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Review

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Abstract: In modern times, sustainability in supply chain management is one of the keys to boosting the performance of the supply chain, and it enables the accomplishment of SSCM. It has been found in recent years that SSCM with assist of industry 4.0 applications, can benefit splendid productivity and efficiency in the supply chain. The numerous industry 4.0 applications that are involved are Artificial intelligence (AI), Machine Learning (ML), Internet of Things (IoT) Big Data Analytics (BDA), etc. Industry 4.0 with SSCM has gained a lot of interest from various authors and scholars across the world. Healthcare is one of the most critical sectors due to its importance in handling public health. More recently, the COVID-19 pandemic and other viruses (SARS and Ebola) have highlighted supply chain vulnerabilities that are further mitigated by their lean and globalized structures. Covid-19 underlined the need for supply chain visibility problems within the healthcare sector. When the need for medical supplies became urgent and global distribution was disrupted, companies faced the consequences of needing the technology, systems, and plans in place to correctly predict the onslaught. One report shows that about 94 percent of Fortune 1000 companies reported supply chain disruptions due to the COVID-19 global outbreak. Existing studies have discussed supply chain issues and the importance of AI in addressing these challenges. AI, like Industry 4.0 in the healthcare supply chain, is proving to be a game-changer. This paper aims to review and present the various aspects of SSCM and industry 4.0 applications to get a comprehensive literature review, which contains the analysis of multiple articles published from 2010-2020. In addition, the various challenges SSCM and industry 4.0 applications face are identified and discussed. Also, the impact of Industry 4.0 and sustainable practices brings together the healthcare supply chain. This study will help in getting a good understanding of the different industry 4.0 technologies that are important for setting up SSCM.

Keywords: Industry 4.0; healthcare; sustainable supply chain management; sustainability; literature review; sustainable chain management(scm); Sustainable Supply Chain Management(SSCM)

1. Introduction

Sustainability is vital in a supply chain to acquire great productivity and efficiency in SCM. Sustainable supply chain management (SSCM) signifies actions, including the linkage between the elements and relations in the supply chain that are taken to obtain sustainable development. A completely sustainable SCM guarantees socially responsible business practices in supply chain management. A sustainable supply chain helps improve the continuity of supply and also helps in preventing costly downtime and reputation damage. Using sustainable techniques and resources increases the efficiency of a whole supply chain at a significant cost saving. SSCM is an essential tool that involves proper cooperation between suppliers, recipients, and managers to form a good

relationship between these systems. [1] mentioned that sustainable SCM is an excellent function that helps support the organization and manage the whole supply chain. [2] predicted that with the help of SSCM, it is possible to get an excellent perspective regarding the product's entire life. [3] opined that SSCM is critical as it considers the complete value chain for each cycle at all stages. [4] observed that sustainable supply chain management also emphasizes a very efficient supply chain system for better productivity. [5] committed that SSCM helps get an outstanding supply management advantage by lowering costs and building an effective supply chain. There are various importance of sustainability in SCM, such as increasing the visibility of value chains, supporting new business models, increasing the information-sharing capabilities, and supporting the robust intake of resources. Conceptualizing the term sustainability, its broad meaning in healthcare institutions is related to the environment, society, and the economy.

'Industry 4.0' means the smart factory in which smart digital devices are networked and communicate with raw materials, machine tools, robots, and men. Industry 4.0 includes additive manufacturing, Advanced manufacturing systems, Sensors, CPS, the IOT, BDA, AI, Logistics 4.0, and mass customization [6]. Industry 4.0 is characterized by flexibility, efficient use of resources, and integration of customers and business partners in the business process. Industry 4.0 has enabled a firm's advancement in SCM by significantly enhancing productivity and efficiency. Today, the developed Industry 4.0 solution is considered a key enabler for SSCM. Sensors play an important role in collecting appropriate data, and protocol development for data integration is the key factor for sustainability in supply chain management. [7], observed that blockchains are very significant for regularizing sustainability as they help improve the efficiency of emission trading schemes by reducing fraud in the supply chain. [8] concluded that big data algorithm has very good access to optimized processes due to their flexibility and access to data. The rising difficulty of sustainable development with the help of Industry 4.0 has gathered a lot of attention in the development of SCM and identifying the key challenges in the supply chain. SSCM practices are now becoming a widespread business trend for sustainable development in the industry. Nowadays, the various applications of Industry 4.0, like IoT, AI BIG-DATA, etc., are used in SCM to gain great efficiency and productivity rate. Industry 4.0 and sustainable practices can be integrated and are capable of bringing contributions to the market through strengthening quality programs. These applications allow competitiveness through the offer of new products and better services.

In recent years, the healthcare industry has been experiencing a significant shift due to the emergence of Industry 4.0, the fourth industrial revolution marked by integrating digital technologies into manufacturing and supply chain operations. This integration has notable implications for the healthcare industry, particularly in sustainable supply chain management. Managing a sustainable healthcare supply chain involves managing information, supply, suppliers, services, providers, internal and external customers, and end users, as outlined by [9]. The healthcare industry has always been known for its sustainability and social responsibility commitment. Still, in recent times, there has been a growing emphasis on incorporating sustainable supply chain management practices. This focus on sustainability and SCM has been fueled by the realization that it can provide significant benefits, including cost reduction, better patient outcomes, and improved reputation for healthcare organizations. The challenges posed by the COVID-19 pandemic and other viruses have further compounded the difficulties that providers face in acquiring the necessary items for quality care at an affordable price. The advent of Industry 4.0 has prompted firms to explore ways to achieve sustainability by shifting their focus from economic performance to becoming more socially and environmentally conscious. The primary objective of this literature review is to investigate the impact of Industry 4.0 applications on supply chain management (SCM). To achieve this objective, a systematic literature review covering the years 2010 to 2020 was conducted, allowing for a comprehensive understanding of the relevant research on Sustainable Supply Chain Management (SSCM) with Industry 4.0. This study's research question is: "How does Industry 4.0 contribute to sustainable SSCM?" The review includes an introduction to the importance of SSCM, a basic definition, and a

literature review. It also explores Industry 4.0 applications, such as IoT AI, and how Industry 4.0 is linked to SSCM, followed by descriptive analysis and research methodology. Finally, this review concludes by listing some benefits of integrating Industry 4.0 (AI) and SSCM in the healthcare sector.

2. Research Methodology

For in-depth identification of the relationship between Industry 4.0 and sustainable scm, a literature review was analyzed and implemented. At first, the equality between Industry 4.0 and SSCM was investigated. Secondly, the different applications of Industry 4.0, like AI, and IoT, were discussed, and their relation with SSCM was also analyzed. In this part, how the data are gathered, analyzed, and reported is described. At the start, the search criteria were selected. Then, the papers and other documents were classified to consider for the analysis, followed by the document analysis in detail by observing the publication year, methodology, and the contributions of different researchers.

2.1. Search criteria

Specific data were considered for a systematic review and to secure the validity of collected data. The databases that were followed are Elsevier MDPI, which provides very well-reviewed journals. The study considered only formal and informal literature by considering various titles, abstracts, and keywords. The papers that were written in English and published in a complete decade between 2010 and the first months of 2020 were selected and reviewed, and this search was from various papers and editorials.

2.2. Article Search

For getting the articles centering on Sustainable Supply Chain Management with Industry 4.0, the database search began with the article that includes the combination of words "SSCM and Industry 4.0 applications like AI and IoT". Various articles were found from Elsevier MDPI, and the articles 'titles, keywords, and abstracts were examined. The different keywords were: "Sustainable", "supply chain", and "industry 4.0 applications AI, IoT, Machine learning"

2.3. Results

The databases accumulated from different literature reviews were analyzed, and the graphs containing the number of papers published in a particular year, the Titles of the papers and their numbers, the Name of the Author, and the number of publications were drawn in the first part. In addition to this, for each technology, a subset of topics was identified from the different research papers and were discussed with their classification. In the second part, the various applications of Industry 4.0 and their relation with SSCM were discussed and analyzed thoroughly.

Figure 1 The number of published articles has increased between 2009 and 2020, with a maximum number of published articles in 2018. This increasing number of documents shows the interest of the authors and researchers in Industry 4.0 with SSCM.
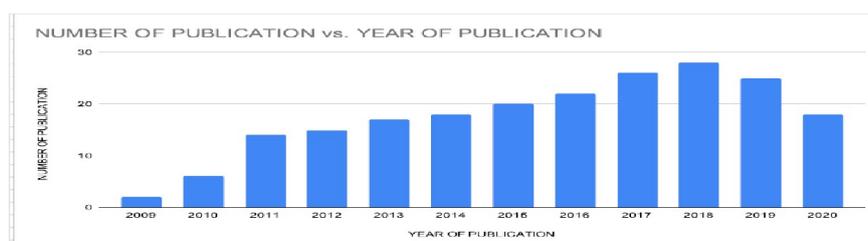

Figure 1. Series of published papers between 2009-2020.

Figure 2, shows that the various applications of Industry 4.0 have emerged as a very effective tool in SSCM. ML has been identified as a leader in this series. Also, other applications like AI, IoT, CBS, BDA, etc., have often been used for retaining sustainability
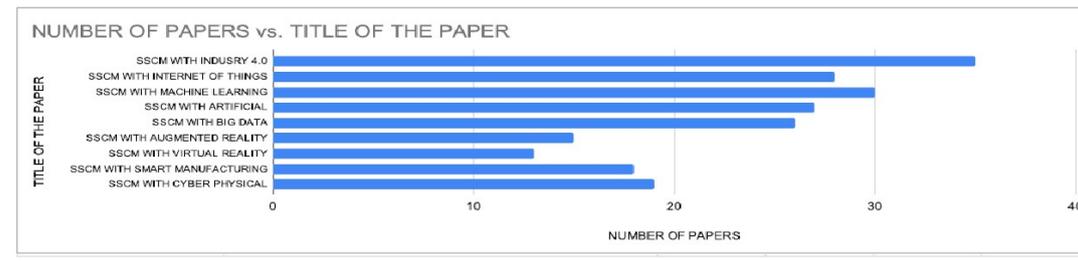

Figure 2. Title of the paper and the number of publications.

Figure 3 hows the number of authors and their publications within the years 2009-2020; many authors have already worked in this area, and still, many of them are working and presenting good knowledge in identifying the technologies that can lead to sustainability in the supply chain.
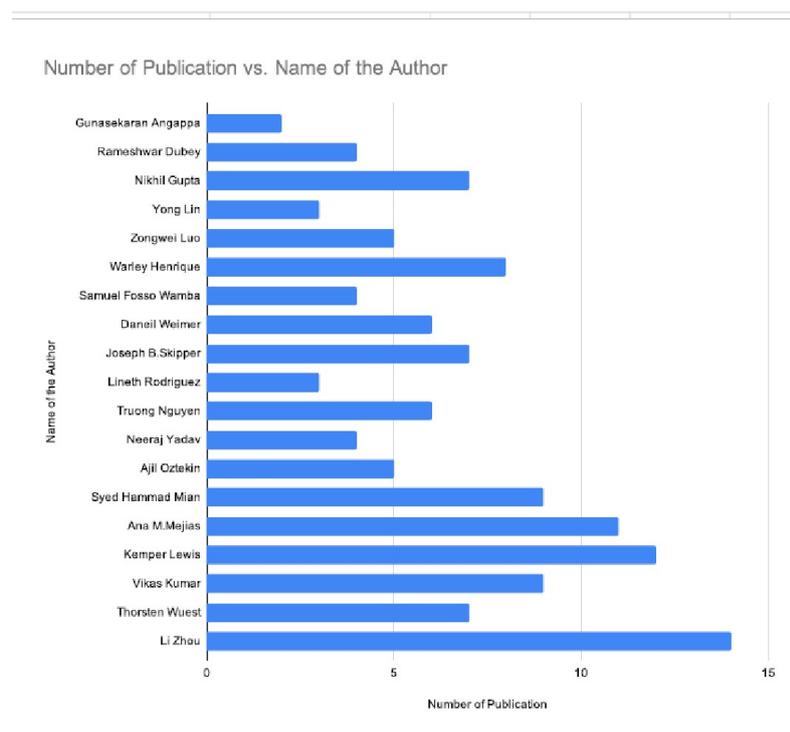

Figure 3. Name of the authors with several publications.

3. Industry 4. O and SSCM

For a better method, SSCM and Industry 4.0 are classified on the basis of various items. For SSCM, the related classification is MNC, which stands for manufacturing; PRC indicates procurement; DSA implies distribution angle; similarly, INF and COLLAB for information and collaboration. Industry 4.0 related items are IoT, which stands for internet of things, AI artificial intelligence; CPS cyber-physical system; AM additive manufacturing; BDA big data and analytics; MI machine learning; and SMS and BC, which stands for smart manufacturing system and blockchain technology. The role of each industry 4.0 item in SSCM is discussed in the next section

3.1. Artificial intelligence (AI) and SSCM

Artificial intelligence is called the usage of computer systems for reasoning learning. [10] state that AI makes sustainable supply chain management more efficient because of the optimization process. [11] explained that AI helps predict data and provides accurate and reliable results in sustainable scm. [12] found that AI enabled the SSCM system to identify the best possible combination of algorithm sets for the predictions. Silver et al. (2015) AI can be applied to use the data more effectively in sustainable scm. [13] used various AI techniques to find the best-optimized services in scm and found that with the application of AI, scm can be enhanced easily. [14] explained that the AM techniques help in getting flexibility towards the development of sustainable scm

3.2. Internet of things (IoT) and SSCM

The IOT is a network of connected device, objects, and sensors that collect and helps in communicating information. There are various advantages of IoT in sustainable scm. [15] concluded that Development in IT has played a key role in enhancing the planning, controlling, and increasing the efficiency of sscm [16] explained that through the use of IoT, suppliers can easily ensure safety in SSCM. [17] found that IoT ensures the convenience of activities and sustains a competitive advantage in scm. Mehl et al., (2015) observed that IoT offers substantial efficiency gains across all the stages of scm. [18] explained that IOT coupled with the supply chain helps an organization to make informed decisions. [19] concluded that IoT helps in building a smart and secure supply chain management. [20] concluded that IoT positively affects the SCM by its application.

3.3. Additive manufacturing (AM) and SSCM

Additive manufacturing led to various solutions in traditional scm and can help to increase the efficiency of scm. [21] found that AM designs are completely free from any design constraints which is imposed by the traditional method of supply chain management. [22] explained the emergence of consumer-centric business in SCM with the advent of AM. [23] concluded that due to AM, there is increased agility in scmt. [24] found that total supply chain costs, transport costs, and production sites can be easily improved and increased with the use of AM in scm, and also it was observed that the total cost of transportation can be decreased by 50% after conducting few experiments in scm. [25] observed that the use of 3D printing processes could completely replace mass manufacturing in scm [26] found that AM is a disruptive technology that will radically change supply chain management. [27] found that the use of AM supply chain can be made more attractive and effective. [28] concluded that AM-enabled system in supply chains helps in reducing transportation, upgrading the products, reducing the material consumption, and reducing the time in scm. [29] found that AM is truly innovative, helps in endless product design, and enhances scm.

3.4. Cyber-physical system (CPS) and SSCM

The growing technologies in the world of CPS promise a new solution to the problem in manufacturing and supply chain management. [30] explained that for proper implementation of CPS in the supply chain, sensors form a very effective integral part. [31] analyzed that the cyber aspect is an important part that combines with CPS in managing the supply chain. [32] observed that with the help of CPS, a new dimension for full transparency of supply chain material flow can be enabled. [33] concluded that the synchronization of supply chains with the support of CPS embodies a relevant opportunity for enhancing performance in scm. [34] found that applications of CPS have grown in all areas, supporting managers in decision-making and enabling a better understanding of processes in complex systems in scm. [35] explained that CPS promises a new problem solution in manufacturing in supply chain management. [36] concluded that CPS integrates the obtained data into the virtual world of information by mastering complex data structures and helps in supply chain management. [37]

observed that with the use of CPS in SCM, flexibility, productivity, and modularity could be increased easily.

3.5. Machine learning (ML) and SSCM

ML has become one of the best technologies that has revolutionized supply chain management by improving its processes. [38] found that the models in machine learning can react to new, unknown data and help in predictions in scm. [39] explained that machine learning techniques enhance data-driven decisions in scm. [40] concluded that machine learning applications support and lead to sustainability in SCM. [41] observed that machine learning deals with computer-aided modeling which helps in improving performance or in making concrete predictions in SCM. [42] analyzed that the machine learning technique helps to simplify the findings of new possible partners in SCM. Pat et al., (2011) concluded that machine learning could bring actual value for supply chain management. [43] explained that machine learning algorithms combined with sensors to provide end-to-end visibility across the SCM. [44] concluded that with the help of ML, manufacturers can reduce SCM latency for components and parts used in products. [45] observed that the machine learning algorithms can yield the lead-time prediction in production with a shorter response time in scm.

3.6. Smart manufacturing (SM) and SSCM

Smart manufacturing, today is attracting much interest in scm. [46] found that smart manufacturing helps mass customization of products and allows the companies to meet consumers' demand in scm. [47] concluded that smart manufacturing helps develop and will improve the workers' safety to enhance manufacturing in supply chain management. [48] explained that smart manufacturing provides flexibility to increase productivity and efficiency in SCM. [49] said that SM aims towards a fully integrated sequence of planning and production solutions to create a more visible manufacturing process in supply chain management. Jsoo et al., (2019) concluded that SM helps in response-efficient tactical supply planning model with flexibility in scm. [48] explained that the production systems aim to process multiple products in scm in a smart manufacturing unit. [50] found that smart manufacturing is the mode of product design, manufacturing in scm, and even how products are sold.. [51] concluded that smart manufacturing is an implementation of a wide variety of digital technologies that help increase the efficiency of SSCM.

3.7. Big data (BD) and SSCM

Big data is a way to investigate information from data sets that are large or complex to be dealt with by traditional methods that are used in supply chain management. Big data has been applied in SCM for procurement, sourcing cost improvement, and production planning and control. [52] concluded that big data and its applications have revolutionized supply chain management. [53] found that big data is significant because it can transform the entire business process in supply chain management. [54] analyzed the various dimensions of big data and concluded that they have all the potentials that help capture all the benefits of scm. [55] found that big data helps maximize productivity, collaboration, speed, and visibility in supply chain management, avoiding losses in the supply chain. [56] found that big data enables real-time analysis and supports manufacturing optimization, which helps increase the efficiency of scm.

3.8. Blockchain technology (BCT) and SSCM

Blockchain technology today helps enable more transparent and accurate end-to-end tracking in supply chain management. [57] found that blockchain technology helps maintain sustainability in the supply chain. [58] explain that blockchain integration in the supply chain can lead to a more reliable, authentic, and secure system. [59] concluded that blockchain technology is a recommended tool for sustainability in the manufacturing industry because of the benefit of real-time transparency. [60] found the various advantages of blockchain technology, like accessibility, data management,

data safety and decentralization, and quality control in supply chain management. [61] concluded that blockchain technology is an enabler of real-time, verifiable, and transparency and also improves auditing practices, reducing trading costs, reducing fraud risk, enhancing the audibility of transactions and increasing the effectiveness of monitoring in an SCM.

4. Framework

Figure 4 depicts a framework of present trends in healthcare utilizing I4.0 and SSCM components to provide a sustainable evolution of I4.0 technologies immersing into the healthcare sector. Technologies like artificial intelligence, the Internet of things, additive manufacturing, cyber-physical systems, machine learning, smart manufacturing, big data, and blockchain technology have been harnessed to bring fruitful evolution in the modern healthcare sector. Moreover, I4.0 is growing sporadically worldwide rapidly, and its powers to transform and impact lives are gaining broad visibility.

Sustainable supply chain management (SSCM) components, which already exist in their traditional forms, are getting into the transition phases of evolving into digitized versions. This would facilitate more coherent and synchronized supply chain systems with faster and easier supply with enhanced transparency and flow of materials for utility in healthcare corridors. I4.0 technologies and digitized SSCM components have started immersing into healthcare to enrich sustainability paradigms. Predictive maintenance, quality control, demand forecasting, and patient-centered care are successfully witnessing the diffusion of I4.0 and SSCM components. Figure 5 showcases a typical example of a hospital [H] receiving a medical product produced in a factory and supplied to a customer [H]. Along the course of procuring raw materials from suppliers to a factory, conversion of raw material into finished products inside the factory [F], and then supply chains to transport the product to the customer, the various I4.0 technologies have varied degrees of influence on multiple sections of the core SSCM process. This is depicted as an example that aids in improving the multiple facets of the healthcare sector, such as predictive maintenance, quality control, demand forecasting, and patient-centered care.
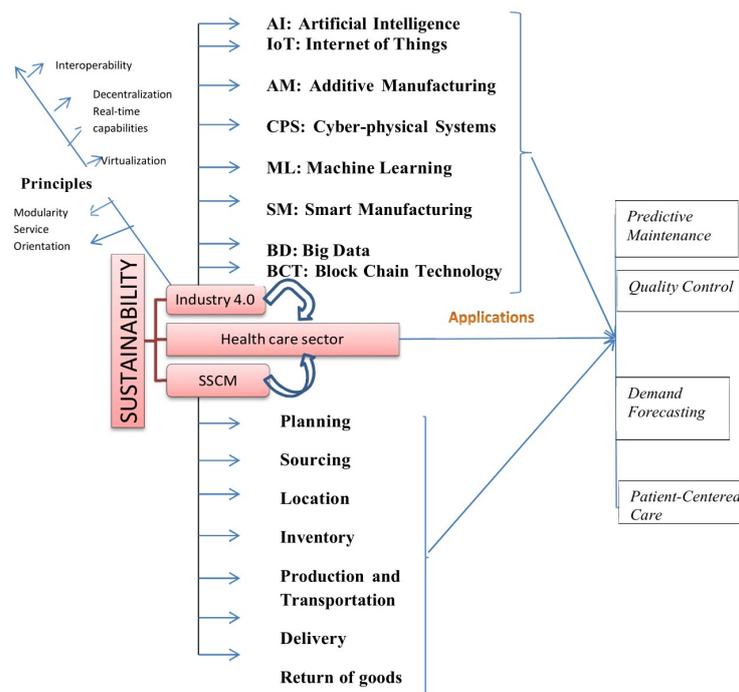

Figure 4. A framework of I4.o and SSCM towards application in healthcare: Present trends.
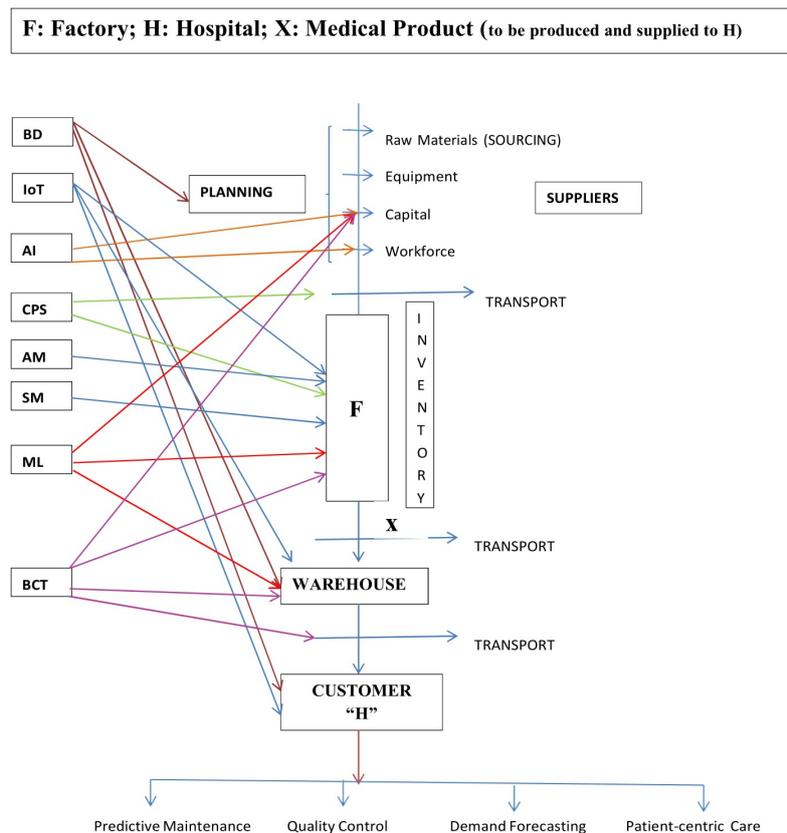
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Figure 5. An Example of a medical product being produced and supplied using I4.0 and SSCM.

5. Healthcare system:Industry 4.0(AI) and SSCM

The advent of Industry 4.0, specifically the utilization of Artificial Intelligence (AI), has presented new possibilities for advancing supply chain management (SCM) in the healthcare sector Figure 4. AI can be employed for various purposes, including predictive maintenance, quality control, demand forecasting, and patient-centric care Figure 5. Furthermore, AI has the potential to enhance supply chain operations and promote sustainability.

5.1. Predictive Maintenance

Recent studies have highlighted the importance of predictive maintenance in the healthcare industry, where equipment upkeep is essential for maintaining the optimal functioning of machines. Predictive maintenance can prevent unplanned downtime and save costs by utilizing Artificial Intelligence (AI) algorithms and Internet of Things (IoT) sensors. Furthermore, it can help healthcare providers optimize inventory management, reduce waste, and improve the overall efficiency of the supply chain (Schweitzer & Wang, 2021). This approach is essential in the current healthcare climate, where the COVID-19 pandemic has pressured healthcare systems to maximize their resources [62].

5.2. Quality control

Quality control is vital in ensuring patients receive optimal care in the healthcare industry. AI technology can help identify defects and potential failures in medical products and devices, allowing manufacturers to take prompt corrective action. By leveraging AI-based quality control techniques, healthcare providers can reduce the risk of medical errors, improve patient outcomes, and decrease the likelihood of adverse events [63].

5.3. Demand Forecasting

The healthcare industry experiences significant fluctuations in demand, especially during public health crises. AI algorithms can analyze vast data to forecast the need for medical products and services, empowering healthcare providers to optimize their inventory levels and minimize costs. This technology can play a crucial role in streamlining supply chain management in the healthcare industry [64].

5.4. Patient-Centered Care

AI technology is becoming increasingly important as healthcare providers shift towards a more personalized approach to patient care. AI can help develop individualized treatment plans and care pathways by analyzing patient data, improving patient outcomes, greater patient satisfaction, and reducing healthcare costs. (Kostkova, P. 2020).

5.5. Sustainability

The healthcare industry is one of the most significant contributors to greenhouse gas emissions and waste generation, making sustainable supply chain management crucial. Adopting Industry 4.0 technologies, such as AI and IoT sensors, can help healthcare providers optimize their supply chain operations, minimize waste, and improve environmental sustainability. Implementing closed-loop supply chains, promoting the reuse of materials, and adopting green supply chain practices are some measures that can be taken to achieve sustainable SCM in the healthcare industry. (World Health Organization. (2021), (Healthcare Supply Chain Association. (2017) and (E&Y., 2020).

6. Discussion

From the sustainability perspective, the focus was on industry 4.0 technologies, and it is easier than what industry 4.0 technology better fits with sustainable supply chain management. Industry 4.0 brings a revolution in the supply chain through smart manufacturing. AM, BDA, and IOT are the most frequently used industry 4.0 applications regarding manufacturing and distribution angle.AM leads to product optimization, and with AM, innovative solutions can be applied, leading to sustainability. Big Data enhances the sustainability and effectiveness of supply chains by collaboration. Many organizations operating with industrial IoT solutions saw improvement in the sustainability of the supply chain. CPS helps manage big data, forming pillars for sustainability in the supply chain. SM, which includes a system like GPS and sensors, leads to excellent efficiency and helps in achieving sustainability in the supply chain. AI can help organizations make a positive change, ensuring sustainability in the SCM. Some dark side of Industry 4.0 affects the sustainability of the supply chain, including challenges like management, technical barriers, and political challenges. [65] concluded that other challenges are faced by industry 4.0 applications, such as insufficient research and development, poor quality data, and lack of infrastructure. Therefore, comprehensive strategies and applications of framework are required to realize the applications of industry 4.0 technologies in maintaining sustainability in the SCM.

From the healthcare perspective, along with Industry 4.0, the integration of AI in healthcare SCM, within the context of Industry 4.0, has been a focus in healthcare to enhance efficiency, cut costs, improve patient outcomes, and promote sustainability. One notable advantage of AI in healthcare SCM is predictive maintenance, which relies on AI algorithms and IoT sensors to detect problems before they become critical, avoiding unplanned downtime and reducing expenses. Additionally, AI can aid in demand forecasting, crucial for managing demand fluctuations in the healthcare industry. AI can also boost patient safety by ensuring that medications are dispensed accurately to the intended patients at the correct time. With the help of AI, healthcare providers can track medication movements throughout the supply chain and ensure that they are appropriately labelled, stored, and distributed.

7. Conclusions

Through a well-ordered literature analysis, this paper offers a very good idea about the relationship between industry 4.0 applications and sustainable supply chain management. This entire study forms a very good work for maintaining SSCM. Considering how industry 4.0 applications influence the supply chain, it is possible to confirm that industry 4.0 applications are essential in SSCM. In the second part, depending on each industry 4.0 application, other topics were discussed. AI, IoT, and ML help in developing information technology that increases efficiency and maintains sustainability in the supply chain. CPS supports the development of innovative services like maintenance applications. Considering different industries, 4.0 technologies help identify technology corresponding to the particular area in maintaining sustainability in the supply chain. Finally, with the practical implementation of different industry 4.0 technologies, SSCM requires continuous monitoring and control such that sustainability can be easily ensured in the supply chain, which will ultimately add to the efficiency of the supply chain. Applications of Industry 4.0 need very good attention as various works have been done in this area. Still, there are various challenges these technologies face for which continuous monitoring is required so that the use of these technologies can be increased, leading to the enhancement of sustainability in the supply chain. This study provides a good allusion for future work and investigations.

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