A REVIEW OF LEVERAGING BIG DATA ANALYTICS FOR SUSTAINABLE SUPPLY CHAIN MANAGEMENT

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Abstract

As organizations aim to drive sustainability in their supply chain management practices, big data analytics has emerged as one of the effective approaches. However, data security and privacy challenges remain since big data analytics continue evolving in the supply chain. Organizations need to address these challenges to ensure business performance. This paper conducts systematic literature reviews of the potential of big data analytics in driving sustainability in supply chain management. The findings show that big data analytics enables organizations to make data-driven decisions, optimize business processes, and enhance sustainability through techniques like machine learning, predictive, and prescriptive analysis. Future research directions are suggested, focusing on addressing the challenges with appropriate strategies and exploring the impact of other Industry 4.0 technologies on sustainable supply chain management.

Keywords: *Big Data Analytics (BDA), Supply Chain Management (SCM), Sustainability*

1. Introduction

Sustainability has become an essential business requirement across various industries in recent years. As society's expectations continue to evolve and environmental issues become a concern globally, more organizations are starting to see the importance of integrating sustainability principles into their operations [1]. A supply chain refers to an extensive network of organizations, activities, technologies, and resources, from production to delivery of goods and services [2]. It involves information and operational flow from many parties, including suppliers, manufacturers, logistic companies, retailers, and customers. Consequently, Sustainable Supply Chain Management (SSCM) has gained significant attention in this area, where organizations consider the environmental, social, and economic factors in the entire supply chain to improve sustainability performance and thus reduce negative impacts effectively. However, traditional supply chain management often encounters significant challenges in effectively

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addressing sustainability issues. One of the main challenges is the lack of transparency within supply chains. This lack of transparency might cause the origin of products to be hard to track, higher environmental and social risks, and unfair labor practices within the supply chain [3]. Organizations may unintentionally contribute to unethical practices due to lacking visibility among suppliers and subcontractors.

Despite the growing interest of scholars in the big data analytics field [10] [11], the contribution of big data analytics to the SSCM area needs to be examined. This paper aims to comprehensively review the role and application of big data analytics in sustainable supply chain management. A systematic literature review will be conducted to investigate the potential technologies used in SSCM. The research questions are:

1) How can big data analytics be leveraged within sustainable supply chain management to enhance performance?
2) What are the technologies and methodologies used in big data analytics for SSCM?
3) What are some potential benefits and challenges of applying big data analytics in SSCM?

2. Methodology

To conduct a Systematic Literature Review (SLR), the approach applied in this paper to identify relevant past literature on big data analytics in SSCM is based on a three-phase process used in [12]. Figure 1 illustrates the SLR process flow, which includes three main stages: planning, conducting, and reporting.

Figure 1. Systematic Literature Review by [12]

2.1 First Stage: Planning

After the research questions are defined in the previous section, the search strategy that is most appropriate to address the research questions will be identified and implemented. Multiple important terms are extracted from the questions to improve the relevancy of journal articles searched in the databases. The keywords identified to conduct the search strategy are: "Big Data Analytics," "Supply Chain Management," and "Sustainability." Advanced search strings are constructed based on the identified terms.

(TITLE-ABS-KEY (sustainable) OR TITLE-ABS-KEY (sustainability)) AND TITLE-ABS-KEY (supply AND chain AND management) AND (TITLE-ABS-KEY (big AND data) OR TITLE-ABS-KEY (big AND data AND analytic))

This study then performs the search strategy on the popular multidisciplinary abstract and citation Scopus database. In the first stage, 334 documents were identified based on the advanced search string.

2.2 Second Stage: Data Collection

The study selection process involves the consideration of inclusion and exclusion criteria. This study's primary context for these criteria is surrounded by big data analytics in the SSCM area. The previous literature selected for the SLR must be open-access peer-reviewed papers written in English. The papers that contain information relevant to big data analytics in supply chain management will be considered. These articles must be published between 2018 to 2022. Table I shows the inclusion and exclusion criteria specified for this SLR.

Table 1. Inclusion Criteria

Inclusion Criteria	Exclusion Criteria
The paper discussing bigdata analytics in supply chain	Grey literature
Publications from 2018 to 2022	Paper written in non-English

After the inclusion and exclusion criteria were considered, the number of papers was reduced to 30. All articles are then reviewed carefully based on the abstract and conclusion to filter out the less relevant articles and only include quality ones. Twenty-two studies remain as the primary reference to be included in this SLR. After reading the articles, essential findings from the data extraction and analysis process will be reported in the next stage.

2.3 Third Stage: Reporting

In this section, the findings of the systematic literature review that aims to address the research questions will be presented. The findings are based on the selected articles that met the inclusion and exclusion criteria constructed in the methodology part. Table II shows the number of articles published in the last five years (2018- 2022).

Table 2. Articles by Publication Year

Year	Number of Articles	References
2018	Nil	Nil
2019	Nil	Nil
2020	1	[4]
2021	9	[2] [13] [14] [15] [16] [17] [18] [10] [3]
2022	12	[19] [5] [9] [6] [20] [1] [7] [21] [22] [23] [24] [25]

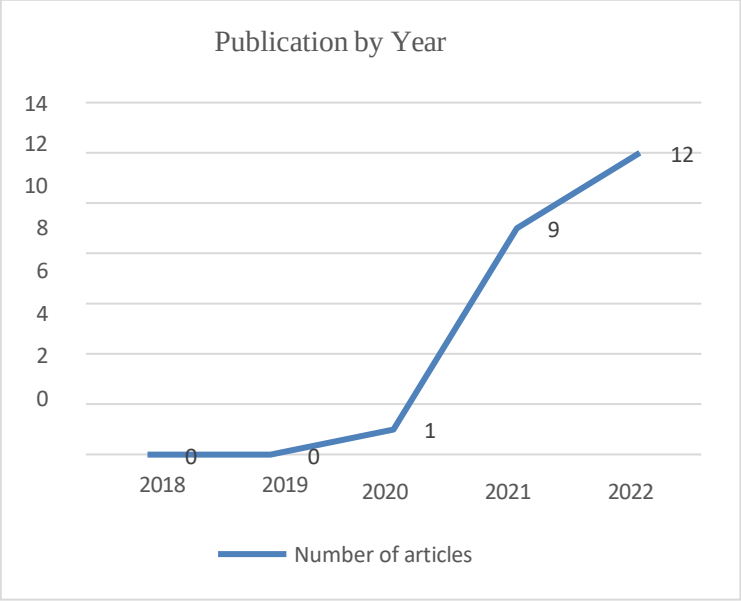

Figure 2. Line Graph showing Publication by Year

Based on Figure 2, which illustrates the trend discovered from Table II, it is evident that the number of publications focusing on big data analytics for SSCM was limited before 2020, showing that the field was still in its early stages. However, there was a significant surge in 2021. The continuous increase in publications indicates that the application of big data analytics in supply chain management is evolving and expanding. It also proves that the awareness of data-driven decision-making in enhancing supply chain sustainability is growing among researchers, and through the review of the articles, this study successfully answers the following research questions.

A: RQ1: How can big data analytics be leveraged within sustainable supply chain management to enhance performance?

Several studies highlighted the potential of big data analytics in enhancing the performance of SSCM. Sustainability, which focuses on three main areas, including economy, environment, and society, needs to be considered when applying big data analytics to supply chain management [16] [21] [24]. The author of [[1] outlined the role of information technology and sustainability in supply chain management, specifically logistic outsourcing, where big data analytics helps improve logistic processes. The selection of logistic service providers considering advanced technology capabilities like machine learning and sustainability impact is more competitive than traditional logistic outsourcing.

There are many techniques used in big data analytics to optimize business processes. A study by [2] emphasized the utilization of different machine learning algorithms like decision trees and support vector machines in solving specific issues related to supply chain management. The study provides a comprehensive overview of the main areas where machine learning can be applied to production, supplier selection, and sustainable development. Real-time data enables the organization to reduce human labor and optimize operational processes.

The e-commerce sector has experienced rapid growth in the past few years and has greatly benefited from big data analytics. Sustainability is closely linked to the success of these e-commerce platforms, where external factors such as environmental, economic, and social objectives need to be considered [20]. Big data analytics can support electronic business models in improving operational performance by integrating partners and supervising distribution, transportation, and delivery strategies.

Several studies have highlighted the potential of big data analytics in improving the performance of SSCM. This review believes that sustainability should be one of the key components in supply chain management that must be focused on since it helps the organization drive long-term success. By utilizing big data analytics, organizations can gain valuable insights and make data-driven decisions that maximize operational efficiency and sustainability impact. Integrating advanced

technologies like predictive analytics in the food and agriculture supply chain is a notable example of how organizations can achieve a competitive advantage in the market.

B: RQ2: What technologies and methodologies are used in big data analytics for SSCM?

Various technologies and methodologies were identified in the previous literature for applying big data analytics in SSCM. One highlighted technology is the wireless sensor network (WSN), which enables the data to be collected in real-time. Industries like agriculture and horticulture have utilized WSN to manage and monitor products and business processes [14] [25]. For instance, parameters such as soil characteristics and weather conditions collected through WSN can be used as input data for predictive analytics to improve sustainability by producing high-quality coffee [14]. Additionally, in the food supply chain, the author from [9] demonstrated that using prescriptive analytics, decision support tools, and digital resource management processes could enhance supplier selection and improve sustainability in the agriculture supply chain.

Machine learning techniques are also employed in SSCM to analyze big data and create valuable insights. Due to the pandemic crisis, sustainability, which focuses on food waste reduction, is among the main challenges faced by the food supply chain [18]. Organizations can transform a sustainable and transparent food system by utilizing machine learning algorithms to digitalize the production of food commodities.

From the perspective of manufacturers and distributors, selecting a suitable supply chain model based on machine learning can transform supply chain decision-making, encompassing both operational improvement and strategic policy decisions [19]. Manufacturers and distributors can accurately estimate customer demand using advanced predicting strategies based on special events and market trends.

Identifying various technologies used in big data analytics for sustainable supply chain management presents potential opportunities for innovation. The utilization of prescriptive analytics for demand forecasting and machine learning algorithms shows promising impacts. Applying machine learning in production, supplier selection, and sustainable development can effectively improve resource allocation practices and drive continuous improvement in sustainability performance.

C. RQ3: What potential benefits and challenges are associated with applying big data analytics in SSCM?

Applying big data analytics in SSCM provides many advantages, but challenges arise. The author of [23] states that big data analytics work explicitly well in managing supplier-related risks and identifying sustainable sourcing strategies in circular procurement. Big data analytics can potentially automate the selection of sustainable suppliers through procurement operation optimization [23]. In a study by [1] on the sustainability of logistic outsourcing, the author mentioned that implementing advanced analytical systems in selecting suitable logistic service providers can effectively improve business efficiency, minimize cost, and maintain sustainable characteristics.

Moreover, transparency and risk management can be achieved by using big data analytics to analyze supply chain data to make data-driven decisions [3]. In effect, emissions and disruptions that have been reduced enable the SSCM performance to improve. However, the author also highlighted some challenges regarding applying big data analytics. The workforce that is less skilled and incapable of processing big data might affect the effectiveness of operational performance [3]. This study believes that organizations should provide training and development programs to ensure workers are well-equipped with data analytics skills to deal with data. Investing in upskilling and reskilling initiatives is crucial for employees to adapt and interpret big data effectively.

On the other hand, most of the reviewed literature identifies data privacy and security challenges when employing big data analytics in SSCM. For example, [18] points out that the sustainability of data integration remains uncertain in the food supply chain industry since the technologies continue to develop. The risk of data manipulation is higher when data security measures are not strong enough to safeguard confidential data. Organizations should implement robust data protection measures, such as secure data storage systems, encryption techniques, and access controls, to protect sensitive information. Regular audits and assessments of data protection practices can also be conducted to identify vulnerabilities or areas for improvement.

Rules and regulations from the government are another concern that affects the level of data security. National environmental regulations that are closely related to pollution and safety must be taken into consideration by organizations when constructing big data strategies in supply chain management [7]. Organizations need to handle these challenges carefully to ensure the optimization of the technologies used. In order to comply with sustainability practices and regulations, organizations need to integrate sustainability considerations into their data management processes. For instance, organizations can align data analysis with environmental objectives and collaborate with regulatory bodies to stay updated on evolving sustainability requirements.

Applying big data analytics in sustainable supply chain management offers significant benefits. This study agrees with the findings highlighting improved risk management, supplier selection, and transparency as crucial advantages. Organizations can also better identify risks and reduce operational costs. However, it is essential to acknowledge and address the challenges related to big data analytics in SSCM. Organizations can maximize the benefits of big data analytics and ensure sustainable practices within the supply chain by proactively addressing these challenges.

3. Critical Analysis

Limited collaboration among supply chain partners can also hinder identifying environmental risks and optimizing energy consumption. In traditional supply chain management, organizations face challenges in collecting and sharing data on energy usage or carbon emissions within the supply chain, as the information flow is usually fragmented. Consequently, organizations might be unable to capture the opportunities to optimize and improve sustainability performance. Furthermore, traditional supply chain management may struggle to manage product lifecycles for sustainable practices. Product lifecycle management is a complex process that presents challenges at different stages, ranging from raw material extraction to end-of-life disposal.

In parallel to the rise of SSCM, the fourth industrial revolution, known as Industry 4.0, has been accelerating the transformation of business operations. In Industry 4.0, advanced technologies like the Internet of Things (IoT), artificial intelligence, robotics, cloud computing, and Big Data Analytics (BDA) are integrated into different industrial processes. Real-time data collection, connection, and informed decision-making can revolutionize supply chain management [4].

Concerning the rapid growth of SSCM, applying big data analytics has become a transformative strategy in the SSCM area to drive sustainability. Big data refers to the large and diverse volumes collected from structured, semi-structured, or unstructured sources. According to [1], big data is characterized by its high volume, velocity, and variety, which are complex and hard to process and analyze. Organizations must adapt to the rapid environmental changes where technologies are evolving continuously since traditional data management tools might be unable to cope with a large amount of data. At the same time, big data analytics involving innovative technologies and tools is advantageous to organizations since meaningful insights, trends, and patterns can be discovered from these data [5].

Through big data analytics, organizations can uncover previously underutilized, valuable information hidden within supply chain data. In effect, they can make data-driven decisions easily while optimizing the operational performance for sustainability. Big data analytics also provide a wealth of supply chains by applying various related tools and methodologies in data processing, analysis, and visualization. For instance, hidden insights related to the volume of inventory, energy consumption level, supplier performance, customer buying behavior, and societal impact can be well uncovered [6].

Applying big data analytics in SSCM practices enables organizations to address critical sustainability challenges [4] [7]. These critical challenges include greenhouse gas emissions reduction, energy consumption minimization, fair labor practices consistency, supply chain transparency, product lifecycle management, and sourcing and procurement responsibility. Data-driven insights unlocked from big data analytics help organizations identify areas for improvement, optimize business processes, and drive innovation toward a more sustainable supply chain [8].

Besides using various technologies and tools, big data analytics improves the supply chain's visibility, collaboration, and traceability. For instance, predictive analytics and real-time monitoring help organizations discover potential bottlenecks, environmental risks, and logistic disruption faster and more effectively [9]. In effect, organizations can respond to sustainability issues in a shorter period and quickly implement corrective measures to ensure consistency of improvement in the supply chain.

4. Conclusions

In conclusion, this study has comprehensively reviewed valuable findings in applying big data analytics in sustainable supply chain management. The results show that big data analytics has a high potential to enhance business performance and drive data-driven decisions across different industries like logistic outsourcing, agriculture, food, and manufacturing supply chain management.

The utilization of big data analytics in Industry 4.0 enables organizations to achieve long-term sustainability and higher efficiency by leveraging real-time data and the latest technologies. Big data analytics is crucial in informing strategic decision-making, supplier selection, operational optimization, and demand forecasting by discovering hidden patterns, trends, and relationships in the data. It also supports organizations in achieving sustainability by considering economic, environmental, and social perspectives in developing supply chain management strategies.

However, some challenges still exist in applying big data analytics in SSCM. Data privacy and security concerns are among the critical issues frequently arising when using big data analytics and artificial intelligence technologies. Technical and operational challenges must be addressed from the data integration and processing stages. Organizations should focus on developing appropriate data security measures and governance frameworks to tackle these challenges.

This systematic literature review highlights big data analytics' potential to drive sustainable supply chain management practices. Organizations can make informed decisions, optimize business processes, and achieve long-term sustainability using big data and advanced technologies. Future research should address challenges like data security and privacy issues and identify the impact of other technologies like artificial intelligence, specifically in sustainable supply chain management.

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