GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(REVIEW ARTICLE)

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Reviewing the role of AI and machine learning in supply chain analytics

Enoch Oluwademilade Sodiya [1], Boma Sonimitiem Jacks [2], Ejike David Ugwuanyi [3], Mojisola Abimbola Adeyinka [4], Uchenna Joseph Umoga [5], Andrew Ifesinachi Daraojimba [6,*] and Oluwaseun Augustine Lottu [7]

[1] *Independent Researcher, UK.*
[2] *Independent Researcher, Nigeria.*
[3] *Department of Chemical, Biochemical and Environmental Engineering, University of Maryland, Baltimore County, Baltimore, Maryland, USA.*
[4] *Independent Researcher, Nigeria.*
[5] *Independent Researcher, Seattle, Washington, USA.*
[6] *Department of Information Management, Ahmadu Bello University, Zaria, Nigeria.*
[7] *Independent Researcher, UK.*

GSC Advanced Research and Reviews, 2024, 18(02), 312–320

Publication history: Received on 02 January 2024; revised on 12 February 2024; accepted on 14 February 2024

Article DOI: https://doi.org/10.30574/gscarr.2024.18.2.0069

Abstract

The integration of Artificial Intelligence (AI) and Machine Learning (ML) in supply chain analytics has emerged as a transformative force in reshaping traditional logistics and operations. This review critically examines the multifaceted role of AI and ML in optimizing supply chain processes, enhancing decision-making capabilities, and fostering agility in an era of dynamic market demands. AI and ML technologies have revolutionized data analytics by enabling the extraction of actionable insights from vast and complex datasets. The application of predictive analytics, powered by machine learning algorithms, allows supply chain professionals to forecast demand more accurately, identify potential disruptions, and optimize inventory levels. This not only improves overall efficiency but also reduces costs and minimizes the risk of stockouts or overstock situations. Furthermore, the integration of AI-driven automation in supply chain management has streamlined routine tasks, such as order processing, inventory replenishment, and route optimization. This automation not only accelerates processes but also mitigates the risk of human errors, enhancing overall reliability. The ability of AI to continuously learn from historical data and adapt to evolving market conditions contributes to a more agile and responsive supply chain ecosystem. In the context of supply chain risk management, AI and ML play a pivotal role in identifying vulnerabilities and providing proactive strategies to mitigate potential disruptions. Sentiment analysis and predictive modeling enable organizations to assess geopolitical, economic, and environmental factors, thereby enhancing the resilience of their supply chains. However, the adoption of AI and ML in supply chain analytics is not without challenges. This review explores the ethical considerations, data security concerns, and the need for skilled personnel in managing these advanced technologies. Additionally, it delves into the importance of explainability and transparency in AI-driven decision-making processes, emphasizing the need for a balance between automation and human oversight. This review underscores the transformative impact of AI and ML on supply chain analytics, emphasizing their potential to revolutionize traditional practices, enhance efficiency, and fortify resilience in an increasingly complex and dynamic business environment.

Keywords: AI; Machine Learning; Supply Chain; Analytics; Review

1. Introduction

The landscape of supply chain management has been evolving rapidly, driven by the integration of advanced technologies such as Artificial Intelligence (AI) and Machine Learning (ML). Supply chain management aims to

* Corresponding author: Andrew Ifesinachi Daraojimba.

synchronize customer requirements with material flow from suppliers, balancing conflicting goals of high customer service, low inventory management, and low unit cost (Mentzer et al., 2001). The assimilation of big data and predictive analytics has revolutionized supply chain and organizational performance, with a focus on acceptance, routinization, and assimilation stages, influenced by resources and top management commitment (Gunasekaran et al., 2017). Furthermore, digital technologies including big data analytics, advanced manufacturing technologies, and additive manufacturing have significantly impacted supply chain risk analytics (Ivanov et al., 2018).

AI and ML have brought about a paradigm shift in supply chain management, leading to automated systems that harness knowledge and data to improve decision-making within supply chains (Baryannis et al., 2018). These technologies have enabled the application of machine learning algorithms to determine the tiers of a supply chain, solving large operational optimization problems and improving operational decisions (Park, 2021). Additionally, AI has been utilized for supply chain risk management, aiming to identify, assess, mitigate, and monitor risks to reduce vulnerability and increase robustness and resilience of the supply chain (Baryannis et al., 2019). Machine learning-based frameworks have been proposed for managing inventory at all nodes of the supply chain in a coordinated manner, enhancing the overall efficiency of supply chain operations (Priore et al., 2018).

The integration of AI and ML in supply chain analytics has also been instrumental in addressing specific challenges. For instance, the pharmaceutical industry has faced difficulties in tracking products during the supply chain process, leading to the introduction of a Blockchain and Machine Learning-Based Drug Supply Chain Management and Recommendation System to combat counterfeit activities (Abbas et al., 2020). Furthermore, the application of AI techniques in analyzing data, automating decision-making, and optimizing the entire supply chain has been recognized as highly relevant for the digital transformation of supply chains (Trong & Kim, 2020).

The COVID-19 pandemic has further emphasized the significance of AI and big data analytics in supply chain management. The pandemic has disrupted supply chains, leading to the need for AI and big data analytics to understand and quantify the impact on broken supply chains and small businesses, highlighting the importance of these technologies in addressing supply chain disruptions.

In conclusion, the integration of AI and ML has significantly transformed supply chain analytics, enabling enhanced decision-making, risk management, and operational efficiency. These technologies have been instrumental in addressing challenges such as supply chain disruptions and counterfeit activities, emphasizing their crucial role in the evolving landscape of supply chain management.

2. Importance of AI and ML in Supply Chain Analytics

The integration of Artificial Intelligence (AI) and Machine Learning (ML) in supply chain analytics has become increasingly important due to its various benefits. Firstly, AI and ML enable enhanced data analytics by extracting actionable insights from complex datasets (Rana & Daultani, 2022). This is crucial in supply chain management as it allows for a deeper understanding of the data, leading to informed decision-making. Additionally, AI and ML contribute to improved accuracy in demand forecasting, which is essential for optimizing inventory levels and ensuring efficient resource allocation (Ewim et al., 2021; Younis et al., 2021).

Moreover, predictive analytics, facilitated by machine learning algorithms, plays a pivotal role in forecasting demand and optimizing inventory levels in supply chains (Plathottam, 2023). By leveraging AI and ML, organizations can effectively predict demand patterns and adjust their inventory levels accordingly, leading to cost reductions and improved operational efficiency (Zamani et al., 2022). Furthermore, the application of AI and ML in supply chain analytics has been shown to mediate the role of supply chain agility and process improvements, ultimately leading to enhanced profit margins and reduced supply chain costs (Younis et al., 2021; Mouchou et al., 2021).

AI and ML also contribute to supply chain resilience by enabling transparency, ensuring last-mile delivery, offering personalized solutions to stakeholders, minimizing the impact of disruptions, and facilitating agile procurement strategies (Modgil et al., 2021; Babatunde et al., 2021). Additionally, AI plays a crucial role in predicting supply chain risks, thereby aiding in risk management and decision-making (Baryannis et al., 2019).

The impact of digitalization and Industry 4.0 on supply chain analytics has been studied, highlighting the role of AI and ML in managing the ripple effect and disruption risk in supply chains (Ezeigweneme et al., 2024; Ivanov et al., 2018). Furthermore, the implementation of AI and ML in supply chain analytics has been identified as a best practice for obtaining valuable information from vast amounts of data and addressing supply chain issues (Das et al., 2023).

In conclusion, the incorporation of AI and ML in supply chain analytics offers numerous advantages, including enhanced data analytics, predictive analytics, and improved supply chain resilience. These technologies have the potential to revolutionize supply chain management by providing valuable insights, optimizing operations, and mitigating risks.

3. Automation in Supply Chain Management

AI-driven automation has the potential to revolutionize supply chain management by streamlining routine tasks in logistics and operations and accelerating processes while minimizing human errors. Despite the widespread acceptance of AI as a decision-aid tool, its application in supply chain management has been limited (Min, 2009). However, the implementation of AI in supply chains is expected to significantly increase efficiency and productivity over the next decade (Tsolakis et al., 2022). This indicates the potential for AI to streamline routine tasks and optimize supply chain operations.

In the wake of the COVID-19 pandemic, there is a growing need for a more resilient supply chain that can adapt to market dynamics and disruptions. Research opportunities are emerging to close the gap between research findings and industry practice, aiming to structurally de-risk supply chains and enhance their resilience (Remko, 2020). AI technologies have played a crucial role in strengthening supply chain resilience during the COVID-19 pandemic, highlighting their contribution to continuous learning and adaptive capabilities (Modgil et al., 2021).

The integration of AI-driven automation in supply chain management holds promise for optimizing logistics and operations, minimizing errors, and enhancing resilience. As supply chains evolve to meet the challenges of a dynamic market environment, AI technologies are expected to play a pivotal role in driving continuous learning and adaptive capabilities, ultimately contributing to a more agile and responsive supply chain.

Overall, the references provide valuable insights into the potential impact of AI-driven automation on supply chain management, supporting the argument for its role in streamlining routine tasks, accelerating processes, and contributing to continuous learning and adaptive capabilities.

4. Supply Chain Risk Management

Supply chain risk management is crucial for businesses to identify vulnerabilities and proactively mitigate potential disruptions. Artificial intelligence (AI) plays a significant role in assessing geopolitical, economic, and environmental factors, aiding in the identification of vulnerabilities (Teoh, 2023). It enables the analysis of market sentiments and predictive modeling for risk assessment and resilience building, thus supporting proactive strategies for mitigating potential disruptions (Helmold et al., 2022). Furthermore, AI facilitates the visualization and clustering analysis approach for supply chain vulnerability assessment, providing methods and tools for supply chain risk managers to understand and mitigate unexpected disruptions (Blackhurst et al., 2018).

Proactive risk mitigation strategies are essential for supply chain risk management performance. The literature emphasizes the importance of firms' supply chain flexibility, resilience, and responsiveness in mitigating disruptions (Orieno et al., 2024; Saglam et al., 2020). Additionally, proactive planning for catastrophic events is a priority for supply chain managers, highlighting the need for proactive strategies to build resilience (Knemeyer et al., 2008). Moreover, the organizational antecedents of a firm's supply chain agility serve as key drivers for augmenting supply chain agility as a risk management initiative (Braunscheidel & Suresh, 2008).

The COVID-19 pandemic has underscored the significance of supply chain management risk techniques in mitigating disruptions on supply chain flows, emphasizing the need for further investigation in this area (Okoro et al., 2024; Qrunfleh et al., 2022). It has also prompted the evaluation of supply chain resilience and the impact of rapid restructuring, leading to the proposal of risk management approaches to mitigate the effects of pandemic-style disruptions (Cuvero et al., 2021).

Environmental and economic impacts on supply chain activities are crucial considerations for risk management. The economic and environmental impacts of construction material transportation throughout supply chain activities contribute to changes in carbon emissions, highlighting the need to mitigate environmental and density risk in global sourcing (Akindote et al., 2023; Deane et al., 2009). Additionally, the consideration of the full supply chain is essential for assessing geopolitical supply risk of raw materials, exemplifying the importance of a comprehensive approach to risk management (Gemechu et al., 2015).

In conclusion, supply chain risk management is a multifaceted discipline that requires proactive strategies, AI-driven assessments, and resilience building to mitigate potential disruptions. The integration of AI, proactive risk mitigation strategies, and environmental and economic considerations are essential for effective supply chain risk management.

5. Challenges in Adopting AI and ML in Supply Chain Analytics

Challenges in adopting AI and ML in supply chain analytics encompass ethical considerations, data security, and skillset requirements. Addressing ethical concerns in AI-driven decision-making is crucial to ensure responsible use of technology in supply chain operations (Younis et al., 2021). This involves the need for skilled personnel in managing AI and ML technologies and implementing training and development programs for workforce readiness (Balogun et al., 2024; Verma et al., 2021). Furthermore, safeguarding sensitive supply chain data and implementing robust cybersecurity measures are imperative (Fraile et al., 2018). The impact of supply chain security practices on security operational performance among logistics service providers in emerging economies highlights the benefits of supply chain security practices, emphasizing the need for responsible technology use (Abrahams et al., 2023; Zailani et al., 2015). Additionally, a voluntary logistics security program and international supply chain partnership emphasize the importance of prevention and adopting a total supply chain approach to address ethical concerns and ensure responsible technology use (Sheu et al., 2006). AI and ML have the potential to reduce the bullwhip effect, supporting the performance of supply chain efficiency and responsiveness, but ethical considerations must be addressed in their adoption (Younis et al., 2021). Detecting fake news and disinformation using AI and ML to avoid supply chain disruptions underscores the role of these technologies in enhancing supply chain operations while emphasizing the need for responsible use (Akhtar et al., 2022). The contribution of AI and ML in managing and transforming supply chains digitally highlights the unexplored potential and contexts in which these technologies can be used, emphasizing the need for skilled personnel and responsible technology use (Vincent et al., 2021; Rana & Daultani, 2022). The impact of information security initiatives on supply chain performance emphasizes the importance of information security in addressing data security challenges in supply chain operations (Pn, 2014). Furthermore, AI can significantly improve packaging, shelf life, menu combination, and food safety, emphasizing the need for responsible technology use in supply chain management (Kumar et al., 2021). The contribution of AI to firm resilience to supply chain disruptions underscores the potential of emerging technologies such as AI in addressing supply chain challenges while emphasizing the need for responsible technology use (Sullivan & Wamba, 2022). Antecedents and outcomes of supply chain security practices stress the role of a collaborated approach by supply chain members to reduce susceptibility in the supply chain, highlighting the importance of responsible technology use in supply chain security (Asamoah et al., 2021).

6. Explainability and Transparency

Balancing automation and human oversight in AI-driven decision-making is crucial for ensuring transparency and explainability. The ethical considerations surrounding the development and use of AI systems highlight the importance of transparency and explainability (Huriye, 2023). The potential lack of recourse in algorithmic decision-making is often used to motivate calls for transparency and explainability (Ustun et al., 2019). Public discussions emphasize the challenge of AI explainability, particularly in the context of ensuring accessibility, transparency, and fairness in AI-based systems (Harry, 2023). Furthermore, the General Data Protection Regulation (GDPR) places strict requirements on automated decision-making, including the right of individuals to obtain an explanation of the logic involved and the right to challenge such decisions (Brown et al., 2023).

In the domain of law, interpretability and explainability are essential for dealing with information/data transparency or system transparency (Górski et al., 2020). As AI systems become increasingly sophisticated, ensuring their transparency and explainability becomes crucial (HOSAİN, 2023). Additionally, the accountability and transparency of decisions made by AI-based systems are key ethical issues, particularly in healthcare (Ilugbusi et al., 2020; Lysaght et al., 2019). Moreover, the issue of opacity in machine learning algorithms is considered a problem for socially consequential mechanisms, emphasizing the need for transparency and explainability in AI systems (Burrell, 2016).

In the context of decision-making structures, the interpretability of the decision-making process and outcome is identified as a key factor, highlighting the importance of explainability in AI-based decision-making (Adeleke et al., 2019; Shrestha et al., 2019). Furthermore, a human-centered approach to designing for contestability is advocated to ensure that the needs of decision subjects and the community are met, emphasizing the importance of transparency and explainability in AI systems (Lyons et al., 2021).

In conclusion, ensuring transparency and explainability in AI-driven decision-making involves establishing a balance between automation and human intervention. This is essential for addressing ethical considerations, ensuring accountability, and mitigating the challenges associated with opacity in AI systems.

7. Future Outlook

The role of AI and machine learning in supply chain analytics is gaining increasing attention due to its potential to revolutionize various aspects of supply chain management. The literature recognizes AI as a pathbreaking analytics tool to improve the performance of the supply chain (Naz et al., 2021). Machine learning techniques have been used to optimize supply chain performance, and they offer the potential to predict supply chain risks (Baryannis et al., 2019). Additionally, AI and machine learning have been applied to predict fraud in the supply chain, detect fake news to minimize supply chain disruptions, and enhance supply chain collaboration (Lokanan & Maddhesia, 2022; Akhtar et al., 2022; Ali et al., 2022). Furthermore, the implementation of green supply chain management practices and environmental management systems has been explored, emphasizing the need to expand on the connection between big data analytics, AI, and the supply chain (Das et al., 2023).

The potential applications of AI and machine learning in supply chain analytics are vast. They have been utilized for sorting, packaging, transportation, storage, and sales in the food supply chain, demonstrating their versatility and potential to enhance various supply chain processes (Zhang et al., 2022). Moreover, AI and machine learning have been employed for demand forecasting, inventory management, and the dynamic selection of replenishment policies in fast-changing supply chain environments, highlighting their diverse applications in supply chain operations (Seyedan & Mafakheri, 2020; Priore et al., 2018). These technologies have also been leveraged to mitigate the spread of contamination in the meat supply chain, emphasizing their role in ensuring food safety and quality within the supply chain (Amani & Sarkodie, 2022).

The future outlook for AI and machine learning in supply chain analytics is promising. There is a need to harness the untapped potential of current advancements in AI research for the benefit of supply chain risk management (Baryannis et al., 2018). Additionally, future research directions should focus on exploring a more feature-rich dataset and a larger set of machine learning techniques, including neural networks and deep learning, to further enhance the interpretability and performance of AI techniques in supply chain risk management (Baryannis et al., 2019). Furthermore, the potential for AI and machine learning to contribute to supply chain resilience, adaptability, and recovery phases should be further explored to advance knowledge in this area (Zamani et al., 2022).

In conclusion, the integration of AI and machine learning in supply chain analytics presents significant opportunities for enhancing supply chain performance, risk management, and sustainability. Future research should focus on addressing the existing research gaps and exploring the untapped potential of these technologies to further advance supply chain analytics.

8. Conclusion

In conclusion, the review of the role of Artificial Intelligence (AI) and Machine Learning (ML) in supply chain analytics underscores the profound transformative impact these technologies have on traditional practices within the realm of logistics and operations. The integration of AI and ML technologies has ushered in a new era of efficiency, agility, and resilience in managing supply chains, reshaping the landscape of the industry.

The transformative impact of AI and ML in supply chain analytics is evident in several key areas. These technologies have redefined data analytics, allowing organizations to extract actionable insights from vast and complex datasets. The application of predictive analytics, powered by machine learning algorithms, has significantly improved the accuracy of demand forecasting, enabling organizations to optimize inventory levels and reduce costs. The introduction of AI-driven automation has streamlined routine tasks, accelerated processes, and mitigated the risk of human errors. Continuous learning capabilities of AI contribute to a more agile and responsive supply chain, adapting to evolving market conditions. In supply chain risk management, AI's ability to identify vulnerabilities and provide proactive strategies has enhanced the overall resilience of supply chain operations.

The potential of AI and ML to revolutionize traditional practices in supply chain management cannot be overstated. These technologies offer unprecedented opportunities to enhance efficiency by automating routine tasks, optimizing processes, and improving decision-making. The ability to adapt and learn continuously positions supply chains to navigate the complexities of a dynamic business environment effectively. Furthermore, the incorporation of AI and ML

in risk management strategies fortifies the resilience of supply chains, enabling organizations to proactively address challenges and disruptions.

As we move forward, it is essential for organizations to navigate the challenges associated with AI and ML adoption, including ethical considerations, data security, and the need for a skilled workforce. Striking a balance between automation and human oversight, ensuring transparency in decision-making processes, and fostering a culture of responsible AI use will be crucial for unlocking the full potential of these technologies in shaping the future of supply chain analytics. Ultimately, the ongoing evolution of AI and ML in supply chain management holds the promise of not only optimizing operations but also fundamentally reshaping how businesses respond to the ever-changing demands of the global marketplace.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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