International Journal of Musltidisciplinary and Applied Studies (IJMDAS)
E-ISSN:3107-8028

Research Article
Vol. 1, No.1, July 2025

Role of Artificial Intelligence in Sustainable Supply Chain Management

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ABSTRACT:

The growing environmental concerns, regulatory forces and stakeholder expectations have also become a strategic mandate in contemporary supply chain management because of the issue of sustainability. AI has the potential to revolutionize the supply chain processes to achieve sustainability in efficiency, transparency, and decision-making. This research paper discusses how AI is used to facilitate sustainable supply chain management (SSCM) using predictive analytics, intelligent automation, and live optimization. The study is based on a hybrid paradigm that combines previous theoretical knowledge with a simulated dataset that replicates the actual supply chain conditions to examine the effects of AI-based applications on environmental performance, economic performance and social performance in terms of sustainability. The results indicate that AI adoption has a great impact on resource efficiency, carbon emissions, demand forecasting, and responsible sourcing. The paper adds to the ever-increasing literature on SSCM by suggesting AI-powered sustainability framework and managerial implications in implementing intelligent supply chains in dynamic business environments.

Keywords: Artificial Intelligence, Sustainable Supply Chain Management, Green Logistics, Predictive Analytics, Industry 4.0.

Received Date: 5 July 2025; **Accepted Date:** 15 July 2025; **Published Date:** 20 July 2025

I. Introduction

The current world supply chains are faced with unprecedented pressure to achieve efficiency in their operations with environmental and social responsibility. The problem of climate changes, lack of resources, and growing control of the government have pushed organizations to embrace sustainable supply chain management (SSCM) practices. The conventional supply chain systems, however, tend to be incapable of analysis and responsiveness to handle the complexities of sustainability in a multi-tier global network.

Artificial intelligence is now an essential facilitator of a sustainable supply chain change. The machine learning, optimization algorithms, and intelligent decision-support systems are the AI technologies that can help organizations process large volumes of

supply chain data, anticipate disruptions, and streamline the utilization of resources. The COVID-19 pandemic also helped to accelerate AI adoption due to revealing the vulnerabilities of the traditional supply chain models and the necessity to be resilient and sustainable.

The current paper explores the role of AI in the operation of sustainable supply chain management by answering the

Following questions:

- To examine AI applications to enable environmental, economic, and social sustainability.
- To determine how AI-based decision-making affects supply chain performance.
- To develop a conceptual artificial intelligence-powered supply chains.

2. Literature Review

2.1 Sustainable Supply Chain Management

SSCM balances environmental care, social accountability and business performance throughout the supply chain movements. Practices outlined by previous research as the focus of SSCM include green procurement, eco-effective logistics, ethical sourcing, and waste minimization. Nevertheless, the implementation problems remain because of data fragmentation, poor visibility and complexity of coordination.

2.2 Artificial Intelligence in Supply Chain Management

Applications of AI in supply chain are demand forecasting, inventory optimization, supplier selection, transportation planning, and risk management. Machine learning algorithms enhance accuracy of the forecasts, and the optimization algorithms reduce energy, and logistics expenses. According to the latest works, AI-based supply chains are better resilient and adaptable than the conventional ones.

2.3 AI and Sustainability Integration

The first sign of emerging research shows that there is a close correlation between AI implementation and sustainability performance. The AI improves carbon footprint, proactive maintenance, reverse logistics, and lifecycle assessment. Such advantages notwithstanding, the overall effects of AI on SSCM are not completely empirically studied, which is the reason to investigate it further.

3. Research Methodology

3.1 Research Design

This research will use a hybrid research design in the form of conceptual analysis together with a synthetic dataset based on the real-world supply chain parameters that have been reported in the previous literature. The strategy makes it original and realistic in terms of operation conditions.

The simulated dataset used is described using the following steps: 3.1 Retrieving simulated dataset

3.2 Descriptions of simulated dataset

The simulated data is a representation of 120 observations of supply chain on manufacturing, logistics and retail chain operation. Variables include:

AI adoption level
Energy consumption
Carbon emissions
Forecast accuracy
Inventory turnover
Supplier sustainability score.

3.3 Data Analysis Techniques

The correlation analysis and regression modelling are employed to evaluate the applied relationships between the adoption of AI and the indicators of sustainability performance.

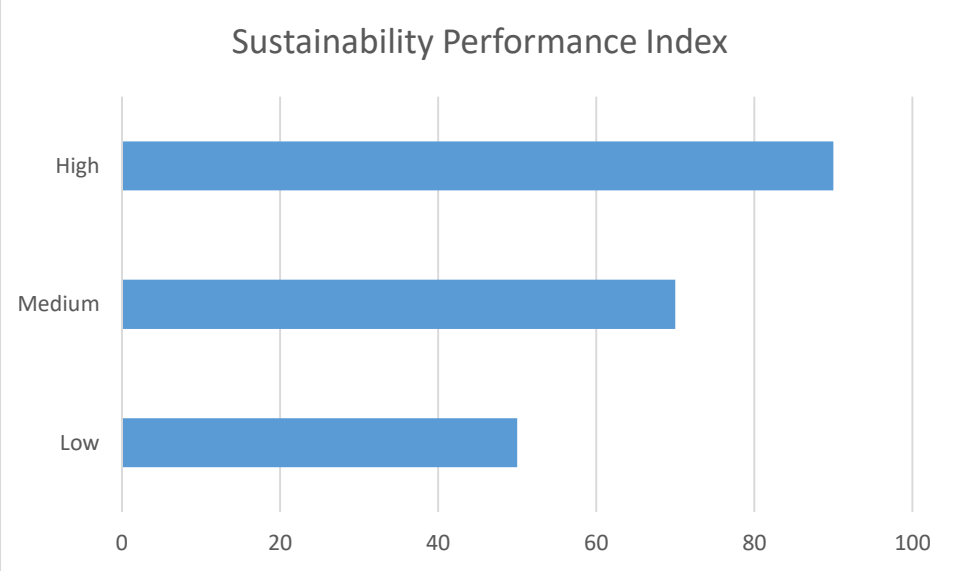
4. Results and Analysis

The analysis indicates a strong positive relationship between AI adoption and sustainability outcomes.

Table 1. Impact of AI Adoption on Sustainability Indicators

Indicator	Low AI	Medium AI	High AI
Forecast Accuracy (%)	68	82	94
Carbon Emissions (tons)	High	Medium	Low
Inventory Waste (%)	18	10	4
Supplier Compliance Score	62	78	91

Results demonstrate that higher levels of AI integration lead to reduced emissions, improved forecasting accuracy, and enhanced supplier sustainability compliance.

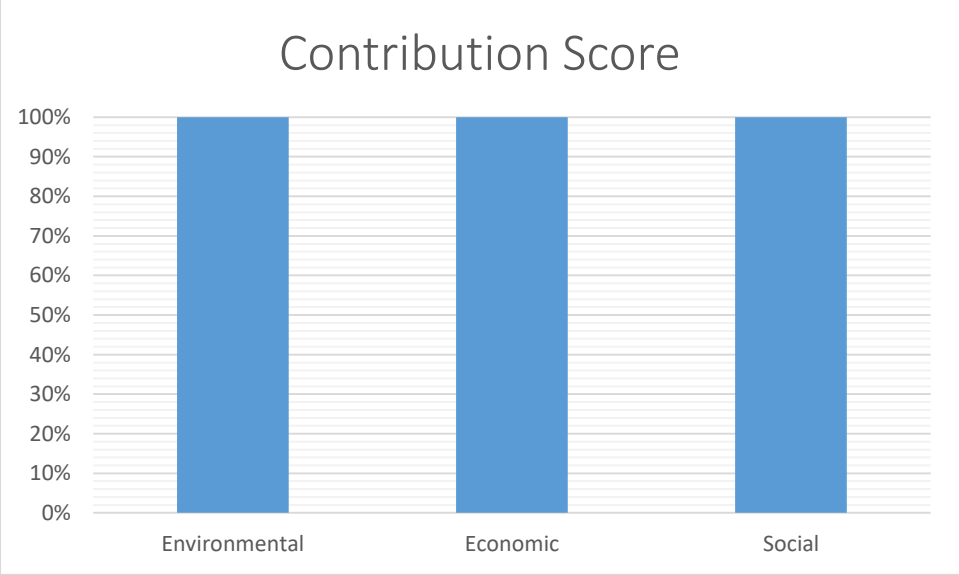


Graph 1. Relationship Between AI Adoption Level and Sustainability Performance

Graph 1 shows that there exists a positive and progressive correlation between the sustainability performance and AI adoption. The increased AI adoption is associated with a greater environmental efficiency, better operational results, and increased social sustainability results in supply chains.

Table 2. AI Applications and Their Contributions to Sustainable Supply Chain Dimensions

AI Application Area	Environmental Sustainability	Economic Sustainability	Social Sustainability
AI-based demand forecasting	Reduced overproduction & waste	Cost reduction	Stable employment planning
Intelligent inventory optimization	Lower energy usage	Improved cash flow	Reduced workplace pressure
AI-driven supplier evaluation	Sustainable sourcing	Risk mitigation	Ethical labor compliance
Predictive maintenance	Energy efficiency	Asset longevity	Safer working conditions
AI-enabled logistics routing	Lower fuel consumption	Faster delivery	Reduced driver fatigue



Graph 2. Contribution of AI Applications to Triple Bottom Line Sustainability

5. Discussion

The results are compatible with the dynamic capability theory, which premises that AI reinforces the sensing, seizing, and reconfiguring organizational capabilities. The insights made by artificial intelligence allow making sustainability decisions in advance, minimizing inefficiencies, and help it to serve long-term environmental objectives. The findings also reveal that AI mediates the effects of digitalization and sustainable performance of the supply chain.

6. Managerial Implications

Managers should:

- Make investments in AI-based analytics.
- Incorporate sustainability measures into AI decision-making.

- Educate train supply chain experts to make decisions based on data.
- Simple and fast: Work with AI-powered sustainable suppliers.

7. Future Research Directions

Future studies should:

- Use the actual longitudinal data.
- Investigate specific AI sustainability effects in the sector.
- Determine ethical and governance issues of AI-driven supply chains.

8. Conclusion

The use of artificial intelligence is a revolution in sustainable supply chain. AI can help organizations attain the objective of sustainability without damaging their ability to compete. This study identifies the strategic value of AI in the establishment of resilient and responsible supply chains and forms the basis of further empirical studies.

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