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Harnessing big data for Sustainable Supply Chain Management (SSCM): Strategies to reduce carbon footprint

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Abstract

In today's global economy, managing supply chains sustainably is crucial for businesses wanting to reduce their environmental impact while still making a profit. This article reviews how big data analytics can help achieve these sustainability goals. By using big data, companies can improve their supply chain practices, reduce carbon emissions, and implement more sustainable business strategies. Big data provides detailed insights and better levels of control over various supply chain activities, making it a vital tool for driving sustainability. Big data isn't just about internal operations; it also uncovers supplier practices, letting businesses assess their supply chains' environmental impact. Predictive maintenance, driven by big data, plays a powerful role here. It keeps operations running smooth by monitoring equipment health and foreseeing issues before they cause downtime. This proactive approach not only ensures machinery runs efficiently but also lowers energy consumption and emissions associated with breakdowns. Big data also plays a crucial role in optimizing transportation, where it analyzes traffic flow, weather data, and fuel efficiency to design smarter delivery routes. This approach cuts down on fuel consumption and emissions, making logistics more eco-friendly. Energy efficiency is also a priority; big data tracks energy usage across facilities, uncovering areas where consumption can be reduced. This not only lowers energy bills but also decreases greenhouse gas emissions. Big data goes beyond just making things greener; it also helps businesses save money! Here's how: by using big data to predict exactly how much of a product people will buy, companies can avoid making more than they need. This means less waste and less sitting around in warehouses, which is good for the environment and good for the company's bottom line. In short, big data is a win-win for both the planet and your wallet. Case studies from top industry players like Walmart, Nestlé and Maersk illustrate how big data improves sustainable supply chain management (SSCM) with tangible benefits. Yet, integrating big data has its own challenge: ensuring data accuracy, addressing privacy issues, and recruiting skilled personnel are key hurdles. Looking ahead, trends in SSCM—such as AI, machine learning, blockchain, and IoT advancements—hold promise for enhanced insights and predictive capabilities, shaping the future of sustainable supply chains.

Keywords: Big data analytics; Energy efficiency; Sustainable supply chain management; Carbon emissions reduction; Transportation Optimization; Predictive maintenance

1. Introduction

The global push for environmental sustainability requires a careful look at how supply chains impact the environment.[1] Traditional supply chain models prioritize efficiency and cost savings, often neglecting environmental

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concerns. This approach results in significant greenhouse gas emissions from sectors like logistics and transportation, which are crucial parts of global supply chains. Emphasizing efficiency can lead to practices that prioritize quick delivery and cost cutting without considering environmental impacts. [2] As consumers and regulators increasingly focus on environmental issues, businesses face increasing pressure to adopt sustainable practices across their supply chains. This involves rethinking how goods are sourced, transported, and manufactured to reduce carbon footprints and promote efficient resource use. [3] Integrating sustainability into supply chain management not only supports global environmental goals but also enhances brand reputation and resilience in a market that values eco-friendly practices. Big data analytics transforms supply chain management by serving as a sophisticated tool to organize and analyze extensive operational data. [4] It helps businesses optimize various aspects of their supply chain, from sourcing materials to delivering products. By interpreting this data, companies gain insights that enhance efficiency across critical areas. For instance, big data predicts demand patterns to optimize inventory levels, preventing both excess stock and shortages. It also identifies inefficiencies in manufacturing processes, improves production workflows, and predicts maintenance needs to minimize downtime. In logistics, big data analyzes factors such as traffic and weather to streamline operations, reduce fuel consumption, and lower emissions. [5] It also enhances customer service by understanding consumer preferences through data analysis, thus improving satisfaction and loyalty. Moreover, big data forecasts demand based on historical data and market trends, enabling businesses to align production strategies and minimize waste. Ultimately, big data empowers businesses to make informed decisions, boost operational efficiency, and gain a competitive edge in the global market.

2. The Role of Big Data in Sustainable Supply Chain Management

2.1. Boosting Energy Efficiency

Picture having a powerful tool in your supply chain arsenal that not only slashes energy bills but also reduces your environmental impact. That’s exactly what big data offers! Big data goes beyond just collecting vast amounts of information; it's like a high-powered microscope that analyzes data to uncover hidden inefficiencies in energy usage. It works this way: Big data analyzes real-time patterns of energy consumption across your entire supply chain.[6] Pointing out areas where energy is being used inefficiently, such as outdated equipment in factories or inefficient heating systems in warehouses. Once these energy consumers are identified, companies can take targeted actions. This could mean upgrading energy-efficient equipment, installing smart lighting systems that adjust based on occupancy, or optimizing heating and cooling based on current weather conditions. But the innovation doesn't stop there. When big data combines with the Internet of Things (IoT), the possibilities expand. [7] Imagine smart sensors and meters throughout warehouses, constantly monitoring energy use in real-time. [8] This data empowers managers to make immediate adjustments, like powering down unused equipment or optimizing heating and cooling systems for peak efficiency. By harnessing big data and IoT, companies not only reduce energy consumption but also create a more sustainable and cost-effective supply chain. [9] It’s a win-win for both business profitability and environmental responsibility.

2.2. Optimizing Logistics

Transportation plays a significant role in supply chain carbon emissions. But there’s a way to curb this, Companies leverage various data sources such as GPS locations, traffic conditions, and even weather forecasts to optimize their truck routes effectively. [10] It's similar to using an advanced GPS system that considers every detail. By employing sophisticated algorithms, businesses can identify the most efficient routes for their deliveries. This approach isn't just about speeding up deliveries (although that's a benefit); it also means reducing fuel consumption, resulting in lower emissions and a healthier environment overall. Assessing GPS data enables companies to track vehicle movements in real-time, making on-the-fly route adjustments to avoid traffic jams and improve efficiency. Integrating weather data helps in planning routes that steer clear of adverse weather conditions, boosting reliability and cutting down on fuel use. By examining traffic patterns, companies can schedule deliveries during quieter times or opt for less congested routes, smoothing out operations and reducing emissions per trip. These data-driven strategies not only enhance operational efficiency but also contribute to a greener and more sustainable approach to logistics and transportation management**.** [11] In the end, by using data to find the best transportation routes, businesses can save a lot of money and help the environment. This not only makes operations run better but also supports efforts to reduce carbon footprints in supply chain activities as part of corporate responsibility efforts. For instance, Amazon's logistics operations utilize AI-powered algorithms to optimize delivery routes for their fleet of vehicles.[12] These programs look at things like traffic, how customers want their packages delivered, and what the roads are like right now. By doing this, Amazon saves a lot of fuel and makes sure deliveries happen quickly and on time. It's all part of their plan to be more environmentally friendly and efficient.

2.3. Sustainable Consumption

Analyzing production and inventory data using big data analytics goes beyond simply predicting customer demand. It involves leveraging advanced algorithms and machine learning models to detect patterns and trends in historical data.[13] By integrating data from various sources such as sales records, market forecasts, and even external factors like weather patterns or geopolitical events, businesses can refine their production schedules and inventory management strategies with greater precision. This not only reduces the risk of overproduction and waste but also optimizes resource utilization and operational efficiency. Additionally, big data analytics enables companies to adopt a proactive approach to inventory management. They can anticipate shifts in consumer demand and adjust production levels, accordingly, ensuring that goods are available when needed without excess inventory buildup. [14] This agility not only enhances customer satisfaction but also supports sustainability goals by minimizing the environmental footprint associated with manufacturing and logistics. In essence, harnessing big data for production and inventory management empowers businesses to make data-driven decisions that optimize efficiency, reduce costs, and promote environmental stewardship across their supply chains. [15]

2.4. Predictive Maintenance

Predictive maintenance transforms how businesses handle equipment by using advanced analytics instead of waiting for breakdowns. [16] Imagine small sensors on machines monitoring temperature, vibration, and sound in real-time. This data, combined with past performance records, reveals the equipment's health. Algorithms then predict potential issues before they disrupt operations. This proactive approach prevents costly downtime and repairs that halt productivity and increase expenses. It also extends equipment life, similar to catching a cold early to prevent a more serious illness. Well-maintained equipment operates smoothly and efficiently, boosting productivity and profitability. Predictive maintenance isn't just about technology; it's about staying ahead, ensuring equipment runs at its best, and achieving operational success. [17] Predictive maintenance offers a dual advantage. Firstly, it ensures your production line operates seamlessly, eliminating costly and unplanned shutdowns. Secondly, it benefits the environment. When machines unexpectedly fail, factories may rush repairs, consuming more energy or replacing parts unnecessarily. Predictive maintenance prevents this rush, reducing energy use and environmental impact by addressing issues before they escalate. It's a proactive approach that not only optimizes operations but also promotes sustainability by minimizing resource wastage and energy consumption during equipment breakdowns. **[**18]

3. Case studies

The article features case studies from industry leaders like Maersk, Walmart and Nestlé, showcasing the practical applications and benefits of big data in SSCM.

Maersk, a global shipping leader, uses big data to boost efficiency and cut fuel use across its fleet. By analyzing data from ship sensors, weather reports, and ocean currents, Maersk can choose the best routes and speeds. [19] This helps them avoid bad weather and save fuel. They also use this data to practice slow steaming, where ships travel at slower speeds to use less fuel. Predictive analytics allows them to forecast maintenance needs, preventing expensive breakdowns and keeping ships running smoothly. Generally, big data helps Maersk reduce its carbon footprint by lowering emissions per container shipped. **[20]** This aligns with global sustainability goals and sets a strong example for eco-friendly practices in the shipping industry.

Walmart uses big data to make its delivery routes more efficient, which helps reduce fuel consumption and lower its carbon footprint.[21] By analyzing information from GPS, traffic patterns, and delivery schedules, Walmart can figure out the best routes for its trucks. This means trucks travel fewer miles and use less fuel. With advanced algorithms Walmart can predict the best times for deliveries, avoiding traffic jams and ensuring trucks take the fastest routes. [22] This not only saves money on fuel but also cuts down on emissions, supporting Walmart's sustainability goals. Additionally, Walmart uses big data to manage inventory and distribution centers more effectively. By accurately predicting demand, the company can reduce the number of trips needed to restock stores, which further reduces fuel use and emissions.

Nestlé uses big data to carefully track how much water is used across its entire supply chain, especially in its manufacturing processes. [23] By analyzing this data, Nestlé can find ways to use water more efficiently and implement strategies to save water. Nestlé also uses advanced technology to predict when water might be wasted and takes action to prevent it. This proactive approach not only helps them save money but also supports their goal of being more environmentally friendly by reducing their impact on the planet.[24] They collaborate with their suppliers and partners to promote better water management practices throughout their supply chain. By sharing what they've learned and

working together, Nestlé helps everyone involved use water more responsibly. Overall, it shows their commitment to sustainability by using technology to make smarter and more improved choices.

4. Challenges and Best Practices

Integrating big data into supply chain management requires analyzing and addressing certain challenges. Overcoming challenges such as data privacy concerns, substantial technology and infrastructure investments, and the demand for skilled personnel to analyze and interpret data is crucial. Implementing best practices is key to surmounting these obstacles.

Fostering collaboration across the supply chain is essential for big data integration. It involves working closely with suppliers, logistics partners, and other stakeholders to share data transparently. [25] This collaboration ensures that all parties have access to valuable insights, improving decision-making and operational efficiency. By pooling together information from different sources, businesses can optimize processes, manage risks, and innovate more effectively.[26] This cooperative approach strengthens relationships within the supply chain, making it more resilient and adaptable to changing market conditions.

Data Accuracy forms an integral part of successful big data analytics. To ensure the insights gained are trustworthy, it's important to have strong systems in place for collecting and managing data.**[27]** This means establishing clear processes for gathering information from various sources and making sure it's accurate, complete, and up to date. Keeping data quality high throughout its lifecycle is key. This involves storing and organizing data properly, as well as setting up governance rules to avoid errors or inconsistencies that could affect analysis. By focusing on robust data management practices, businesses can confidently use their data to make informed decisions.[28] This approach not only boosts operational efficiency but also helps with long-term planning and innovation. In the end, having reliable data allows businesses to spot trends, predict outcomes, and stay competitive in their industries.

Continuous Improvement: Big data analytics is an ongoing process where businesses continually update their analytical models and integrate new data. **[29]** This approach helps them stay adaptable to changing market conditions and improve their sustainability efforts over time. By regularly refining their models and incorporating fresh data, companies can spot emerging trends, optimize operations, and make decisions that align with environmental goals. **[30]** This proactive strategy allows businesses to enhance efficiency, like modifying production schedules based on current demand or optimizing logistics routes to reduce environmental impact. Overall, adopting big data as a continuous practice enables businesses to not only cut costs and improve competitiveness but also to lead in sustainability initiatives by making informed and timely changes to their operations. [31].

5. Evolving Trends

In the future, sustainable supply chain management is set to undergo a profound transformation driven by advancements in artificial intelligence (AI) and machine learning (ML). [32] These technologies will act as advanced analysts, swiftly processing immense volumes of data to offer businesses unique insights into supply chain efficiency and environmental impacts. Demand forecasting will see a major upgrading. AI and ML algorithms will predict consumer needs with exceptional accuracy, enabling businesses to produce goods precisely when and where they are needed.[33] This will eliminate excess inventory and waste, streamlining inventory management across the board. Logistics will also evolve significantly toward sustainability. AI, combined with real-time data, will optimize delivery routes dynamically. [34] Trucks will take the most fuel-efficient paths, avoiding congestion and adverse weather conditions. This efficiency not only speeds up deliveries but also reduces fuel consumption and emissions, benefitting both businesses and the environment. Future supply chains will prioritize transparency and traceability. Blockchain technology will ensure every product's voyage is tracked securely, verifying ethical sourcing and sustainable practices at every stage. [35] By incorporating these cutting-edge technologies, businesses can harness the full potential of big data to build greener, more efficient supply chains. [36] This approach promises to deliver environmental benefits alongside expanded profitability, shaping a future of sustainability and responsibility in international business practices.

6. Conclusion

In summary, using big data for sustainable supply chain management is an effective strategy for reducing carbon footprints and enhancing environmental responsibility. By making data-driven decisions, businesses can realize substantial environmental benefits. One major area where big data proves beneficial is in optimizing transportation

routes. Companies can leverage real-time information on traffic, weather, and fuel consumption to plot the most efficient delivery routes, resulting in less travel time, lowered fuel usage, and lesser emissions. Another significant advantage is improving energy efficiency. Big data can identify areas where energy is being wasted in factories and warehouses. Addressing these inefficiencies helps companies cut down on energy consumption and greenhouse gas emissions. Minimizing waste is also essential. With accurate demand forecasting powered by big data, companies can ensure they produce only what is necessary, reducing overproduction and excess inventory. This saves up resources and the energy used in manufacturing and storage. Predictive maintenance is another transformative aspect. By anticipating equipment collapses before they occur, businesses can maintain smooth operations and avoid sudden downtimes. This proactive strategy saves money and reduces energy use and emissions tied to emergency repairs and replacements. As technology advances, it's crucial for businesses to keep up with the latest developments in big data analytics. Adjusting to new tools and techniques will help companies achieve their sustainability goals and maintain a competitive edge. Adopting big data in sustainable supply chain management not only fosters environmental responsibility but also ensures long-term business feat in a more eco-conscious market.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Vachon S, Klassen RD. Extending green practices across the supply chain: the impact of upstream and downstream integration. International journal of operations & Production Management. 2006 Jul 1;26(7):795-821.

[2] Govindan K, Azevedo SG, Carvalho H, Cruz-Machado V. Impact of supply chain management practices on sustainability. Journal of Cleaner production. 2014 Dec 15; 85:212-25.

[3] Schanes K, Giljum S, Hertwich E. Low carbon lifestyles: A framework to structure consumption strategies and options to reduce carbon footprints. Journal of Cleaner Production. 2016 Dec 15; 139:1033-43.

[4] Wang G, Gunasekaran A, Ngai EW, Papadopoulos T. Big data analytics in logistics and supply chain management: Certain investigations for research and applications. International journal of production economics. 2016 Jun 1; 176:98-110.

[5] Lu X, Ota K, Dong M, Yu C, Jin H. Predicting transportation carbon emission with urban big data. IEEE Transactions on Sustainable Computing. 2017 Jul 19;2(4):333-44.

[6] Zhong RY, Newman ST, Huang GQ, Lan S. Big Data for supply chain management in the service and manufacturing sectors: Challenges, opportunities, and future perspectives. Computers & Industrial Engineering. 2016 Nov 1; 101:572-91.

[7] Botta A, De Donato W, Persico V, Pescapé A. Integration of cloud computing and internet of things: a survey. Future generation computer systems. 2016 Mar 1; 56:684-700.

[8] Palensky P, Dietrich D. Demand side management: Demand response, intelligent energy systems, and smart loads. IEEE transactions on industrial informatics. 2011 Jun 27;7(3):381-8.

[9] Corbett CJ. How sustainable is big data?. Production and Operations Management. 2018 Sep;27(9):1685-95.

[10] Neilson A, Daniel B, Tjandra S. Systematic review of the literature on big data in the transportation domain: Concepts and applications. Big Data Research. 2019 Sep 1; 17:35-44.

[11] Gutierrez-Franco E, Mejia-Argueta C, Rabelo L. Data-driven methodology to support long-lasting logistics and decision making for urban last-mile operations. Sustainability. 2021 Jun 1;13(11):6230.

[12] Solanki A, Jadiga S. INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING.

[13] Bharadiya JP. Machine learning and AI in business intelligence: Trends and opportunities. International Journal of Computer (IJC). 2023;48(1):123-34.

[14] Kache F, Seuring S. Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. International journal of operations & production management. 2017 Jan 3;37(1):10-36.

[15] Shahid NU, Sheikh NJ. Impact of big data on innovation, competitive advantage, productivity, and decision making: literature review. Open Journal of Business and Management. 2021 Mar 18;9(02):586.

[16] Wireman T. Developing performance indicators for managing maintenance. Industrial Press Inc.; 2005.

[17] Blanchard D. Supply chain management best practices. John Wiley & Sons; 2021 May 6.

[18] Amjad MS, Rafique MZ, Khan MA. Leveraging optimized and cleaner production through industry 4.0. Sustainable Production and Consumption. 2021 Apr 1; 26:859-71.

[19] Brouer BD, Karsten CV, Pisinger D. Big data optimization in maritime logistics. Big data optimization: Recent developments and challenges. 2016:319-44.

[20] Cariou P, Parola F, Notteboom T. Towards low carbon global supply chains: A multi-trade analysis of CO2 emission reductions in container shipping. International Journal of Production Economics. 2019 Feb 1; 208:17-28.

[21] Marr B. Big data in practice: how 45 successful companies used big data analytics to deliver extraordinary results. John Wiley & Sons; 2016 May 2.

[22] LeCavalier J. The rule of logistics: Walmart and the architecture of fulfillment. U of Minnesota Press; 2016 Aug 26.

[23] Van Rijmenam M. Think bigger: Developing a successful big data strategy for your business. Amacom; 2014 Apr 3.

[24] Biswas AK. Water management: some personal reflections. Water International. 2009 Dec 7;34(4):402-8.

[25] Mageto J. Big data analytics in sustainable supply chain management: A focus on manufacturing supply chains. Sustainability. 2021 Jun 24;13(13):7101.

[26] Manyika J, Chui M, Brown B, Bughin J, Dobbs R, Roxburgh C, Hung Byers A. Big data: The next frontier for innovation, competition, and productivity.

[27] Grover V, Chiang RH, Liang TP, Zhang D. Creating strategic business value from big data analytics: A research framework. Journal of management information systems. 2018 Apr 3;35(2):388-423.

[28] Fisher T. The data asset: how smart companies govern their data for business success. John Wiley & Sons; 2009 Jun 22.

[29] Walker R. From big data to big profits: Success with data and analytics. Oxford University Press; 2015 Jul 1.

[30] Carillo KD. Let's stop trying to be "sexy"–preparing managers for the (big) data-driven business era. Business Process Management Journal. 2017 Jun 5;23(3):598-622.

[31] Sanders NR. Big data driven supply chain management: A framework for implementing analytics and turning information into intelligence. Pearson Education; 2014 May 7.

[32] Cioffi R, Travaglioni M, Piscitelli G, Petrillo A, De Felice F. Artificial intelligence and machine learning applications in smart production: Progress, trends, and directions. Sustainability. 2020 Jan 8;12(2):492.

[33] Javaid M, Haleem A, Singh RP, Suman R. Artificial intelligence applications for industry 4.0: A literature-based study. Journal of Industrial Integration and Management. 2022 Mar 21;7(01):83-111.

[34] Abduljabbar R, Dia H, Liyanage S, Bagloee SA. Applications of artificial intelligence in transport: An overview. Sustainability. 2019 Jan 2;11(1):189.

[35] Cole R, Stevenson M, Aitken J. Blockchain technology: implications for operations and supply chain management. Supply chain management: An international journal. 2019 Jun 11;24(4):469-83.

[36] Rane N. Integrating leading-edge artificial intelligence (AI), internet of things (IOT), and big data technologies for smart and sustainable architecture, engineering and construction (AEC) industry: Challenges and future directions. Engineering and Construction (AEC) Industry: Challenges and Future Directions (September 24, 2023). 2023 Sep 24.