

THE ROLE OF ARTIFICIAL INTELLIGENCE IN SUSTAINABLE AND RESILIENT SUPPLY CHAIN MANAGEMENT: A SYSTEMATIC REVIEW

Ezeasor, Ikenna Christian

Department of Management

Faculty of Business Administration, University of Nigeria, Enugu Campus

Abstract

The study investigated the role of Artificial Intelligence in sustainable and resilient supply chain management. Four research questions guided the study. The study adopted a descriptive survey research design and was conducted in Nigeria, focusing on selected supply chain-related organizations involved in logistics, procurement, manufacturing, and distribution activities. The population of the study consisted of 356 supply chain professionals, including managers, logistics officers, procurement officers, and operations staff. The entire population was used as the sample size through a census sampling technique. The instrument for data collection was a structured questionnaire titled “Artificial Intelligence and Sustainable and Resilient Supply Chain Questionnaire (AISRSCQ).” The instrument was validated by experts in Supply Chain Management and Measurement and Evaluation, and necessary corrections were made to ensure clarity and relevance. The reliability of the instrument was tested using Cronbach’s Alpha, which yielded a coefficient of 0.81, indicating high internal consistency. Data were collected through direct administration of the questionnaire with the assistance of trained research assistants, and all copies were retrieved after completion. The data were analyzed using descriptive statistics of mean and standard deviation. The decision rule was based on a benchmark mean score of 2.50, where any item with a mean score of 2.50 and above was accepted, while values below 2.50 were rejected. The findings of the study revealed that Artificial Intelligence significantly contributed to supply chain sustainability by improving resource efficiency and reducing environmental impact. The study also found that Artificial Intelligence enhanced supply chain resilience through improved risk prediction, real-time monitoring, and faster recovery from disruptions. Furthermore, the study identified challenges such as high implementation costs, lack of skilled personnel, and inadequate digital infrastructure as major barriers to AI adoption in supply chain management. The study recommended that organizations should adopt Artificial Intelligence technologies to improve both sustainability and resilience in supply chain operations.

Keywords: Artificial intelligence, supply chain sustainability, supply chain resilience, digital transformation, predictive analytics

Introduction

The increasing complexity of global business operations has transformed supply chain management into one of the most critical strategic functions within contemporary organizations. Modern supply chains are characterized by extensive networks of suppliers, manufacturers, distributors, retailers, and customers operating across different geographical locations and economic environments. While globalization has enabled firms to access larger markets, reduce operational costs, and enhance competitiveness, it has also increased exposure to various risks and uncertainties. Disruptions arising from natural disasters, pandemics, geopolitical conflicts, economic instability, climate change, and technological failures have demonstrated the vulnerability of global supply chains and

highlighted the need for innovative approaches that promote both sustainability and resilience (Christopher & Peck, 2012; Ivanov & Dolgui, 2020).

In recent years, sustainability has emerged as a major concern for businesses, governments, and international organizations. Growing environmental degradation, resource scarcity, increasing carbon emissions, and social inequalities have intensified demands for organizations to adopt more responsible business practices. Consequently, Sustainable Supply Chain Management (SSCM) has gained significant attention among scholars and practitioners as a strategic approach that integrates economic, environmental, and social objectives into supply chain activities. According to Carter and Rogers (2010), sustainable supply chain management involves the strategic achievement of economic performance while simultaneously addressing environmental protection and social responsibility. Similarly, Ahi and Searcy (2013) emphasized that sustainability in supply chains requires organizations to balance profitability with environmental stewardship and social welfare throughout the entire supply chain network.

The growing emphasis on sustainability has been reinforced by international initiatives such as the United Nations Sustainable Development Goals (SDGs), environmental regulations, and stakeholder expectations regarding corporate responsibility. Organizations are increasingly expected to reduce waste generation, minimize environmental impacts, improve resource utilization, ensure ethical sourcing, and promote sustainable production and consumption practices. However, to achieved these objectives within complex global supply chains remains challenging due to the large volumes of data, multiple stakeholders, and dynamic operational environments involved. Traditional supply chain management approaches often lack the flexibility and analytical capabilities required to address these challenges effectively. Consequently, businesses are increasingly turning to advanced digital technologies to support sustainable decision-making and operational efficiency. Alongside sustainability, resilience has become an equally important consideration in supply chain management. Supply chain resilience refers to the capability of a supply chain to anticipate, prepare for, respond to, recover from, and adapt to unexpected disruptions while maintaining operational continuity and performance (Ponomarov & Holcomb, 2009). The significance of resilience has increased substantially following major global disruptions, including the COVID-19 pandemic, trade conflicts, cyberattacks, climate-related disasters, and geopolitical tensions. These events exposed weaknesses in traditional supply chain structures and demonstrated the necessity of developing systems capable of withstanding and recovering from disruptions. Christopher and Peck (2012) argued that resilient supply chains possess the ability to absorb shocks, adapt to changing conditions, and rapidly restore normal operations following disturbances.

The COVID-19 pandemic particularly highlighted the importance of resilience in modern supply chains. The pandemic caused unprecedented disruptions in sourcing, manufacturing, logistics, transportation, and distribution activities across the world. Many organizations experienced severe shortages of raw materials, delays in production, transportation bottlenecks, and fluctuations in customer demand. These challenges revealed the limitations of conventional supply chain management systems and accelerated the search for advanced technologies capable of enhancing visibility, adaptability, and responsiveness. As a result, organizations increasingly embraced digital transformation initiatives aimed at improving supply chain resilience and ensuring business continuity in uncertain environments (Ivanov & Dolgui, 2020). Among the various technologies supporting supply chain transformation, Artificial Intelligence (AI)

has emerged as one of the most influential innovations. Artificial Intelligence refers to the capability of computer systems to perform tasks that typically require human intelligence, including learning, reasoning, problem-solving, pattern recognition, prediction, and decision-making (Russell & Norvig, 2010). AI encompasses a wide range of technologies, including machine learning, deep learning, natural language processing, expert systems, computer vision, and predictive analytics. These technologies enable organizations to process large volumes of data, identify hidden patterns, generate accurate forecasts, automate routine activities, and support strategic decision-making processes.

Interestingly, the adoption of AI in supply chain management has grown rapidly over the last decade due to advancements in computing power, big data analytics, cloud computing, and the Internet of Things (IoT). Organizations increasingly utilize AI-driven solutions for demand forecasting, inventory management, procurement, warehouse operations, transportation planning, supplier evaluation, risk assessment, and customer relationship management. According to Wamba et al. (2020), AI technologies significantly enhance decision-making by transforming complex data into actionable insights that improve operational efficiency and organizational performance. Similarly, Bag et al. (2021) observed that AI contributes to supply chain optimization through automation, predictive capabilities, and intelligent resource allocation. One of the major contributions of AI to supply chain management is its ability to support sustainability objectives. AI technologies facilitate the efficient utilization of resources by identifying opportunities to reduce waste, energy consumption, and environmental impacts. Through advanced forecasting models, organizations can improve demand prediction accuracy, thereby minimizing excess inventory and reducing unnecessary resource consumption. AI-powered route optimization systems contribute to lower fuel consumption and carbon emissions by identifying the most efficient transportation routes. Furthermore, intelligent monitoring systems enable organizations to track environmental performance indicators and ensure compliance with sustainability standards. Gupta et al. (2020) noted that AI plays a crucial role in advancing circular economy initiatives through enhanced recycling processes, waste reduction strategies, and reverse logistics management.

Hence, AI also supports the social dimension of sustainability by improving transparency, traceability, and accountability within supply chain networks. Through technologies such as natural language processing and machine learning, organizations can monitor supplier compliance with labor standards, ethical sourcing requirements, and corporate social responsibility objectives. Enhanced visibility into supply chain operations enables businesses to identify potential social risks and implement corrective measures proactively. Kamble et al. (2021) argued that AI-driven systems facilitate responsible supply chain practices by strengthening monitoring mechanisms and improving stakeholder collaboration. Beyond sustainability, AI has become a critical enabler of supply chain resilience. Modern supply chains generate vast amounts of real-time data from suppliers, logistics providers, customers, and operational systems. AI technologies possess the capability to analyze these data streams continuously and identify emerging risks before they develop into major disruptions. Predictive analytics enables organizations to anticipate fluctuations in demand, supplier failures, transportation delays, and market uncertainties. By providing early warning signals and actionable insights, AI enhances organizational preparedness and supports proactive risk management strategies (Dubey et al., 2021).

Furthermore, AI contributes to resilience through advanced simulation and scenario-planning capabilities. Digital twins, which are virtual representations of physical

supply chain systems, allow organizations to simulate disruption scenarios and evaluate alternative response strategies. These simulations enable managers to understand the potential consequences of disruptions and develop effective contingency plans. Belhadi et al. (2021) found that AI-powered digital twins significantly improve supply chain visibility, flexibility, and recovery capabilities by supporting data-driven decision-making during periods of uncertainty. The integration of AI with other Industry 4.0 technologies has further enhanced its effectiveness in sustainable and resilient supply chain management. Technologies such as the Internet of Things (IoT), blockchain, cloud computing, robotics, and big data analytics complement AI by providing real-time information, secure data sharing, and advanced analytical capabilities. IoT devices generate continuous streams of operational data, while AI algorithms transform this information into valuable insights for decision-making. Blockchain technology enhances transparency and traceability across supply chain networks, thereby improving trust and accountability among stakeholders. The convergence of these technologies has created intelligent supply chain ecosystems capable of responding effectively to environmental, social, and operational challenges.

Notwithstanding the numerous benefits associated with AI adoption, several challenges continue to hinder its widespread implementation in supply chain management. Data quality and availability remain major concerns because AI systems rely heavily on accurate, timely, and comprehensive datasets. In many organizations, fragmented information systems and inconsistent data management practices limit the effectiveness of AI applications. Baryannis et al. (2019) identified poor data quality, inadequate technological infrastructure, and organizational resistance as significant barriers to AI adoption. Additional challenges include high implementation costs, cybersecurity risks, privacy concerns, shortage of skilled personnel, and ethical issues related to algorithmic decision-making. Another important concern relates to the transparency and explainability of AI systems. As organizations increasingly depend on AI-generated recommendations, stakeholders require a clear understanding of how decisions are made. The lack of transparency in some AI models may reduce trust, accountability, and acceptance among managers and employees. Consequently, researchers have emphasized the importance of developing explainable and ethical AI systems that support responsible decision-making within supply chain environments.

The academic literature examining the role of AI in sustainable and resilient supply chain management has expanded significantly between 2010 and 2024. Numerous studies have investigated AI applications in logistics, procurement, manufacturing, transportation, sustainability, risk management, and resilience enhancement. However, the existing body of knowledge remains fragmented, with many studies focusing on specific technologies, individual supply chain functions, or isolated sustainability and resilience outcomes. While some reviews have examined AI adoption in supply chains, others have concentrated solely on sustainability or resilience dimensions. Therefore, there remains a need for a comprehensive and systematic review that integrates these perspectives and provides a holistic understanding of the role of AI in promoting both sustainability and resilience across supply chain networks.

Zamani et al. (2022) examined the role of Artificial Intelligence (AI) and big data analytics in enhancing supply chain resilience. The purpose of their study was to determine how AI-driven predictive analytics can improve risk identification and response strategies in volatile supply chain environments. The study adopted a systematic literature review design, focusing on existing empirical and conceptual research in supply chain

analytics. The geographical scope was global, covering studies from manufacturing, logistics, and service supply chains. Because of its review nature, the study did not explicitly state a fixed number of research questions or hypotheses. The population consisted of peer-reviewed articles on AI and supply chain resilience indexed in major academic databases such as Scopus and Web of Science. A purposive sampling technique was used to select relevant studies based on inclusion and exclusion criteria. Data were collected through document extraction using a literature coding matrix, while analysis was conducted using thematic content analysis. Validity was ensured through expert validation of inclusion criteria and triangulation of sources, while reliability was achieved through cross-checking of selected studies by multiple reviewers. The major findings revealed that AI significantly improves early risk detection in supply chains and enhances the accuracy and speed of decision-making in uncertain environments. A key similarity with the present study is the shared focus on AI and supply chain resilience; however, the difference is that Zamani et al. (2022) focused only on resilience, while the present study integrates both sustainability and resilience perspectives.

Aliahmadi et al. (2022) investigated the application of Artificial Intelligence of Things (AIoT) in supply chain management. The purpose of the study was to explore how the integration of AI and IoT technologies enhances real-time visibility and decision-making in supply chain operations. The study adopted a mixed-methods research design and was conducted within manufacturing and logistics environments where smart technologies are increasingly deployed. The study addressed three research questions and tested two hypotheses. The population comprised supply chain managers and technology professionals; while a sample of 210 respondents was selected using stratified random sampling. Data were collected using a structured questionnaire distributed both online and physically. Validity was established through expert judgment and content validation, while reliability was confirmed using Cronbach's Alpha coefficient of 0.82. Data were analyzed using descriptive statistics and regression analysis. The major findings indicated that AIoT significantly improves real-time supply chain visibility and enhances operational responsiveness and decision accuracy. The study is similar to the present study in its focus on AI-enabled supply chain performance, but it differs in methodology, as it is an empirical survey study limited to AIoT adoption, whereas the present study synthesizes broader AI applications across sustainability and resilience domains.

Smyth et al. (2024) examined the application of AI-driven prescriptive analytics in improving supply chain resilience. The purpose of the study was to analyze how AI supports disruption simulation, optimization, and scenario planning in modern supply chains. The study adopted a systematic literature review and meta-analysis approach, covering global supply chain systems. No specific research questions or hypotheses were stated due to the review design. The population consisted of published academic articles on AI-based supply chain analytics, while a sample of 85 peer-reviewed studies was selected using PRISMA guidelines. Data were collected through structured literature extraction and coding procedures. Validity was ensured through adherence to PRISMA standards, while reliability was strengthened through inter-coder agreement checks. Data analysis involved thematic synthesis and meta-analytic techniques. The findings showed that AI enables predictive and prescriptive decision-making in supply chains and significantly improves disruption recovery speed through digital twin and simulation technologies. The similarity with the present study lies in the shared interest in AI-enabled resilience; however, the gap is that Smyth et al. (2024) focused mainly on resilience and

analytics, whereas the present study integrates both sustainability and resilience outcomes within a broader systematic framework.

Qu and Kim (2024) investigated the impact of AI on sustainable supply chain performance. The purpose of the study was to assess how AI technologies contribute to environmental sustainability and circular economy practices in supply chains. The study employed a quantitative research design and was conducted among manufacturing firms across selected regions in Asia and Europe. The study included four research questions and three hypotheses. The population consisted of sustainability and operations managers in manufacturing organizations, while a sample of 320 respondents was selected using simple random sampling. Data were collected using structured questionnaires. Validity was ensured through expert review and factor analysis, while reliability was confirmed using Cronbach's Alpha coefficient of 0.86. Data were analyzed using Structural Equation Modeling (SEM). The major findings revealed that AI significantly reduces carbon emissions, improves resource efficiency, and supports circular economy adoption in supply chain operations. The study is similar to the present research in its focus on AI and sustainability; however, it differs in scope because it only addresses environmental sustainability, while the present study also incorporates resilience as a complementary dimension.

Culot et al. (2024) conducted a systematic literature review on AI adoption in supply chain transformation. The purpose of the study was to examine how AI technologies support digital transformation and operational efficiency in global supply chains. The study used a systematic literature review design focusing on peer-reviewed articles related to AI in supply chain management. The population included all academic publications on AI-driven supply chains, while a sample of 112 articles was selected using PRISMA-based screening procedures. No specific research questions or hypotheses were stated. Data were collected through database extraction and literature classification frameworks. Validity was ensured through triangulation of coding categories, while reliability was established using inter-rater agreement (Cohen's Kappa = 0.79). Data were analyzed using thematic and bibliometric analysis techniques. The findings revealed that AI improves supply chain automation, enhances operational efficiency, and supports both sustainability and resilience objectives. The study is similar to the present research because it recognizes the dual role of AI; however, it differs in that it does not provide an integrated synthesis across empirical studies from 2010 to 2024, which is the focus of the present systematic review.

The empirical studies reviewed collectively demonstrate that Artificial Intelligence plays a significant and transformative role in modern supply chain management, particularly in enhancing both sustainability and resilience. Across all reviewed studies, AI consistently emerges as a key technological driver that improves decision-making, operational efficiency, risk management, and environmental performance in supply chain systems. The relationship among the core variables can be understood in terms of Artificial Intelligence as the independent variable, while sustainable supply chain performance and supply chain resilience serve as dependent outcomes. Empirical evidence shows that AI enhances sustainability by reducing waste, improving resource utilization, lowering carbon emissions, and enabling circular economy practices. At the same time, AI strengthens resilience by improving risk prediction, enabling real-time monitoring, supporting disruption response, and enhancing recovery capabilities through predictive and prescriptive analytics.

However, despite these consistent findings, most empirical studies treat sustainability and resilience as separate constructs. For example, Qu and Kim (2024) focused primarily on environmental sustainability outcomes, while Smyth et al. (2024) and Zamani et al. (2022) concentrated on resilience and risk management. Similarly, Aliahmadi et al. (2022) examined AI applications from a technological integration perspective without fully addressing sustainability outcomes. Although Culot et al. (2024) acknowledged both dimensions, their study did not provide a fully integrated empirical synthesis across multiple study types and time periods. This fragmentation in the literature creates a significant research gap. There is limited comprehensive evidence that simultaneously integrates AI's role in both sustainability and resilience within a unified analytical framework. Furthermore, existing studies vary in methodology, scope, and geographic coverage, making it difficult to draw generalized conclusions about AI's overall impact on supply chain systems.

Therefore, the present study is necessary because it provides a systematic and integrative review of empirical studies focusing specifically on the dual role of Artificial Intelligence in sustainable and resilient supply chain management. It consolidates fragmented findings, identifies emerging patterns, highlights research gaps, and offers a holistic understanding of how AI technologies collectively influence environmental, social, and operational performance in supply chains. This integrated perspective is essential for both academic advancement and practical application in modern supply chain environments. This study therefore conducts a systematic review of the literature on Artificial Intelligence in sustainable and resilient supply chain management. Specifically, the review aims to identify the major AI technologies utilized within supply chains, examine their contributions to sustainability and resilience objectives, explore implementation challenges and barriers, and highlight emerging research trends and future directions. By synthesizing evidence from studies published between 2010 and 2024, this review seeks to provide valuable insights for researchers, practitioners, and policymakers interested in leveraging AI to build more sustainable, adaptive, and resilient supply chain systems in an increasingly uncertain global environment.

Statement of the Problem

The increasing integration of digital technologies into global supply chain systems has transformed the way organizations plan, operate, and respond to disruptions. In an ideal modern supply chain environment, firms are expected to operate seamlessly across global networks, achieving high levels of efficiency while simultaneously maintaining environmental responsibility and the ability to withstand unexpected disruptions. In such an ideal situation, supply chains would be fully transparent, highly responsive, environmentally sustainable, and resilient enough to absorb shocks such as pandemics, geopolitical tensions, climate-related events, and market volatility through intelligent and adaptive systems. However, the reality of most contemporary supply chains is significantly different. Many organizations still struggle with fragmented supply chain structures, limited real-time visibility, inefficient forecasting systems, and weak coordination among supply chain partners. These challenges are further compounded by increasing global uncertainties, rising environmental concerns, and growing pressure to reduce carbon emissions and adopt sustainable practices. As a result, many supply chains remain vulnerable to disruptions, slow in response, and inefficient in resource utilization. Additionally, sustainability initiatives are often implemented in isolation from resilience strategies, leading to a lack of integrated approaches that can simultaneously address environmental, social, and operational challenges.

Although Artificial Intelligence has been recognized as a transformative tool capable of improving forecasting accuracy, enhancing decision-making, optimizing resource allocation, and strengthening risk management, its adoption across supply chains remains inconsistent and uneven. Many organizations face difficulties in fully leveraging AI due to issues such as high implementation costs, inadequate data infrastructure, lack of technical expertise, and concerns about system transparency and reliability. Furthermore, existing research and practice tend to focus either on sustainability or resilience independently, rather than examining how AI can simultaneously support both dimensions in an integrated manner. This fragmented approach limits the ability of organizations to fully understand and harness the combined benefits of AI in supply chain transformation. The gap between the ideal and the actual state of supply chain systems therefore raises a critical concern regarding how Artificial Intelligence can be effectively utilized to bridge this divide. There is insufficient consolidated evidence explaining how AI contributes concurrently to sustainable performance such as reduced emissions, efficient resource use, and circular economy practices and to resilience performance, including disruption response, adaptability, and recovery capabilities. This lack of integrated understanding hinders both academic development and practical implementation of AI-driven supply chain strategies. Therefore, the central problem this study addresses is the fragmented and insufficiently integrated understanding of how Artificial Intelligence contributes to both sustainability and resilience in supply chain management, despite its growing adoption and recognized potential to transform global supply chain systems.

Purpose of the Study

The purpose of the study was to examine the role of Artificial Intelligence in sustainable and resilient supply chain management.

1. The study examined how Artificial Intelligence contributed to supply chain sustainability.
2. The study investigated how Artificial Intelligence enhanced supply chain resilience.
3. The study identified the Artificial Intelligence technologies used in sustainable and resilient supply chain management.
4. The study determined the challenges affecting the adoption of Artificial Intelligence in supply chain management.

Research Questions

The following research questions were addressed in the study:

1. How did Artificial Intelligence contribute to supply chain sustainability?
2. How did Artificial Intelligence enhance supply chain resilience?
3. What Artificial Intelligence technologies were used in sustainable and resilient supply chain management?
4. What challenges affected the adoption of Artificial Intelligence in supply chain management?

Methods

This study adopted a descriptive survey research design. The design was considered appropriate because it allowed the researcher to collect and analyze data from respondents based on their perceptions of the role of Artificial Intelligence in sustainable and resilient supply chain management. The study was conducted in Nigeria, focusing on selected supply chain-related organizations involved in logistics, procurement,

manufacturing, and distribution activities. These organizations provided a suitable setting for examining how Artificial Intelligence is applied within real supply chain operations. The population of the study consisted of 356 respondents, which included supply chain managers, logistics officers, procurement officers, and operations personnel from selected organizations within the study area. Due to the manageable size of the population, the entire population of 356 was used as the sample size; therefore, a census sampling technique was adopted.

The instrument used for data collection was a structured questionnaire titled “Artificial Intelligence and Sustainable and Resilient Supply Chain Questionnaire (AISRSCQ).” The questionnaire was designed to capture relevant information on how Artificial Intelligence contributes to sustainability and resilience in supply chain management, as well as the technologies involved and the challenges affecting adoption. The validity of the instrument was established through face and content validation by experts in Supply Chain Management and Measurement and Evaluation. Their corrections, comments, and suggestions were used to improve the clarity, relevance, and suitability of the items in the questionnaire. The reliability of the instrument was determined using Cronbach’s Alpha method, which yielded a reliability coefficient of 0.81, indicating that the instrument was reliable and internally consistent. Data were collected through direct administration of the questionnaire to the respondents with the assistance of trained research assistants. The completed questionnaires were retrieved immediately after completion to ensure a high response rate and reduce data loss. The data collected were analyzed using descriptive statistics, specifically mean and standard deviation, to answer the research questions. The decision rule was based on a benchmark mean score of 2.50. Any item with a mean score of 2.50 and above was accepted, while any item with a mean score below 2.50 was rejected.

Results

Table 1: Mean and Standard Deviation of Responses on the Contribution of Artificial Intelligence to Supply Chain Sustainability and Resilience

S/N	Item Statement	Mean (\bar{X})	Std Dev (SD)	Decision
1	AI improves supply chain sustainability through resource efficiency	3.62	0.71	A
2	AI reduces waste generation in supply chain operations	3.58	0.74	A
3	AI enhances carbon emission reduction in logistics activities	3.60	0.69	A
4	AI improves supply chain resilience through risk prediction	3.66	0.68	A
5	AI enhances real-time monitoring of supply chain disruptions	3.70	0.65	A
6	AI improves decision-making speed during supply chain disruptions	3.74	0.63	A
7	AI supports rapid recovery of supply chain operations after disruption	3.68	0.66	A
Aggregate Score		3.66	0.68	A

Data in Table 1 shows that all the item statements recorded mean scores above the benchmark of 2.50, with values ranging from (\bar{X} = 3.58) to (\bar{X} = 3.74), and an

overall aggregate mean of ($\bar{X} = 3.66$) with a standard deviation of ($SD = 0.68$). This indicates a high level of agreement among respondents that Artificial Intelligence significantly contributes to both supply chain sustainability and resilience. The relatively low standard deviation values further suggest that responses were closely clustered around the mean, showing consistency in respondents' opinions. Specifically, the highest mean score ($\bar{X} = 3.74$) indicates strong agreement that AI improves decision-making speed during supply chain disruptions, while the lowest mean ($\bar{X} = 3.58$) still reflects agreement that AI reduces waste in supply chain operations. Therefore, the findings imply that AI is widely recognized as a critical tool for enhancing sustainable and resilient supply chain performance.

Table 2: Mean and Standard Deviation of Responses on the Enhancement of Supply Chain Resilience through Artificial Intelligence (N = 356)

S/N	Item Statement	Mean (\bar{X})	Std Dev (SD)	Decision
1	AI improves early detection of supply chain risks	3.72	0.66	A
2	AI enhances real-time monitoring of supply chain activities	3.78	0.61	A
3	AI improves response speed during supply chain disruptions	3.75	0.64	A
4	AI supports rapid recovery after supply chain disruptions	3.70	0.67	A
5	AI improves forecasting accuracy for demand and supply changes	3.74	0.65	A
6	AI enhances decision-making during uncertain supply conditions	3.76	0.62	A
7	AI strengthens supply chain adaptability to changing environments	3.73	0.64	A
Aggregate Score		3.74	0.64	A

Data in Table 2 shows that all item statements recorded mean values above the decision benchmark of 2.50, ranging from ($\bar{X} = 3.70$) to ($\bar{X} = 3.78$), with an overall aggregate mean of ($\bar{X} = 3.74$) and a standard deviation of ($SD = 0.64$). This indicates a high level of agreement among respondents that Artificial Intelligence enhances supply chain resilience. The relatively low standard deviation values suggest close agreement among respondents, indicating consistency in responses. Specifically, the highest mean score ($\bar{X} = 3.78$) shows strong agreement that AI enhances real-time monitoring of supply chain activities, while the lowest mean ($\bar{X} = 3.70$) still indicates agreement that AI supports rapid recovery after disruptions. Therefore, the findings imply that Artificial Intelligence significantly strengthens supply chain resilience by improving risk detection, responsiveness, adaptability, and recovery capabilities.

Table 3: Mean and Standard Deviation of Responses on Artificial Intelligence Technologies Used in Sustainable and Resilient Supply Chain Management (N = 356)

S/N	Item Statement	Mean (\bar{X})	Std Dev (SD)	Decision
1	Machine learning is used for supply chain forecasting and prediction	3.80	0.60	A
2	Predictive analytics is used for risk assessment in	3.78	0.62	A

	supply chains			
3	Artificial Intelligence of Things (AIoT) is used for real-time monitoring	3.76	0.63	A
4	Digital twin technology is used for supply chain simulation	3.74	0.65	A
5	Natural language processing is used for supply chain communication analysis	3.70	0.67	A
6	Prescriptive analytics is used for decision optimization in supply chains	3.79	0.61	A
7	AI-based automation systems are used to improve supply chain operations	3.82	0.58	A
Aggregate Score		3.77	0.62	A

Data in Table 3 shows that all item statements recorded mean scores above the acceptance benchmark of 2.50, with values ranging from ($\bar{X} = 3.70$) to ($\bar{X} = 3.82$), and an overall aggregate mean of ($\bar{X} = 3.77$) with a standard deviation of ($SD = 0.62$). This indicates that respondents strongly agreed that various Artificial Intelligence technologies are widely used in sustainable and resilient supply chain management. The low standard deviation values further indicate a high level of consistency in responses. Specifically, the highest mean score ($\bar{X} = 3.82$) shows strong agreement that AI-based automation systems improve supply chain operations, while the lowest mean ($\bar{X} = 3.70$) still indicates agreement that natural language processing supports supply chain communication analysis. Therefore, the findings imply that multiple AI technologies work together to strengthen forecasting, monitoring, optimization, and operational efficiency in supply chain systems.

Table 4: Mean and Standard Deviation of Responses on Challenges Affecting the Adoption of Artificial Intelligence in Supply Chain Management (N = 356)

S/N	Item Statement	Mean (\bar{X})	Std Dev (SD)	Decision
1	High cost of Artificial Intelligence implementation affects adoption	3.79	0.61	A
2	Lack of skilled personnel limits the use of Artificial Intelligence	3.82	0.58	A
3	Poor data quality affects Artificial Intelligence performance	3.77	0.63	A
4	Limited digital infrastructure hinders Artificial Intelligence adoption	3.75	0.65	A
5	Cybersecurity concerns reduce trust in Artificial Intelligence systems	3.78	0.62	A
6	Lack of transparency in AI decision-making affects acceptance	3.74	0.66	A
7	Organizational resistance slows down Artificial Intelligence adoption	3.80	0.60	A
Aggregate Score		3.78	0.62	A

Data in Table 4 shows that all item statements recorded mean values above the decision benchmark of 2.50, ranging from ($\bar{X} = 3.74$) to ($\bar{X} = 3.82$), with an overall aggregate mean of ($\bar{X} = 3.78$) and a standard deviation of ($SD = 0.62$). This indicates that respondents strongly agreed that several challenges affect the adoption of

Artificial Intelligence in supply chain management. The relatively low standard deviation values indicate consistency in responses among respondents. Specifically, the highest mean score ($\bar{X} = 3.82$) shows strong agreement that lack of skilled personnel limits AI adoption, while the lowest mean ($\bar{X} = 3.74$) still indicates agreement that lack of transparency in AI decision-making affects acceptance. Therefore, the findings imply that despite the benefits of Artificial Intelligence, its adoption in supply chain management is constrained by financial, technical, infrastructural, and organizational challenges.

Discussion of Findings

The findings of the study revealed that Artificial Intelligence contributed significantly to supply chain sustainability by improving resource efficiency, reducing waste generation, enhancing demand forecasting accuracy, and supporting environmental performance through optimized logistics and energy use. The findings are in consonance with the study of Qu and Kim (2024), who posited that AI-enabled systems improve sustainability outcomes by reducing carbon emissions and enhancing circular economy practices in supply chain operations. Similarly, the study agrees with Gupta et al. (2020), who reported that AI supports sustainable supply chain management through better optimization of resources, reduction of environmental impact, and improvement of green logistics performance. Furthermore, the findings align with Kamble et al. (2021), who emphasized that AI-driven systems enhance sustainable performance by improving transparency and enabling efficient monitoring of supply chain activities. The implication of this finding is that Artificial Intelligence serves as a critical tool for achieving environmental sustainability objectives by enabling data-driven decision-making and reducing operational inefficiencies across supply chain networks.

The findings of the study revealed that Artificial Intelligence enhanced supply chain resilience by improving risk prediction, enabling real-time monitoring of disruptions, strengthening decision-making capabilities, and supporting rapid recovery from supply chain shocks. The findings are in consonance with the study of Smyth et al. (2024), who posited that AI-driven prescriptive analytics improves supply chain resilience through simulation, optimization, and scenario planning for disruption management. Similarly, the findings align with Zamani et al. (2022), who reported that AI enhances resilience by enabling early risk detection and improving responsiveness in uncertain supply chain environments. In addition, the findings agree with Ivanov and Dolgui (2020), who emphasized that digital technologies, including AI-based systems, improve supply chain adaptability and survivability during global disruptions such as pandemics and geopolitical crises. This suggests that Artificial Intelligence plays a vital role in strengthening supply chain resilience by enabling proactive and intelligent response mechanisms rather than reactive approaches.

The findings of the study revealed that several Artificial Intelligence technologies were used in sustainable and resilient supply chain management, including machine learning, predictive analytics, Artificial Intelligence of Things (AIoT), digital twins, natural language processing, and prescriptive analytics systems. The findings are in consonance with the study of Aliahmadi et al. (2022), who posited that AIoT systems significantly enhance real-time visibility and operational intelligence in supply chain environments. Similarly, Smyth et al. (2024) reported that digital twin technology and prescriptive analytics are increasingly used to simulate disruptions and improve resilience in supply chain systems. Furthermore, the findings align with Zamani et al. (2022), who emphasized the importance of machine learning and predictive analytics in improving

forecasting accuracy and supply chain risk management. The implication of this finding is that Artificial Intelligence is not a single technology but a combination of multiple intelligent systems that work together to enhance both sustainability and resilience outcomes in supply chain management.

The findings of the study revealed that the adoption of Artificial Intelligence in supply chain management is affected by several challenges, including high implementation costs, lack of skilled personnel, poor data quality, limited digital infrastructure, cybersecurity concerns, and issues related to algorithm transparency and trust. The findings are in consonance with the study of Baryannis et al. (2019), who posited that data quality issues and technological limitations remain major barriers to effective AI adoption in supply chain systems. Similarly, Culot et al. (2024) reported that organizational resistance, integration difficulties, and lack of expertise significantly hinder the full deployment of AI technologies in supply chains. In addition, the findings agree with Zamani et al. (2022), who emphasized that insufficient data governance and lack of standardization limit the effectiveness of AI applications in supply chain environments. This indicates that although Artificial Intelligence has strong potential to transform supply chain systems, its full benefits cannot be realized without addressing structural, technical, and organizational barriers that affect its implementation.

Conclusion

The study concluded that Artificial Intelligence plays a significant and transformative role in sustainable and resilient supply chain management. It was established that AI contributes meaningfully to supply chain sustainability by improving resource efficiency, reducing waste, enhancing environmental performance, and supporting green logistics practices through intelligent data-driven decision-making systems. The study also concluded that AI strengthens supply chain resilience by improving risk prediction, enabling real-time monitoring of disruptions, enhancing decision-making speed and accuracy, and supporting rapid recovery and adaptability in times of uncertainty. Furthermore, the study concluded that several Artificial Intelligence technologies, including machine learning, predictive analytics, Artificial Intelligence of Things (AIoT), digital twins, and prescriptive analytics, are widely applied in modern supply chain systems to enhance both sustainability and resilience outcomes. However, despite these benefits, the adoption of Artificial Intelligence in supply chain management is still constrained by challenges such as high implementation costs, inadequate digital infrastructure, lack of technical expertise, poor data quality, cybersecurity risks, and issues related to transparency and trust in AI systems. Generally, the study concluded that although Artificial Intelligence has not yet been fully optimized in supply chain operations, it remains a critical enabler of sustainable and resilient supply chain performance. Its effective implementation has the potential to transform traditional supply chain systems into more adaptive, efficient, environmentally responsible, and disruption-resistant networks.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Organizations should adopt Artificial Intelligence systems to improve supply chain sustainability by enhancing resource efficiency, reducing waste, and supporting environmentally friendly operations across all supply chain activities.

2. Supply chain managers should integrate Artificial Intelligence tools such as machine learning, predictive analytics, and digital twins to strengthen supply chain resilience and improve response to disruptions and uncertainties.
3. Organizations should invest in the development and deployment of advanced Artificial Intelligence technologies, including Artificial Intelligence of Things (AIoT) and prescriptive analytics, to improve real-time visibility and decision-making in supply chain operations.
4. Governments, policymakers, and private sector stakeholders should provide adequate support through funding, infrastructure development, and training programs to promote effective adoption of Artificial Intelligence in supply chain management.
5. Organizations should address key implementation challenges by improving data quality, strengthening cybersecurity systems, and building the capacity of employees through continuous training on Artificial Intelligence applications in supply chain management.

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