Blockchain Technology on IOT Characteristics

Source: [56]

It has been observed that it has combined with the power of analytics, cloud and mobile computing that has changed the management process to manage SCs and logistics. The infrastructure of the IOT has been impacted in developing of the SC network [56]. IoT devices have included a computer sensor as well as which has helped to track all the information related to management processes as shown in Figure 12. Traditional businesses have changed their business strategies to develop their performance of SCM in the global marketplace. IOT emerged as a growing in evolving new technologies that have adopted and improved efficiency which has been related to the SCM of the manufacturing sector.

4.2 Implementation of IOT in Global Manufacturing Supply Chains

The IOT has been considered a recent improvement of digital technologies and information which has delivered immense opportunities in different industries of manufacturing to restructure the advantages of the machinery improvement in the manufacturing sector to deliver opportunities and modification of patterns. It has been seen that monitoring remote manufacturing operations has one of the topmost implementations of technology which has been impacted while taking proper

decisions in the business to make it more effective and scientific.

IoT implementation is an effective way in the process of decision-making by providing appropriate solutions which have been optimised for everything from monitoring to manufacturing [57]. It has been found that intelligent machine interconnectivity and the collection of remote data have been regarded as the implementation technology of IoT in the manufacturing sector to limit production as well as growing technology. It has been observed that IoT is the ability to maintain real-time information from the multiple parts of the textile and clothing manufacturing value chains. This technology has been used for data management for getting support to support transaction services to develop the business management and supply chain network of the manufacturing sector [58]. IoT approaches have been based on the process of innovation of the manufacturing sector to provide more productive space within organisations.

4.3 Challenges for IoT implementation for Supply Chain Performance

Implementing IoT in SC has offered numerous potential benefits such as increased visibility, real-time tracking, and improved efficiency. Several challenges must be addressed to fully harness the advantages of IoT in enhancing SC performance as shown in Figure 13 [6].

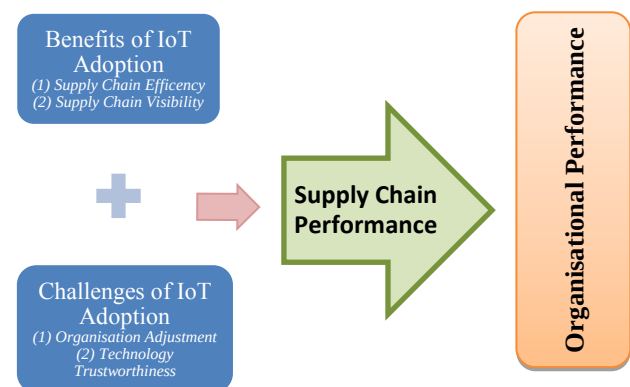


Fig. 13: IOT Framework

Source: [6]

IoT implementation has required substantial investments in hardware, software, and infrastructure. Many firms have been facing costs and investment issues during the implementation of IoT in their SC system to enhance their performance. Moreover, firms have been facing extra cost charges during the implementation of IoT technologies which has been creating an extra financial burden [59]. Firms have been facing

challenges in data security and privacy concerns in SCM performance. Firms have been facing challenges in handling large numbers of data when it is generated and transmitted through interconnected devices. It has been ensuring the security and privacy of sensitive information has become crucial in supply chain management. Cyber-attacks and data breaches have been creating significant risks to the SC ecosystem which led to potential disruptions and losses. The lack of universally adopted standards for IoT devices can result in compatibility issues between different components within the SC depicted in Figure 14 [60].

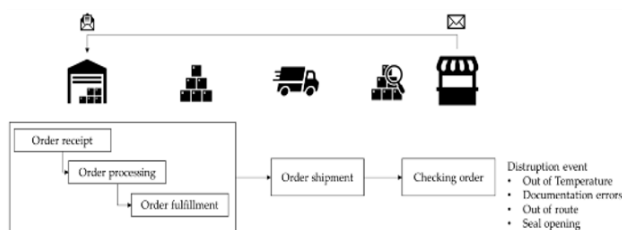


Fig. 14: IoT Implementation Challenges in SC Performance

Source: [60]

Many organisations have been facing challenges with interoperability and standardisation in the implementation of IoT technologies in the supply chain. Ensuring seamless integration and data exchange among various IoT devices and systems has been considering the challenge. IoT technologies have been relying heavily on stable and high-speed internet connectivity. Remote or poorly connected regions have been facing challenges to maintain a constant network connection which can hamper SCM performance in the remote areas [61]. The vast amount of data generated by IoT devices can overwhelm SC managers. Extracting meaningful insights from this data has required more powerful advancements in SC performance. These challenges have been faced during the implementation of IoT technologies in SCM to increase performance.

4.4 Reasons for Supply Chain Improvements

Many reasons for improvement have been required for developing the SC performance in the global manufacturing sector. Many companies have been improving their management of SC strategies inside manufacturing firms to increase their profitability and reputation in the marketplace. Many companies have been introducing innovative SC structures for the improvement of their global SC performance as well as manufacturing development [62].

Traditional businesses have been changing their business strategies to improve their performance in SCM in the global marketplace. Manufacturing companies have been implementing different automation and technological devices for the development of manufacturing processes, which directly influence the SC performance. Various companies have been installing different types of technologies for improving production performance to maintain distribution strategies in the global marketplace [59]. Managers have been influencing their management policy to increase production processes inside manufacturing firms. Distributors have been providing great support to their manufacturing firms in developing their distribution systems through the help of IoT technologies and devices or systems in the SC process.

Most manufacturing firms have understood that IoT devices have been installed inside the working areas to maintain their inventory control in SCM. IoT technological devices have been implemented to increase SC distribution strategies in the global marketplace to sustain the firm's reputation [63]. Firms have been facing information-sharing issues during SC distribution in the global marketplace with the help of third-party services. For that reason, companies have been improving their technological support during the distribution of the SC in the international marketplace. Companies have been facing several issues during unreliable and complex distribution mediums when transmitting information. Earlier studies shown that firms have been facing those issues due to a lack of IoT technological devices' operations and performance in SCM [64]. SC has been facing credibility issues due to the uncertainty of device transmission of signals to communicate with their distributors in the international marketplace.

4.5 IoT Implementation Process for SC

IoT has been implemented through different procedural steps in the SCs. Managers of SCM have been introducing new technological devices to maintain interconnection between production houses to transferable destinations via different communication tools or devices. Many technological firms have been providing technical and technological support to manufacturing companies to maintain their SC procedure appropriately and significantly [65]. The IoT implementation process for supply chains is shown in Figure 15. Technologies have been enhancing the overall performance of manufacturing companies after the implementation of IoT technologies. Technological companies have been implementing

tracking systems in manufacturing companies to sustain their market reputation and increase profitability margin.

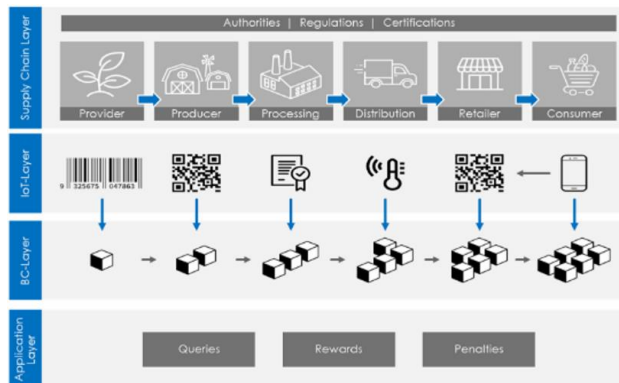


Fig. 15: IoT Implementation Process for SC
Source: [66]

Firms have been installing GPS trackers inside their containers to track container recorders without any extra burden of cost [67]. This GPS tracking device has improved the overall distribution system and techniques instead of the previous business strategies of the distribution system. GPS tracking devices have been providing security and safety prevention control for companies to distribute their products safety.

Many companies have designed their types of safety and security procedural systems for tracking of their SCM system. Manufacturing firms have been developing their inventory control system through IoT technologies and devices [68]. This IoT technology has improved businesses' strategies to maintain the company's reputation and data security. Companies have been facing troubling situations during the implementation of Internet of things devices inside manufacturing firms for developing management systems. Technology companies have been introducing new innovative devices to support business operations and maintain SC distributions [66]. Likewise, manufacturing firms have gained profit by using those devices for the installation of their operational sides.

4.6 Impact Analysis of IoT on Supply Chain Performance Development

In modern days IoT technology has played an important role in the development of SCs within the manufacturing sector. In the UK most manufacturing firms have been focused on the use of IoT technologies for the improvement of the SC. IoT has been one of the topmost effective technologies as it has helped in the business improvement of manufacturing firms as well as

tracking business and monitoring all the activities of different firms [9]. It has been seen that IoT has been responsible for giving accurate data for SC managers and transportation and distribution companies to get accurate information and data. In the UK, the statistics of the manufacturing sector have benefited effectively from the IoT as it has almost got 4000+ billion GBP in the year 2015 to 2020 [1], as shown in Figure 16. It has been observed that IoT has been responsible for enabling predictive maintenance and giving real-time visibility that has helped in the development of the SC performance in the manufacturing sector. IoT device has been used by most manufacturing firms to get accurate verticals and consumer market information. Zara has been implementing IoT in their business for improving their business supply chain management performance [69].

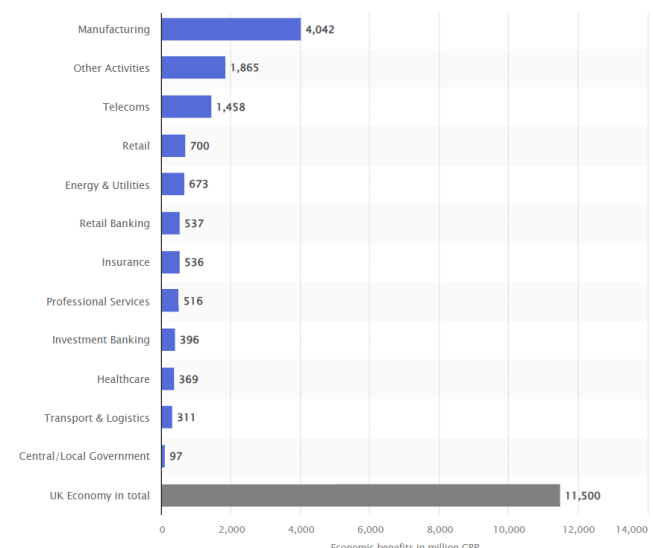


Fig. 16: IoT-SCM Benefits in UK 2015-2020
Source: [1]

In the UK many manufacturing firms have benefited from the IoT devices which are the most popular technology. It has been analysed that in the UK manufacturer has been able to track parameters of quality such as temperature, humidity pressure and some particulate matter with greater accuracy. Sometimes IoT sensors have helped to collect data that has been determining product quality standards and can be inspected more efficiently. In respect of the manufacturing sector managers have been strategically conducting and identifying anomalies for a root to prevent the failure of machines and production delays [70]. Combine with big-data analytics IoT also been optimised for the safety of employees, operations and manufacturing plants.

From the market study and research in the year 2022, the estimated market value of IoT

manufacturing is approximately 294.4 billion globally [1]. It has been found that IoT solutions have been used to track the flow of assets by the factory as well as autonomous robots have been moving the products and picking and packing orders without human interaction. There are so many devices that have been implemented by IoT device in the manufacturing sector such as supply chain optimization, automation, digital twins, remote monitoring, and prediction maintenance.

4.7 Strategies for Supply Chain Performance Development

SCM has been an important part of every organisation, especially in the manufacturing sector in the UK. Some strategies that have helped to improve SC performance such as increasing visibility by mapping organisational SCM and using technology to manage and identify the SC risk [71]. In organisations, SCM has need some efficiency for better development which has been able to improve the business. Most manufacturing firms have been focused on the adoption of automation processes and ensuring the route of optimisation for improving overall SCM. Shareholder collaboration enhancement has been responsible for improving the performance of the organisations as well as focusing on optimising and measuring inventory levels. In the UK global SCM development has contributed to the process of sustainable transformation. Internal operations and communication efficiency collaboration are most important for manufacturing firms to improve their SC performance.

It has been suggested that firms can adopt big data analytics (BDA) to develop the transparency and visibility of SCM. Studies has shown [72], firms can be more concerned about reviewing, measuring, and revising processes which can help them ensure better SC development. In modern days manufacturing firms can focus on partnering with their suppliers as well as increasing information visibility and sharing that has been responsible for improving performance. I4.0 and IoT solution has been implemented to rearrangement of the strategy of the SC and has focused on a more sustainable way. There are some ways of SC strategies which can improve SC performance such as demand-oriented planning, building a strong partnership with the suppliers, conducting a routine review and ensuring risk mitigation. Studies stated [22], SC disruption has been defined as the disturbance of an firms product network and normal operations. Depending on the level of disruption, it may impact the business's reputation, productivity, and profit. It has been seen that to improve SCM firms have

increased visibility by mapping their SC disruption. AstraZeneca has been mapping its SCM which also enables businesses to prioritise areas of distribution and concern according to their resources [73].

4.8 Discussions

Recently, technology has been playing an essential role in the global business world speciality in the manufacturing sector of the UK. It has been seen that technology has helped to develop SC performance within manufacturing. IoT technologies have played an effective role in global SCs helping firms enhance business performance [74]. It has been found that IoT is an effective technology which has helped in business for developing organisational business as well as tracking all the activities of the business. The IoT impacts SC systems to improve business operational processes. It has been analysed that IoT technology has been combined with the power of analytics, mobile computing and cloud which has been changed in the process of management as well as managing SC. The infrastructure of IoT has been impacted positively in improving the SC network [6]. Also, IoT devices have included a computer sensor that has helped to track all information and data which are related to the processes of management. It has been seen that most traditional businesses have changed their business strategies to improve their performance of SC in the global marketplace. IoT emerged as a growing implementation of new technologies that has improved and adopted efficiency related to manufacturing SCs.

The IoT has been considered a recent development of digital technologies and information that has delivered many opportunities in different industries of the manufacturing process for restructuring as well as machinery development in the manufacturing sector. Remote manufacturing operations have one of the top digital technologies that have been impacted when tracking any business operation decisions to make it more scientific and effective [59]. It has been seen that intelligence of machine interconnectivity and the collection of remote data have been considered while IoT has been followed within UK manufacturing [40]. From the statistical data revenue in the industrial IoT market has projected to reach 8.81 billion GBP by 2023 [1]. The technology has distributed management data for getting support to the transaction services to improve the business management and SC network within the manufacturing sector of the UK. IoT approaches have been focused on the process of creativity and

innovation in the business as well as to provide some space for productivity within the organisations.

It has been seen that organisations have implemented IoT technologies in the SC of the business which has offered many potential opportunities such as real-time tracking, increased visibility and developed efficiency. Many issues have been addressed to fully harness the advantages of IoT in expanding supply chain performance [75]. It has been analysed that IoT implementation requires substantial investment in the software, hardware and infrastructure. Most firms have been facing investment and cost-related issues for IoT implementation within their SCs to extend their performances. However, firms have been facing extra cost charges while the use of IoT technologies has created an extra financial burden.

Data security and data privacy concern has been one of the most issues in the SC performance. IoT has been implemented by various sector including the manufacturing sector to develop SC related issues [40]. It has been seen that IoT has been beneficial for organisations to manage their raw materials shortage and help them to refill before finishing. IoT has been considered the most effective and innovative development of digital information technology that has provided many opportunities to the manufacturing sector. These all technologies in the form of IoT have created many opportunities for business management of their raw materials shortage and help them to refill before finishing.

From this study, it could be summarised that in modern era, technology has played an important role for most manufacturing firms. There have multiple issues in SCM which has been faced by the organisations. In the manufacturing sector SC has been developed and has become responsible for organisational overall performance. Many firms have been focused to maintain a good relationship with their suppliers and implement innovative technologies and digitalisation that have been responsible for improving the relationship with them. Some strategies have been discussed in this study which can follow by manufacturing firms for developing their performance of SC.

5 Conclusions and Recommendations

This study demonstrates that pandemic-induced global SC disruptions and ongoing logistical vulnerabilities serve as the primary bottlenecks stifling the manufacturing sector. Rebuilding systemic global resilience across operational activities demands substantial financial capital and

infrastructure investment. To mitigate these pressures, integrating the IoT into logistics networks provides a viable remedy, empowering manufacturing firms to seamlessly track asset availability in real time. By utilising smart sensor frameworks, enterprises can efficiently manage inventory constraints and proactively address material shortages. To evaluate these dynamics, research objectives are directly mapped to empirical findings synthesized from secondary data sources.

Objective 1: To analyse the use of IoT technology for the improvement of SC performance

IoT has been implemented by various industries including the manufacturing sector, to improve the SC issues. The IoT enabled tracking systems of the inventory have been identified to be providing the exact data to the managers of the SC [68]. The IoT has been beneficial for the companies to manage their raw materials shortage and help them to refill before finishing. Thus, it can be said that the IoT has been very efficient in the smooth management of the supply chain in every form. The graph shows a report from IBM that signifies the use of technology in SC.

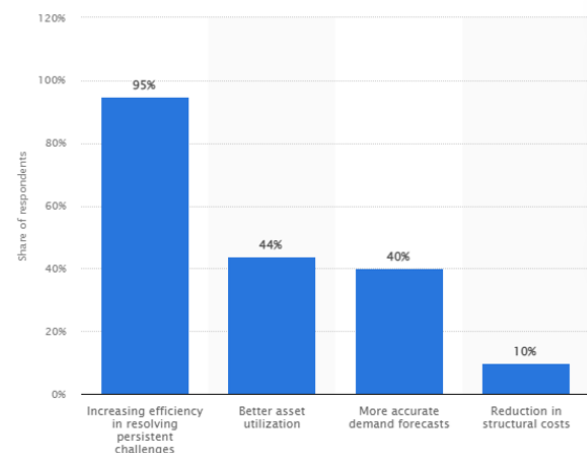


Fig. 17: Benefits of SC Transformation with AI

Source: [1]

Firms that have adopted AI have shown drastic efficiency improvement and reduction in structural cost shown in Figure 17 [1]. Technology has also played important roles in improving SCM. It has been found to increase the efficiency of the SC by real-time actionable data systems. These data can be collected by RFID tags and other technologies used for tracking. Studies has shown that the technology in the operational processes of the supply chain can help the industries to manage everything smoothly [76]. The decision-making process can also be enhanced with the technological implementation in

terms of flexibility, compatibility and confidentiality.

Objective 2: To evaluate the implementation of IoT in the global SC of the manufacturing sector

IoT has been considered the most innovative and new development of digital information technologies that have provided various opportunities to the manufacturing sector. These technologies in the form of IoT have been found to restructure the whole SC operations [77]. To improve the pattern modifications the IoT has been identified to empower the machinery of the manufacturing sector. Thus, it can be said that the monitoring activities related to operations of remote manufacturing have been one of the examples of technological implementations in the manufacturing sector. Hence, the solutions of IoT have provided optimisation to monitor manufacturing and machinery maintenance. The Figure 18 shows that in the years 2019, various industrial manufacturers have been using IoT in their SCs. These solutions were used basically in the logistics and 18% of other companies were planning to adopt the same for future years [1].

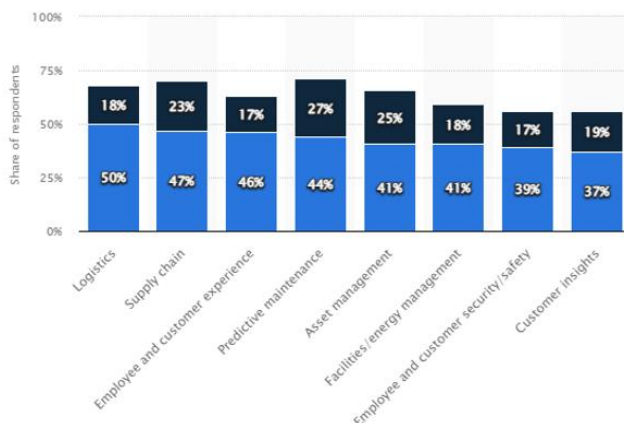


Fig. 18: Industrial Manufacturers implementing IoT
Source: [1]

These have been done with the help of various machines with efficient metrics of real-time equipment. As per the statement of [78], IoT can capture real-time information from various sections of the manufacturing sector including textile and clothing manufacturing value chains.

Objective 3: To discuss the reasons for improvement in the SC in the global manufacturing sector

The manufacturing sector has been identified to implement the technology of IoT for improvement in its SC performance. Studies suggested these improvements have been brought based on various

activities related to optimisation and measurement of inventory levels [59]. Manufacturing has been able to meet the demands of customers on time, reduce the stock-outs and improve operational bottlenecks to improve the SC. There have been various surveys conducted with manufacturers, out of which 55% of the manufacturers have seen a reduction in costs as a benefit of IIoT (Industrial Internet of Things) [1]. Other benefits have been an improvement in availability and uptime of operational equipment and increment in operational speed.

Objective 4: To find procedures which help the manufacturing sector implement IoT in SC

The IoT has been gathering steam in the operational activities of SCM through increased visibility and control. The procedures of IoT that the manufacturing sector implements in its operational activities have been tricky [79]. The manufacturers must check the foundation of the SC, to reject flawed SC processes. The next procedure has been found to assess the issues related to SCs and try to mitigate them effectively. This would make the process smooth and efficient for the industry. The supplier support needs to be secured before purchasing any technologies for the industry. Cobots have been designed to work in support of humans in the same workplace. In the warehouses of Amazon industrial cobots have already been used [2]. Automotive manufacturers also have been supported by IoT.

Objective 5: To recommend strategies to improve SC performance as a response to disruptions

The efficiency and performance of the supply chain need to be better as they have the capabilities to develop business performance. Collaboration with stakeholders has been the reason to increase the efficiency in SCM [80]. Communication efficiency, collaborations with internal operations, and adoption of big data analytics has allowed the manufacturing owners to develop the transparency and visibility of the SC. The framework of circular strategies in the manufacturing companies has been adopted that supports the CE in the process. Sourcing, planning, returning, making, and developing must be focused on by the manufacturing companies to have a positive impact on the process of SC.

5.1 Key Recommendations

The key recommendations from the study in support of the findings shown in Table 1.

Table 1. Key Research Recommendations

Key Area	Recommendations
Various Strategies	Strategies can be used to improve SC performance with the help of IoT technology for the global manufacturing sector. The advanced SC can bring a competitive advantage to the manufacturing firms as it helps in eliminating waste and reducing inherent risks [7]. IoT uses real-time data to improve SC performance by increasing the transformation process of products to customers and reducing inventory levels and warehousing costs for the global manufacturing industries.
Improve Flexibility	IoT can use the strategy of improving the flexibility of Scalability in SC that facilitate the global manufacturing sector in their growth and stability. AI has enabled the SC to improve logistics costs by 15%, enhance inventory level by 35% and increase service level by 65% of manufacturing sector compared to the other competitors [81].
	There have been various other strategies of IoT technology in the global supply chain of the manufacturing industries as it helps firms to manage unprecedented situations. IoT can use the tracking of the positioning process of products as the wrong routes can be identified with the help of this strategy to improve the SC. IoT can use the process of monitoring the storage conditions such as humidity, heat, pressure and cold to improve SC performance.
Automation	IoT with AI can use the strategy of fully automating the warehouse with minimal human supervision that can help in improving SC performance. Estimates in automation and IoT can raise productivity growth on a global basis by 0.8% to 1.4% annually [82]. IoT and BDA can use the process of predicting and planning contingencies such as weather, traffic, possible accidents and delays that can help in the SC. It develops flexible contingency plans based on the movement of products and helps in mitigating risks.
Prediction Modelling	IoT can be used for predicting the equipment maintenance that has been important to manage SC performance. It can use the strategy of proactively fixing the machinery that handles goods throughout the SC. It has been identified that the IoT helps in the SC that provides the largest benefit to manufacturing sector by 1.46b GBP [1]. IoT helps to improve SC performance by transparency and automation in the throughout the SC process [83].
Smart Application	IoT technology can use higher-speed smart route planning tools that can help in increasing the overall SC performance with the help of tracking technology. The tracking of shipment conditions and proactively responding to changes in the SC process can be used by IoT. It can be used to increase the efficiency of warehouse processes improve inventory management and employee safety.
Agile Models	The Agile model can reduce contingency stockpiles and avoid duplication to improve SC. Companies can use the agile mode to

streamline the SC and distribution process to improve the process of production. The strategy to avoid overproduction in manufacturing inductees can be beneficial to improve SC and this can be achieved with the help of an agile model.

Source: Created by Authors

5.2 Future Studies and Research Limitations

The study has the potential to create an analysis of the use of IoT technology in the improvement of SC performance in global manufacturing. Firms can follow findings from this paper to gain knowledge about the importance of advanced supply chains in the production process. The research paper can provide them with a review that IoT technology has been beneficial for their development, and it can help in raw materials transformation with the help of advanced SC. The strategies provided in the study would help improve the performance of the SC in the global manufacturing industries. The usage of IoT technology to improve SC performance would help manage logistics and increase efficiency. Research conducted for this topic has limitations during the conduction of the research and the limitation has been mentioned here. The study has been based on the secondary data collection method as the collection of data required from various sources such as articles, websites, and journals. However, the lack of proper access to all required secondary data has created a barrier to gaining knowledge about the process of completing the research. The study has missed some important relevant data such as other industries faced challenges due to a lack of performance in the supply chain due to the lack of proper access. On the other hand, the time allocated for the research has not been enough to accomplish this research, which creates limitations. The contribution of the research has been to focus on improving SC performance with the help of IoT technology for global manufacturing industries. The research has focused on the implementation of IoT technology to manage SC performance in the manufacturing industries. The study has ensured the recommended strategies related to SC performance as a response to disruption. It has been important for the study to improve its customer experience, increase efficiency, boost employee safety, enhance employee morale and satisfaction and improve visibility for the manufacturing sector.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

The author(s) wrote, reviewed and edited the content as needed and She/He/They has/have not utilised artificial intelligence (AI) tools. The author(s) take(s) full responsibility for the content of the publication.

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DOI: 10.1016/j.rcim.2019.101896.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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