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Leveraging AI for real-time sustainable supply chain visibility: Benefits and implementation barriers

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Abstract

This study explores the role of Artificial Intelligence (AI) in enhancing real-time sustainable supply chain visibility, addressing its benefits and implementation challenges. With supply chains becoming increasingly complex and globalized, the need for transparency, efficiency, and sustainability has never been greater. AI-powered systems offer transformative potential by enabling real-time tracking, predictive analytics, and data-driven decision-making, which improve operational efficiency and support sustainability goals. However, the adoption of AI in supply chains faces significant barriers, including high costs, data integration challenges, resistance to change, and ethical concerns. The research employs a comprehensive literature review to analyze existing studies on AI applications in supply chain management, focusing on demand forecasting, logistics optimization, waste reduction, and sustainability. The study identifies key benefits of AI, such as improved decision-making, enhanced transparency, cost reduction, and environmental impact mitigation. It also highlights critical implementation challenges, such as financial constraints, data quality issues, workforce upskilling needs, and cybersecurity risks. Key findings reveal that AI can significantly enhance supply chain visibility and sustainability but requires strategic planning, investment in infrastructure, and collaboration among stakeholders. The study concludes that while AI holds immense potential for transforming supply chains, addressing implementation barriers and ethical considerations is crucial for its successful adoption. Future research should focus on empirical studies, long-term sustainability impacts, and the integration of AI with emerging technologies like blockchain and IoT. This paper contributes to the growing body of knowledge on AI-driven supply chain management, offering practical insights for organizations aiming to leverage AI for sustainable and resilient operations.

Keywords: Sustainable Supply Chain; Real-Time Visibility; Artificial Intelligence (AI); Forecasting

1. Introduction

Supply chain visibility refers to the ability of organizations to track and monitor the movement of goods, materials, and information across the entire supply chain in real time (Jean, 2024). It is a critical component of modern supply chain management, enabling businesses to make informed decisions, optimize operations, and respond swiftly to disruptions. In an increasingly globalized and interconnected economy, supply chains have become more complex, involving multiple stakeholders, geographies, and processes. This complexity has heightened the need for transparency and real-

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time insights to ensure efficiency, reduce risks, and meet customer expectations. Without adequate visibility, organizations face challenges such as inventory inaccuracies, delayed shipments, and inefficiencies, which can lead to increased costs and reduced competitiveness (Destro et al., 2023).

The importance of supply chain visibility has been further underscored by recent global disruptions, such as the COVID-19 pandemic, geopolitical tensions, and climate change-related events (Bednarski et al., 2023). These disruptions have exposed vulnerabilities in supply chains, highlighting the need for resilience and agility. Real-time visibility allows organizations to anticipate and mitigate risks, adapt to changing conditions, and maintain continuity in operations (Ailyn, 2024). Moreover, it supports compliance with regulatory requirements and enhances customer satisfaction by providing accurate and timely information about product availability and delivery timelines.

1.1. The Role of AI in Enhancing Real-Time Supply Chain Management

Artificial Intelligence (AI) has emerged as a transformative technology in supply chain management, offering advanced capabilities to enhance real-time visibility (Joel et al., 2024). AI-powered tools, such as machine learning algorithms, predictive analytics, and natural language processing, enable organizations to process vast amounts of data from diverse sources, including IoT devices, sensors, and enterprise systems (Nweje and Taiwo, 2025; Adua, et al., 2024). These tools can identify patterns, predict outcomes, and provide actionable insights, allowing businesses to optimize inventory levels, streamline logistics, and improve demand forecasting.

One of the key advantages of AI is its ability to automate and augment decision-making processes (Perifanis and Kitsioset, 2023). AI can analyze historical data and real-time inputs to predict potential disruptions, such as supplier delays or transportation bottlenecks, and recommend alternative strategies. Additionally, AI-driven platforms can facilitate collaboration among supply chain partners by providing a unified view of operations and enabling seamless communication (Riad et al., 2024). By leveraging AI, organizations can achieve greater efficiency, reduce costs, and enhance their ability to respond to dynamic market conditions.

1.2. The Significance of Sustainability in Supply Chain Operations

Sustainability has become a central concern in supply chain management, driven by increasing regulatory pressures, consumer demand for ethical practices, and the need to address environmental challenges (Gurzawska, 2020). Sustainable supply chain operations aim to minimize environmental impact, promote social responsibility, and ensure economic viability (Osei et al., 2023). Achieving sustainability requires organizations to adopt practices such as reducing carbon emissions, optimizing resource utilization, and ensuring fair labor practices throughout the supply chain.

Real-time visibility plays a crucial role in advancing sustainability goals. By providing insights into the environmental and social impact of supply chain activities, organizations can identify areas for improvement and implement targeted interventions. Visibility into transportation routes and energy consumption can help reduce carbon footprints, while monitoring supplier practices can ensure compliance with ethical standards (Esan et al., 2024). AI can further enhances these efforts by enabling predictive and prescriptive analytics, which can optimize sustainable practices and support long-term goals.

This paper seeks to explore the potential of AI in enabling real-time sustainable supply chain visibility, while also examining the barriers to its implementation. The primary research objectives are to:

- investigate the benefits of AI-driven visibility for sustainability and operational efficiency
- identify the challenges and limitations associated with adopting AI in supply chain management, and
- propose strategies for overcoming these barriers.

1.2.1. Key research questions include

- How can AI enhance real-time visibility in sustainable supply chains?
- What are the primary implementation challenges, and how can they be addressed?
- What role do stakeholders play in driving the adoption of AI for sustainable supply chain visibility?

2. Literature Review

2.1. AI in Supply Chain Management

Artificial Intelligence (AI) has revolutionized supply chain operations by introducing innovative solutions that enhance efficiency, transparency, and decision-making (Joel et al., 2024). A growing body of literature highlights the transformative role of AI-driven technologies, such as the Internet of Things (IoT), machine learning (ML), predictive analytics, and blockchain, in addressing the complexities of modern supply chains (Bobroff et al., 2021). These technologies enable real-time data collection, analysis, and actionable insights, empowering organizations to optimize processes and respond to disruptions proactively.

IoT plays a pivotal role in supply chain visibility by connecting physical assets, such as vehicles, warehouses, and products, through sensors and devices (Sallam et al., 2023). This connectivity generates real-time data on location, temperature, and condition, which is critical for monitoring and ensuring product quality. Machine learning algorithms analyze this data to identify patterns, predict demand fluctuations, and optimize inventory levels, reducing waste and improving resource allocation (Gatla and Mandati, 2020). Predictive analytics further enhances decision-making by forecasting potential disruptions, such as supplier delays or market shifts, enabling organizations to implement mitigation strategies. Blockchain technology complements AI by providing a secure and transparent platform for recording transactions and tracking goods across the supply chain (Samanta et al., 2024). Its decentralized nature ensures data integrity and builds trust among stakeholders, particularly in industries requiring traceability, such as food and pharmaceuticals. Together, these technologies create a synergistic ecosystem that enhances supply chain resilience and sustainability.

Recent studies emphasize the potential of AI-driven innovations to address sustainability challenges by optimizing energy consumption, reducing carbon emissions, and promoting ethical sourcing (Adua et al., 2024; Varghese, 2022). However, potential barriers to achieving this include high implementation costs, data privacy concerns, and the need for skilled personnel. Despite these challenges, the integration of AI, IoT, ML, predictive analytics, and blockchain is reshaping supply chain management, offering unprecedented opportunities for innovation and efficiency

2.2. Importance of Real-Time Supply Chain Visibility

Real-time supply chain visibility refers to the ability to monitor and track the movement of goods, materials, and information across the supply chain instantaneously (Jean et al., 2024). Its key components include data integration from multiple sources, advanced analytics for processing and interpreting data, and seamless communication among stakeholders. Real-time visibility enables organizations to gain actionable insights, improve decision-making, and enhance operational efficiency (Holloway, 2024). In today's fast-paced and unpredictable business environment, it is a critical factor for maintaining competitiveness, reducing risks, and meeting customer expectations.

AI plays a transformative role in enhancing real-time visibility across various supply chain functions, including logistics, inventory tracking, and demand forecasting (Verma, 2024). In logistics, AI-powered systems leverage IoT sensors and GPS data to monitor the location and condition of shipments in real time. This allows companies to optimize routing, reduce transportation costs, and mitigate delays caused by unforeseen events such as traffic or weather disruptions. Machine learning algorithms further enhance logistics by predicting potential bottlenecks and suggesting alternative routes or modes of transportation (Khedr and Rani, 2024).

In inventory tracking, AI integrates data from IoT devices, RFID tags, and warehouse management systems to provide real-time updates on stock levels and product movements (Ugbebor et al., 2024). This ensures accurate inventory management, reduces overstocking or stockouts, and improves order fulfillment rates. Predictive analytics, a subset of AI, enables organizations to forecast demand with greater accuracy by analyzing historical sales data, market trends, and external factors such as seasonality or economic conditions (Nweje and Taiwo, 2025). This helps businesses align production and inventory levels with anticipated demand, minimizing waste and maximizing profitability.

By enhancing real-time visibility, AI not only improves operational efficiency but also supports sustainability goals by optimizing resource utilization and reducing waste. However, achieving this level of visibility requires robust technological infrastructure, data integration, and collaboration among supply chain partners. The literature underscores the growing importance of AI-driven visibility as a cornerstone of modern, resilient, and sustainable supply chain management.

2.3. Sustainable Supply Chain Management (SSCM)

Sustainable Supply Chain Management (SSCM) is a holistic approach that integrates environmental, social, and economic considerations into supply chain operations to ensure long-term viability and minimize negative impacts on society and the environment (Abbas et al., 2023). SSCM principles focus on reducing carbon footprints, optimizing resource use, promoting ethical labor practices, and fostering circular economy models. Key strategies include green procurement, energy-efficient logistics, waste reduction, and collaboration with suppliers to ensure sustainability across the entire value chain (Muchenje et al., 2023). Transparency and traceability are also central to SSCM, as they enable stakeholders to verify the sustainability credentials of products and processes. By adopting SSCM principles, organizations can enhance their resilience, comply with regulatory requirements, and meet the growing consumer demand for ethically produced and environmentally friendly products.

2.3.1. AI's Contribution to Reducing Environmental Impact and Waste Management

Artificial Intelligence (AI) has become a critical enabler of sustainability in supply chain management by providing data-driven insights and optimizing resource utilization. AI-powered systems leverage data from IoT sensors, satellite imagery, and other sources to monitor and reduce carbon emissions (Zejjari and Benhayoun, 2024). For example, AI can optimize transportation routes to minimize fuel consumption or predict energy usage patterns to improve efficiency in warehouses and manufacturing facilities. Additionally, AI supports the integration of renewable energy sources by forecasting energy demand and optimizing their use.

In waste management, AI enhances recycling and waste reduction efforts by identifying patterns in waste generation and optimizing disposal processes (Olawade et al., 2024). Machine learning algorithms can classify waste materials for efficient recycling, while predictive analytics helps businesses anticipate waste production and implement preventive measures. AI also facilitates circular economy practices by enabling product lifecycle tracking and promoting the reuse of materials. (Oladapo et al., 2024) By integrating AI into SSCM, organizations can achieve significant environmental benefits, reduce costs, and align with global sustainability goals, making it a critical enabler of greener and more responsible supply chains.

2.4. Review of Prior Studies on AI-Powered Supply Chain Systems

The integration of Artificial Intelligence (AI) into supply chain systems has been a focal point of research in recent years, driven by the need for greater efficiency, transparency, and sustainability. Prior studies have explored various applications of AI in supply chain management, including demand forecasting, inventory optimization, logistics, and sustainability. These studies highlight the transformative potential of AI in addressing the complexities and challenges of modern supply chains.

2.4.1. Demand Forecasting and Inventory Optimization

One of the most widely researched areas is the use of AI for demand forecasting and inventory optimization. Traditional forecasting methods often struggle to account for the volatility and complexity of modern markets. AI-powered systems, particularly those leveraging machine learning (ML) algorithms, have demonstrated superior accuracy in predicting demand by analyzing historical data, market trends, and external factors such as seasonality and economic conditions (Amosu et al., 2024). For instance, a study by Zhodi et al. (2024) found that machine learning models significantly outperformed traditional statistical methods in demand forecasting. Similarly, research by Ismaeil and Lalla (2024) highlighted the role of AI in reducing forecasting errors and improving inventory management, leading to reduced stockouts and overstock situations.

2.4.2. Logistics and Transportation

AI has also been extensively studied for its applications in logistics and transportation. Research by Veluru (2023) demonstrated how AI-powered route optimization algorithms could reduce transportation costs and improve delivery times. More recent studies have explored the integration of AI with IoT devices to enable real-time tracking and monitoring of shipments. For example, Miller et al. (2025) discussed how AI and IoT together could enhance visibility and efficiency in logistics operations, enabling companies to respond swiftly to disruptions and optimize routing in real time.

2.4.3. Sustainability and Waste Management

Sustainability is another critical area where AI has shown significant promise. Studies have explored how AI can help reduce the environmental impact of supply chains by optimizing resource use and minimizing waste. For instance, research by Inavolu and Spiridonova (2025) highlighted the role of AI in promoting sustainable practices through better

demand forecasting and inventory management, which in turn reduces waste and overproduction. Additionally, AI has been reported to be efficient in optimizing energy consumption in warehouses and manufacturing facilities, as demonstrated by a study by Keramati et al. (2024). AI's ability to analyze large datasets and identify patterns has also been leveraged to improve recycling and waste management processes, as discussed by Olawade et al. (2024).

2.4.4. Supplier Relationship Management

AI has also been applied to enhance supplier relationship management. Research by Mohammed (2023) explored how AI could improve supplier selection and evaluation processes by analyzing data on supplier performance, reliability, and risk factors. AI-powered systems can also facilitate better collaboration and communication among supply chain partners, as highlighted by a study by Khedr and Rani (2024). These systems enable real-time data sharing and decision-making, fostering stronger and more transparent relationships with suppliers.

2.4.5. Risk Management and Resilience

Another important area of research is the use of AI for risk management and building resilient supply chains. Studies have shown that AI can predict potential disruptions, such as supplier delays or natural disasters, and suggest mitigation strategies. For example, a study by (Riad, et al. 2024) demonstrated how AI could be used to model and simulate supply chain disruptions, enabling companies to develop contingency plans. More recent research by Ismaeil and Lalla (2024) emphasized the role of AI in enhancing supply chain resilience by providing real-time visibility and predictive analytics.

2.4.6. Research Gaps

Despite the significant advancements in AI-powered supply chain systems, several research gaps remain. First, while there is extensive literature on the technical aspects of AI applications, there is a lack of studies focusing on the organizational and human factors that influence the successful implementation of AI in supply chains. For instance, more research is needed on how to overcome resistance to change, train employees, and integrate AI systems with existing processes.

Second, there is a need for more empirical studies that provide quantitative evidence of the benefits and challenges of AI in supply chain management. Many existing studies rely on theoretical models or case studies, which may not be generalizable. Large-scale empirical studies could provide more robust insights into the impact of AI on supply chain performance.

Third, while AI has shown promise in enhancing sustainability, there is limited research on its long-term environmental and social impacts. For example, the energy consumption of AI systems themselves and their potential to exacerbate e-waste are areas that require further investigation. Additionally, more research is needed on how AI can be used to promote social sustainability, such as ensuring fair labor practices and ethical sourcing.

Fourth, the integration of AI with other emerging technologies, such as blockchain and IoT, is an area that warrants further exploration. While some studies have touched on this, there is a need for more comprehensive research on how these technologies can work together to create more transparent, efficient, and sustainable supply chains.

Finally, there is a gap in research on the ethical and regulatory implications of AI in supply chain management. As AI systems become more pervasive, issues related to data privacy, security, and bias need to be addressed. More research is needed to develop frameworks and guidelines for the ethical use of AI in supply chains.

3. Benefits of AI in Real-time Supply Chain Visibility

The integration of Artificial Intelligence (AI) into supply chain management has revolutionized the way organizations achieve real-time visibility (Jean, 2024). AI-powered systems enable organizations to gain actionable insights, optimize operations, and respond swiftly to disruptions. This section explores the key benefits of AI in enhancing real-time supply chain visibility, focusing on improved decision-making and efficiency, enhanced transparency and traceability, cost reduction and resource optimization, and environmental and social benefits.

3.1. Real-Time Insights and Predictive Analytics

One of the most significant benefits of AI in real-time supply chain visibility is its ability to provide real-time insights and predictive analytics (Joel et al., 2024). Traditional supply chain systems often rely on historical data and manual processes, which can lead to delays and inaccuracies. AI, on the other hand, leverages advanced algorithms and machine learning (ML) to process vast amounts of data from multiple sources, such as IoT sensors, GPS, and enterprise systems,

in real time (Miller et al., 2025). This enables organizations to monitor operations continuously and identify potential issues before they escalate.

For example, AI-powered predictive analytics can forecast demand fluctuations, supplier delays, or transportation bottlenecks, allowing businesses to take proactive measures. AI-driven demand forecasting models can significantly reduce errors compared to traditional methods, enabling organizations to align production and inventory levels with market demand (Amosu et al., 2024). Real-time insights also empower supply chain managers to make informed decisions quickly, improving overall efficiency and responsiveness (Khedr and Rani, 2024).

3.1.1. Data-Driven Decision-Making

AI enhances decision-making by transforming raw data into actionable insights. By analyzing patterns and trends in real-time data, AI systems can recommend optimal strategies for inventory management, logistics, and procurement (Khedr and Rani, 2024). For instance, AI can identify the most cost-effective transportation routes or suggest alternative suppliers in case of disruptions. This data-driven approach minimizes guesswork and ensures that decisions are based on accurate, up-to-date information.

Moreover, AI-powered decision-making tools can automate routine tasks, such as order processing and inventory replenishment, freeing up human resources for more strategic activities (Joel et al., 2024). This not only improves operational efficiency but also reduces the risk of human error. Organizations that adopt AI-driven decision-making tools experience a 20-30% improvement in supply chain efficiency (Kelly, 2024)

3.2. AI-Powered Tracking Systems

Transparency and traceability are critical components of modern supply chains, particularly in industries such as food, pharmaceuticals, and fashion, where product authenticity and safety are paramount (Aung and Chang, 2014). AI-powered tracking systems enable organizations to monitor the movement of goods at every stage of the supply chain, from raw materials to the end consumer (Joel et al., 2024). These systems use technologies such as IoT sensors, RFID tags, and GPS to collect real-time data on location, temperature, and condition.

For example, in the food industry, AI-powered tracking systems can monitor the temperature of perishable goods during transportation, ensuring that they remain within safe limits. If a deviation occurs, the system can alert stakeholders immediately, preventing spoilage and reducing waste. Similarly, in the pharmaceutical industry, AI can track the authenticity of drugs, reducing the risk of counterfeit products entering the supply chain.

3.2.1. Role of Blockchain and IoT in Improving Visibility

AI works synergistically with other emerging technologies, such as blockchain and IoT, to enhance transparency and traceability (Yahaya et al., 2025). Blockchain provides a secure and immutable ledger for recording transactions, ensuring that data cannot be tampered with. When combined with AI, blockchain enables organizations to create a transparent and auditable record of every transaction and movement within the supply chain (Yekeen et al., 2024).

IoT devices, such as sensors and smart tags, generate real-time data that AI systems can analyze to provide insights into supply chain operations. For instance, IoT sensors can monitor the condition of goods in transit, while AI algorithms analyze the data to predict potential issues, such as delays or damage. This combination of AI, blockchain, and IoT creates a robust ecosystem for real-time visibility, enabling organizations to build trust with customers and stakeholders.

3.3. Minimizing Waste and Optimizing Resource Allocation

AI plays a crucial role in minimizing waste and optimizing resource allocation in supply chains. By analyzing real-time data, AI systems can identify inefficiencies and recommend strategies for improvement. For example, AI can optimize inventory levels to reduce overstocking or stockouts, minimizing waste and lowering storage costs (Çaylı and Oralhan, 2024). Similarly, AI-powered predictive maintenance systems can monitor the condition of machinery and equipment, predicting failures before they occur and reducing downtime (Patil, 2024). In addition, AI can optimize resource allocation by analyzing data on production schedules, labor availability, and material requirements. This ensures that resources are used efficiently, reducing costs and improving productivity.

3.3.1. Automation in Procurement and Logistics

AI-driven automation is transforming procurement and logistics processes, leading to significant cost savings (Ismaeil and Lalla, 2024). In procurement, AI-powered systems can analyze supplier performance, market trends, and pricing data to identify the best suppliers and negotiate favorable terms. Automation also streamlines order processing and invoice management, reducing administrative costs and improving accuracy.

In logistics, AI-powered route optimization algorithms can reduce transportation costs by identifying the most efficient routes and modes of transport (Veluru, 2023). For example, AI can analyze traffic patterns, weather conditions, and fuel prices to recommend optimal routes in real time. Additionally, AI-powered warehouse management systems can automate tasks such as sorting, packing, and inventory tracking, improving efficiency and reducing labor costs (Shankaran, 2023).

3.4. AI's Role in Sustainable Practices

AI is a powerful tool for promoting sustainability in supply chain operations. By providing real-time visibility and predictive analytics, AI enables organizations to adopt sustainable practices such as reducing carbon emissions, optimizing energy use, and minimizing waste (). For example, AI can analyze data on energy consumption in warehouses and manufacturing facilities, identifying opportunities for improvement and recommending energy-efficient solutions.

AI also supports circular economy practices by enabling product lifecycle tracking and promoting the reuse of materials (). AI-powered systems can track the condition of returned products and determine whether they can be refurbished or recycled (). This reduces waste and extends the lifecycle of products, contributing to a more sustainable supply chain.

3.4.1. Reducing Carbon Footprints in Supply Chain Networks

One of the most significant environmental benefits of AI is its ability to reduce carbon footprints in supply chain networks. AI-powered systems can optimize transportation routes to minimize fuel consumption and emissions (Miller et al., 2024). For example, AI can analyze data on vehicle load capacity, traffic conditions, and delivery schedules to recommend the most efficient routes (Tsoukas et al., 2023). This not only reduces transportation costs but also lowers the environmental impact of logistics operations.

In addition, AI can support the adoption of renewable energy sources by forecasting energy demand and optimizing the use of solar or wind power (Onwusinkwue et al., 2024). For instance, AI-powered energy management systems can analyze weather patterns and energy consumption data to predict demand and adjust energy usage accordingly. This reduces reliance on fossil fuels and promotes the use of clean energy.

AI also contributes to social sustainability by promoting ethical practices and fair labor conditions (Mienye et al., 2024). AI-powered systems can monitor supplier compliance with labor standards and ethical sourcing practices, ensuring that supply chains are free from exploitation and human rights violations. This enhances the social responsibility of organizations and builds trust with consumers.

4. Implementation barriers and challenges

While the benefits of AI in real-time supply chain visibility are substantial, organizations face several barriers and challenges in implementing AI-powered systems. These challenges range from financial constraints and data quality issues to resistance to change and cybersecurity concerns. Addressing these barriers is critical for successful AI adoption and maximizing its potential in supply chain management. This section explores the key implementation challenges and their implications.

4.1. Financial Constraints in AI Adoption

One of the most significant barriers to AI adoption in supply chain management is the high initial investment cost (Culot et al. 2024). Implementing AI-powered systems requires substantial financial resources for acquiring advanced technologies, such as machine learning algorithms, IoT devices, and cloud computing infrastructure. Additionally, organizations must invest in data storage, processing capabilities, and cybersecurity measures to support AI systems (Aldoseri et al., 2023). For small and medium-sized enterprises (SMEs), these costs can be prohibitive, limiting their ability to adopt AI technologies.

Even for larger organizations, the financial commitment required for AI implementation can be a deterrent (Cannas et al., 2024). Many companies struggle to justify the upfront costs of AI adoption, particularly when the return on

investment (ROI) is not immediately apparent. This financial constraint is exacerbated by the need for ongoing investments in system maintenance, updates, and workforce training.

4.1.1. Implication: Cost vs. ROI Considerations

The high cost of AI implementation often raises concerns about ROI (Ikpe, 2024). While AI has the potential to deliver significant long-term benefits, such as improved efficiency, cost savings, and enhanced decision-making, these benefits may take time to materialize. Organizations must carefully evaluate the cost-benefit ratio of AI adoption and develop a clear business case to justify the investment.

For example, AI-powered predictive analytics can reduce inventory costs and improve demand forecasting accuracy, but the ROI may not be immediate. Similarly, while AI-driven automation can streamline logistics and procurement processes, the initial costs of implementing these systems can be substantial. Organizations must weigh these costs against the potential long-term benefits and consider factors such as payback periods and scalability.

4.2. Data Quality and Integration Issues

Data quality and integration are critical challenges in AI implementation (Aldoseri et al., 2023). Many organizations struggle with data silos, where information is stored in isolated systems that do not communicate with each other. This lack of interoperability hinders the ability of AI systems to access and analyze comprehensive datasets, limiting their effectiveness.

For example, supply chain data may be scattered across multiple platforms, such as enterprise resource planning (ERP) systems, warehouse management systems (WMS), and transportation management systems (TMS). Integrating these disparate systems to create a unified data ecosystem is a complex and resource-intensive process. Without high-quality, integrated data, AI systems cannot provide accurate insights or predictions, undermining their value (Sarikaya, 2024).

4.2.1. Challenges in Integrating AI with Existing Infrastructure

Integrating AI with existing supply chain infrastructure is another significant challenge (Ismaeil and Lalla, 2024). Many organizations rely on legacy systems that were not designed to support AI technologies. Upgrading or replacing these systems to accommodate AI can be costly and time-consuming. Additionally, integrating AI with existing processes often requires significant customization, which can further increase implementation costs and complexity.

For instance, implementing AI-powered predictive maintenance systems may require retrofitting existing machinery with IoT sensors and connecting them to AI platforms. This process can be technically challenging and may disrupt ongoing operations. Organizations must carefully plan and execute AI integration to minimize disruptions and ensure compatibility with existing systems.

4.3. Organizational Resistance to AI Adoption

Resistance to change is a common barrier to AI adoption in supply chain management. Employees and managers may be hesitant to embrace AI technologies due to fear of job displacement, lack of understanding, or skepticism about their effectiveness (Golgeci et al., 2025). This resistance can hinder the successful implementation and adoption of AI systems.

For example, supply chain managers may be reluctant to rely on AI-driven insights for decision-making, preferring to rely on their experience and intuition. Similarly, warehouse workers may resist the introduction of AI-powered automation systems, fearing that they will be replaced by machines (Pudel, 2024). Overcoming this resistance requires effective change management strategies, including clear communication, training, and involvement of stakeholders in the implementation process.

4.3.1. Need for Upskilling Workforce

The successful implementation of AI in supply chain management requires a skilled workforce capable of developing, managing, and utilizing AI systems. However, many organizations face a skills gap, as their employees lack the technical expertise required to work with AI technologies (Moradini et al., 2023). This skills gap can slow down AI adoption and limit its effectiveness.

For instance, data scientists and AI specialists are in high demand, but there is a shortage of qualified professionals in these fields (Bababshahi et al., 2024). Additionally, existing employees may require training to understand and use AI-powered tools effectively. Organizations must invest in upskilling their workforce through training programs,

certifications, and partnerships with educational institutions. This not only enhances the capabilities of employees but also fosters a culture of innovation and continuous learning.

4.4. Cybersecurity and Ethical Concerns

The integration of AI into supply chain management introduces new cybersecurity risks (Ismaeil and Lalla,2023). AI systems rely on vast amounts of data, making them attractive targets for cyberattacks. Data breaches and hacking incidents can compromise sensitive information, disrupt operations, and damage an organization's reputation.

For example, AI-powered supply chain platforms may store data on suppliers, customers, and logistics partners, which could be exploited by cybercriminals (Blake, 2025). Additionally, IoT devices used in AI systems are often vulnerable to hacking, as they may lack robust security features. Organizations must implement strong cybersecurity measures, such as encryption, multi-factor authentication, and regular security audits, to protect their AI systems and data.

4.4.1. Ethical Implications of AI-Driven Decisions

The use of AI in supply chain management also raises ethical concerns (Mohsen, 2023). AI-driven decisions are based on algorithms that analyze data and identify patterns, but these algorithms may inadvertently perpetuate biases or make unethical decisions. For example, AI systems used for supplier selection may favor certain suppliers based on biased data, leading to unfair outcomes.

Additionally, the use of AI in workforce management, such as scheduling or performance evaluation, may raise concerns about fairness and transparency (Majrashi, 2025). Organizations must ensure that their AI systems are designed and implemented in an ethical manner, with clear guidelines for decision-making and accountability. This includes addressing issues such as algorithmic bias, data privacy, and the potential impact of AI on jobs and society.

5. Summary and Recommendation

The integration of AI into real-time supply chain visibility offers transformative benefits, including improved decision-making, enhanced transparency, cost reduction, and environmental sustainability. AI-powered systems enable organizations to gain real-time insights, optimize operations, and respond swiftly to disruptions. However, significant barriers hinder AI adoption, such as high initial investment costs, data quality and integration challenges, resistance to change, and cybersecurity and ethical concerns. Financial constraints and unclear ROI often deter organizations, while data silos and legacy systems complicate AI integration. Workforce resistance and skills gaps further slow adoption, and cybersecurity risks and ethical dilemmas pose additional challenges. Addressing these barriers is critical for unlocking AI's full potential in supply chain management.

5.1. Practical Recommendations

To successfully implement AI in supply chain management, organizations should adopt a strategic and phased approach. Start small by launching pilot projects in high-impact areas such as demand forecasting or inventory optimization. These initiatives can demonstrate AI's value and ROI, building confidence before scaling up. Simultaneously, invest in robust data infrastructure to ensure data quality and integration. Break down data silos and adopt interoperable systems, leveraging cloud-based platforms for seamless data sharing and accessibility.

Upskilling the workforce is equally critical. Provide training programs to equip employees with AI-related skills and foster a culture of innovation and collaboration. This reduces resistance to change and ensures smoother adoption. Prioritize cybersecurity by implementing measures like encryption and multi-factor authentication to safeguard AI systems and sensitive data. Additionally, adopt ethical AI practices by developing guidelines to address algorithmic bias, ensure transparency, and promote fairness in AI-driven decisions.

Finally, collaboration with stakeholders is essential. Engage suppliers, customers, and partners in the AI implementation process to create a unified and transparent supply chain ecosystem. Governments and regulatory bodies should establish frameworks to address ethical and security concerns in AI adoption. Policies should promote data privacy, algorithmic transparency, and fair labor practices. Incentives, such as tax breaks or grants, can encourage SMEs to adopt AI technologies. Additionally, international standards for AI interoperability and cybersecurity should be developed to facilitate global supply chain integration. By following these practical recommendations, organizations can overcome implementation barriers and fully leverage AI to enhance efficiency, transparency, and sustainability in their supply chains.

5.2. Future Research Directions

Future research should focus on several critical areas to advance AI adoption in supply chain management. First, organizational and human factors must be explored to identify strategies for overcoming resistance to change and fostering a culture of innovation. This includes understanding employee concerns, providing training, and demonstrating the value of AI to stakeholders. Second, the long-term sustainability impacts of AI in supply chains need investigation, particularly its environmental and social implications, such as energy consumption, e-waste, and ethical labor practices. Third, research should examine how AI can integrate with emerging technologies like blockchain, IoT, and 5G to enhance supply chain visibility, transparency, and resilience.

Additionally, ethical and regulatory frameworks must be developed to ensure responsible AI use, addressing issues like algorithmic bias, data privacy, and decision-making transparency. Policymakers and researchers should also assess the effectiveness of existing regulations and propose improvements. Finally, large-scale empirical studies are needed to quantify AI's impact on supply chain performance and ROI, providing concrete evidence to support its adoption. By addressing these areas, researchers can offer actionable insights to drive innovation and overcome barriers, enabling organizations to fully leverage AI for efficient, sustainable, and resilient supply chains.

6. Conclusion

In conclusion, this paper aimed to explore the role of AI in enhancing real-time sustainable supply chain visibility, highlighting its benefits and implementation challenges. The research objectives focused on understanding how AI improves decision-making, transparency, cost efficiency, and sustainability while identifying barriers such as high costs, data integration issues, resistance to change, and ethical concerns. Key takeaways reveal that AI-powered systems significantly enhance supply chain operations by providing real-time insights, optimizing resource allocation, and reducing environmental impact. However, successful implementation requires addressing financial constraints, improving data infrastructure, upskilling the workforce, and ensuring cybersecurity and ethical practices.

AI's role in sustainable supply chain visibility is transformative, offering organizations the tools to achieve greater efficiency, resilience, and environmental responsibility. By leveraging AI, businesses can minimize waste, reduce carbon footprints, and promote ethical practices, aligning with global sustainability goals. However, realizing this potential demands a strategic approach, collaboration among stakeholders, and supportive policies. As AI technology continues to evolve, its integration into supply chains will play a pivotal role in driving innovation and sustainability. Future research should focus on overcoming implementation barriers, exploring long-term impacts, and developing ethical frameworks to ensure responsible AI adoption. Ultimately, AI is not just a technological advancement but a catalyst for building smarter, greener, and more transparent supply chains.

Compliance with ethical standards

Disclosure of conflict of interest

Competing Interests in the publication of the manuscript or with any institution or product that is mentioned in the manuscript and/or is important to the outcome of the study presented.

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