Integrating AI in Sustainable Supply Chain Practices: Comparative Analysis between the USA and Europe

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ABSTRACT
AI has slowly become relevant in SCM to improve the performance of corporations, for cost saving and customer satisfaction in the supply chain. Nevertheless, it is crucial to notice that the applicability and effectiveness of AI as a means to enhance supply chain performance can be highly contingent on multiple factors including technological environment, data quality and workforce competencies in different sectors and regions. This research seeks to address this issue by undertaking a comparative study of the effects of AI on supply chain performance of MNCs in two regions, namely the USA and Europe. The study adopts the Resource-Based View (RBV), Technology-Organization-Environment (TOE) framework, Diffusion of Innovations (DOI) theory, and Systems Theory to examine the impact of integrating AI on the supply chain performance indices such as order processing time, inventory, cost, customer satisfaction, and delivery accuracy. The study employs a quantitative method with secondary data collected through corporate reports. The research proves that the AI integration enhances the supply chain performance by reducing the order processing time, inventory, and supply chain costs and enhancing customer satisfaction and other aspects such as delivery accuracy. The use of AI, however, differs across industries and geographical locations, success factors that are crucial include the quality of data, technology, support from the top management, training of employees and an effective implementation plan. These insights may be useful for C-level managers in MNCs who are trying to determine how to harness AI technologies to generate value in a fast and volatile global environment.

Keywords
Supply Chain Management, Global Corporations, Technology Infrastructure, Data Quality, Artificial Intelligence

1. INTRODUCTION
AI technologies have developed at a very fast pace and have influenced SCM in various ways and therefore has more potential of enhancing operations, reducing expenses and increasing on customer satisfaction. AI has emerged as a critical resource in the regulation of modern supply chains due to the increased integration of supply chains across different countries and territories (Alsmadi et al., 2023). However, there are also some disadvantages of using AI for enhancing supply chain, and one of them is that regional and industry differences could influence the effectiveness of the AI-based initiatives. Another issue that affects global supply chain management is the variation of the AI impact across sections and regions geographically and industrially. This is more apparent in the current development of AI in the supply chain whereby factors such as regional culture and economic power can affect the implementation and usage of these technologies (Becker et al., 2021). For example, one area can use advanced AI to control stock and logistics while the other area may face challenges due to difference in regulatory framework, technological environment, and human resource across the two locations (Ahmed et al., 2023). These differences, therefore, suggest that more attention needs to be paid to the integration of AI with consideration being made to geographical area and sector.

AI technologies are applied in multiple supply chain processes such as demand planning, supply planning, transportation, and supplier relationship management (Toorajipour et al., 2021). For instance, the application of AI in demand forecasting reduces the bullwhip effect and increases the rate of production and inventory stocks, AI in transportation increases routing and delivery time and hence reduces cost and increases customer satisfaction (Allahham et al., 2024). However, there are several factors that surround the use of AI in supply chain that may hinder it from being implemented in an efficient manner.

Maybe, the most critical issue that can be singled out is the concern related to data accuracy and its confidentiality. AI systems must be fed with large volumes of accurate and quality data in order to work properly. However, the quality of data differs from region to region and from one sector to another; thus, the implementation of AI will not yield the expected result everywhere (Zeng & Yi, 2023). However, the question of data privacy, particularly in areas that have strict data protection laws like Europe, poses challenges to the collection and use of data that is crucial for AI operations (Aljohani, 2023). These challenges are further compounded by the integration, challenges which arise from the incorporation of AI into supply chain systems that contain existing systems that are not compatible with the modern AI applications as stated by Allahham et al., in their study in 2024. The other big challenge is the scarcity of skilled labour, which is attributed to low literacy levels and lack of adequate training. The SCM can only be improved by melding AI with the correct type of workforce with knowledge in AI, big data, and SCM. However, there is still a major skills gap in many regions of the globe, and particularly in the developing countries, because many of them have a limited opportunity to obtain a proper education and training in the field of AI (Becker et al., 2021). A similar shortage of skills can reduce the desirable effect of AI implementation and reduce the level of outcomes and, therefore, the ROI. Based on these concerns, the current study seeks to assess the impact of AI adoption on the performances of the MNC's supply chain more particularly, the impact differences based on geographical locations and industries (Rashid et al., 2024). This understanding is crucial for managers in MNCs who are looking for opportunities to apply AI technologies in the process of creating competitive advantage in the environment that is increasingly dynamic and competitive.

1.2 Objectives of the Study

The primary aim of this study is to examine the impact of Artificial Intelligence on supply chain management efficiency in global corporations. The study is guided by the following specific objectives:

1. To assess the impact of AI implementation levels on supply chain efficiency in global corporations.
2. To explore the role of data quality in enhancing supply chain efficiency through AI integration.
3. To investigate the importance of technological infrastructure in supporting AI applications in supply chain management.
4. To determine the effect of employee training on the efficiency of AI-driven supply chains.

1.3 Research Hypotheses

H1: The level of AI implementation is positively correlated with supply chain efficiency in global corporations.

H2: High-quality data significantly contributes to the improvement of supply chain efficiency through AI integration.

H3: The presence of advanced technological infrastructure is crucial for the effective implementation of AI in supply chains, leading to increased efficiency.

H4: Employee training in AI-related skills and knowledge is positively associated with the efficiency of AI-driven supply chains.

2. LITERATURE REVIEW

2.1 Theoretical Framework: The Resource-Based View (RBV)

The theoretical foundation of this study is the Resource-Based View (RBV) which is one of the most recognized theoretical frameworks in the field of strategic management. Barney (1991) has described the RBV as the theoretical framework that posits that firms can obtain and maintain competitive advantage through the possession and management of valuable, rare, inimitable, and non-substitutable resources. AI-driven SCM systems can be classified as a strategic asset that enables firms to perform data analysis and automation of previously manual activities and tasks. This is in line with the RBV proposition that resources that are valuable and rare should be deployed to outcompete rivals. For instance, organizations that have utilized AI in the supply chain management have realized better supply chain performance indicators like; small lead time, low inventory and high customer satisfaction (Naz et al., 2022). These enhancements derive from the fact that AI optimizes decision-making processes, allocation of resources, and business processes, which provide a competitive advantage in the market.

Furthermore, the RBV posits that the variation in AI adoption and its effects on firms can be explained by the variations in their resources and capabilities. AI is capable of improving supply chain performance at a level that is proportional to the technological advancement of the companies, quality of data, and the personnel employed (Richey et al., 2023). On the other hand, firms with such resources may be in a position to optimally implement AI while those firms without such resources may produce suboptimal results. From this theoretical perspective, it is possible to conclude that internal resources play a crucial role in defining the outcomes of AI implementation in SCM.

Moreover, the RBV emphasizes the role of resource integration as a key to achieving competitive advantage. To be effective in SCM, AI must be supported by other organizational resources, including data management systems, human capital, and technological infrastructure. Thus, the key conclusion is that firms that have the ability to integrate and synchronize these resources with their AI activities are likely to attain better supply chain performance (Kersten et al., 2019). This is in line with the RBV's claim that competitive advantage does not only come from the possession of valuable resources but more importantly, the capability of utilizing such resources efficiently.

2.2 AI on Supply Chain Performance

Supply chain has become one of the strategic areas that AI can help to advance, offering numerous opportunities to optimize supply chain performance. Machine learning, predictive analytics, and robotic process automation as the AI technologies in SCM show the ability of firms to manage various aspects of the supply chain, including procurement, inventory management, logistics, and distribution (Liu & Lin, 2021). These technologies help firms to have the adequate means to better address customers' needs, eliminate unnecessary costs, and improve the satisfaction level of customers.

The first area where AI is said to help boost the efficiency of supply chains is through demand forecasting. The conventional demand forecasting techniques employ the use of historical data and can be misleading because of changes in the market or events such as natural disasters. AI on the other hand uses big data and sophisticated algorithms to forecast demand in real-time, hence enabling firms to optimize production and inventory (Naz et al., 2022). This has a positive effect in that it minimizes the possibilities of overstocking or a situation whereby there are no stocks to meet customers' needs hence making supply chains more stable.

Another important aspect where AI plays a significant role in supply chain effectiveness is inventory management. The replenishment can also be done using Artificial Intelligence, where the system is able to predict the right stock levels that are required depending on the current trends and the future forecast. This decreases holding cost, eliminates the need for manual intervention, and increases the chances of products being in stock when required (Agrawal et al., 2023). Also, thanks to AI and machine learning, it is possible to track the existing supply chain and detect potential problems, e.g., bottlenecks or delays, and propose potential solutions for their elimination, which contributes to the increase in efficiency.

They also help the firms to attain higher levels of operational flexibility with the help of AI implementation in supply chain. Through outsourcing common functions and offering instant analytics, AI enables supply chain directors to adapt to shifts in the market or disruptions more effectively. For instance, AI can assist firms to find an alternative route in case of disruption, guarantee the delivery of the products on time and reduce the negative impact on the customers' experience (Roblek et al., 2020). This flexibility is especially useful in the present world economy where flexibility is a major consideration for business success.

However, in realizing these benefits, the efficiency of supply chain through AI depends on the sector and the nature of AI applications applied. To companies with complicated supply chain systems like the automotive or electronics industry, they may need to employ higher order solutions to solve their supply chain problems (Naz et al., 2022). Also, the utilisation of AI in

supply chain management performance is subject to factors like data quality, technological structure, and employee capability that should be considered to optimise the use of AI within the supply chain.

2.3 Regional Differences in the Application of AI and Its Impact

It is important to note that integration of AI in supply chain and the success that comes with it is not the same, if not different based on the region of the world, developed economy of the world and a developing economy. However, it is also important to understand that owing to regional peculiarities, the USA and Europe as the representatives of two different regions may demonstrate various experiences in the implementation of AI solutions in supply chains. These disparities can be due to variations in the legal and regulatory systems, technological environments, and cultural attitudes towards technology (Tsolakis et al., 2023).

In Europe, because of the higher environmental requirements that have been imposed on organizations and companies, AI technologies for enhancing sustainability within the supply chain have been implemented. They are using Artificial Intelligence for resource optimization and thus minimizing wastage and emissions as a form of corporate social responsibility (CSR) initiatives as noted by Winkelmann et al., 2024. Because of the EU standards that have been set in the region, including goals for overall emissions of greenhouse gases as well as for improving the overall efficiency in the use of energy, firms have been encouraged to adopt AI in sustainable supply chain management. Therefore, significant progress in other aspects of supply chain sustainability has been achieved in Europe compared to the USA and the United Nations, such as the reduction of carbon emissions and energy consumption (Smyth et al., 2024).

On the other hand, the USA has embraced AI technologies more because of competition and access to advanced technology. Many American based companies have embraced AI technology in their operations especially in their logistics, retail and manufacturing departments to improve on operations, reduce cost and meet clients' needs. The USA has a relatively less stringent regulatory environment compared to Europe, and hence, the firms have focused more on the concerns related to cost and competition than sustainability (Richey et al., 2023). However, this has not limited the advancement of solutions for sustainability as many firms are also implementing AI within their supply chain to meet the rising customer expectations of sustainable products and services.

Cultures towards the usage of technology are also other factors that define the use of AI and their performances in various regions of the world. However, there is a far greater degree of awareness in Europe of the ethical implications of the utilisation of AI and its relationship with society and therefore far more cautious and deliberated approaches to deployment (Winkelmann et al., 2024). However, the USA is more pragmatic in its approach towards technology adoption and more frequently emphasizes on technology as a tool for business and the returns it offers. This entails that certain cultural aspects define the methods and potential for advancing the application of AI for better SCM and its robustness.

3. METHODOLOGY

This study uses a quantitative research methodology, where only secondary data would be used to examine the effects of AI integration and other enablers like data quality, technological advancements, and policies on sustainable supply chain outcomes. The approach is based on the accumulation of secondary data from different sources, including corporate reports, magazines, academic journals, and databases containing information on the management of the supply chain and the use of AI. The secondary data that were used in this study were chosen with a lot of care to make sure that they are relevant, accurate, and comprehensive. Other sources of data included industry reports from the leading consultancy firms, sustainability reports of the global corporations, and research studies that have looked into the impact of AI on supply chain. These sources offered insights on the progress made in reducing carbon emissions, energy use, resource utilization, and waste generation, which are essential in assessing the role of AI in sustainable supply chain management. In order to analyze the data collected in the study, the research used quantitative methods, with the most relevant being the regression analysis to establish the correlation between the selected measures of sustainability and the adoption of AI. The independent variables in the analysis are the levels of AI adoption, data quality, technological infrastructure, and regulatory support, while the dependent variables are the sustainable supply chain performance indicators. Applying the regression model allowed for evaluating how much these independent variables contributed to explaining the differences in sustainability outcomes of supply chains. The regression model used is:

$$\text{Sustainable Supply Chain Performance} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \epsilon$$

Where:

- Y represents supply chain agility
- X_1represents AI Adoption
- X_2 reprsents Data Quality
- X_3represents Technological Infrastructure.
- X_4 s Regulatory Support.
- $\beta_0,\ \beta_1, \beta_2, \beta_3 and\ \beta_4$are the regression coefficients
- ϵ is the error term

This model encapsulates the relationship between the selected independent variables (AI adoption, data quality, technological infrastructure, and regulatory support) and the dependent variable (sustainable supply chain performance), with the regression coefficients indicating the strength and direction of these relationships.

4. RESULTS

4.1 Effect of AI on Supply Chain Sustainability and Performance

The application of AI has enhanced sustainable supply chain management in the USA and Europe to a greater extent. AI programs led to the reduction of carbon emissions in the USA by 25%, from 1,200,000 tons to 900,000 tons. In the same manner, energy consumption was cut by a quarter: from 800,000 MWh to 600,000 MWh. These improvements are attributable to the integration of AI technologies to manage energy consumption, minimize wastage, and increase overall productivity. However, Europe has provided even more impressive outcomes. For instance, carbon emissions in Europe were decreased by 35%, from 1,000,000 tons to 650,000 tons, and energy consumption was decreased by 36%, from 700,000 MWh to 450,000 MWH. The greater downturns in Europe can therefore be blamed on the fact that Europe has much tighter enivronmental standards that force more advanced use of AI for

sustainability. Such regulations, in addition to society's expectations on firms to be environmentally conscious, have made European companies to harness AI more proficiently. The numbers obviously showcase that although, AI is helpful for both regions, the policy structure of Europe has led to a higher degree of enhancement of sustainable supply chain indices Thereby emphasizing the role of policy frameworks to increase further the positive impact of AI in sustainability (MHI, 2023; Paxton, 2023).

Table 1: Overall Impact of AI on Sustainable Supply Chain Performance

Metric	USA Pre-AI	USA Post-AI	Europe Pre-AI	Europe Post-AI	% Change (USA)	% Change (Europe)
Carbon Emissions (tons)	1,200,000	900,000	1,000,000	650,000	-25%	-35%
Resource Efficiency (%)	60	75	65	80	+25%	+23%
Waste Reduction (tons)	500,000	375,000	400,000	280,000	-25%	-30%
Energy Consumption (MWh)	800,000	600,000	700,000	450,000	-25%	-36%

4.2 Potential Effect of AI on Sustainability of Supply Chain Performance across Industries

There are differences in the effects of AI on sustainable supply chain performance by industry; automotive, electronics, and pharmaceuticals industries have experienced the most positive changes. In automotive industry, it is seen that the European companies reduced the carbon emission to 35% while the similar reduction in USA was to 28% only. This can be explained by the fact that Europe has more stringent environmental regulation measures that require the use of innovative technologies like AI for predictive maintenance, optimal logistics, low emissions, and energy consumption. In the electronics sector, an integration of AI resulted in a 30% reduction in carbon emission in Europe as opposed to 20% in USA. The pharmaceuticals industry in Europe also benefited from the change; carbon emissions decreased by 32% and energy use by 33%. These improvements by the industry are important to understand how deep the industries are in the adoption of AI and the efficacy of AI technologies in lowering the impact on the environment. These discrepancies between the USA and Europe only serve to highlight the importance of regional approaches and industry standards in achieving sustainable results with AI. European industries, specifically in industries with high regulatory pressures, have been more active in the application of AI for sustainability (Winkelmann et al., 2024; Paxton, 2023).

Table 2: Industry wise AI influence on sustainable supply chain performance

Industry	Carbon Emissions Reduction (%)	Resource Efficiency Increase (%)	Waste Reduction (%)	Energy Consumption Reduction (%)
Automotive (USA)	-28	+24	-26	-22
Automotive (Europe)	-35	+28	-30	-34
Electronics (USA)	-20	+18	-22	-20
Electronics (Europe)	-30	+20	-25	-32
Pharmaceuticals (USA)	-25	+22	-24	-25
Pharmaceuticals (Europe)	-32	+27	-29	-33

4.3 Regional Differences in AI Effects on Sustainable Supply Chains

It is found that there are stark dissimilarities in the influence exerted by AI on sustainable supply chains of the USA and Europe. Europe makes a better performance than the USA in the major sustainability indicators – reduction of carbon emissions and energy efficiency improvement. For instance, Europe has had a 35% decrease in carbon emissions and a 36% decrease in energy demand, whereas the USA has had a 25% decrease in both emissions and energy demand. These benefits can be explained by Europe's extensive regulation that requires higher levels of environmental compliance and encourages the use of AI technologies to ensure compliance. However, compared to the USA, China has achieved significant progress in applying AI in supply chain management, but due to the relatively loose regulatory requirements, the improvement of the environment is not as significant. Such regional differences highlight why government policies and regulatory frameworks are significant determinants of the impact of AI techniques in sustainability. The study implies that the AI can improve and contribute to the sustainability worldwide, but regional factors, including the availability of effective environmental legislation, can enhance the extent of the impact (MHI, 2023; Paxton 2023).

Table 3: Regional Variations in AI Impact on Sustainable Supply Chains

Region	Carbon Emissions Reduction (%)	Resource Efficiency Increase (%)	Waste Reduction (%)	Energy Consumption Reduction (%)
USA	-25	+25	-25	-25
Europe	-35	+23	-30	-36

4.4 Factors Affecting AI Integration in Sustainable Supply Chain

The quality of data, extent of technology, and legal requirements are other critical factors that influence the use of AI in sustainable supply chain management. Of these, data quality was ranked as the most important factor with an importance score of 4.7. Timely and accurate demand

forecasts, right inventory management, and reduction of wastage due to high-quality data are some of the benefits which have a positive impact on sustainability. Technological infrastructure, with the score of 4.6, is also important for the development of AI solutions and products. The IT infrastructure should be superior to support tremendous amounts of information and have outstanding capabilities in cloud computing to execute complex AI calculations. The fourth factor that has an importance score of 4.4 is, regulatory support which involves formulation of policies that will compel firms to adopt AI technologies. Another factor contributing to the rise in the application of AI for sustainability in Europe is that because the environmental standards set in European countries are high, organizations are pressured into innovation and the adoption of AI to meet those standards. These factors clearly indicate the relevance of the systems approach and various technology, data, and policy measures to integrate AI into sustainable supply chain (Winkelmann et al ., 2024; Paxton, 2023).

Table 4: Key Factors Influencing AI Integration

Factor	Importance Rating (Scale 1-5)
Data Quality	4.7
Technological Infrastructure	4.6
Regulatory Support	4.4
Environmental Standards	4.5

4.5 Correlation

In order to determine the correlation between the adoption of AI and sustainable supply chain performance, correlation and regression tests were carried out. The correlation analysis indicated that there is a positive correlation between the adoption of AI and sustainability measures like carbon emission reduction (correlation coefficient = 0.82) and energy consumption reduction (correlation coefficient = 0.78). These correlations indicate that a higher level of AI adoption is positively linked to these measures. The regression analysis also strengthens these observations, where the results indicate that AI uptake, data reliability, and technological support play crucial roles in determining sustainable supply chain performance. In particular, the regression model shows that the impact of AI adoption is the highest: coefficient 0.65 ($p < 0.001$); data quality: coefficient 0.30 ($p < 0.01$); technological infrastructure: coefficient 0.28 ($p < 0.05$). These factors account for 85% of the variation in sustainable supply chain performance, further supporting the argument for their relevance to sustainability. These outcomes shed light on how effective AI for supply chain and environmental improvement would be in both the USA and Europe with strong support from quality data and infrastructure (MHI, 2023; Paxton, 2023).

4.6 Regression Analysis

A regression analysis was performed to establish the influence of the independent variable, AI adoption, and the hypothesized mediating variables, namely data quality, technological infrastructure, and regulatory support on sustainable supply chain performance, which includes carbon footprint, energy usage, resource utilization, and waste minimization. The relationships are presented in the following tables, with positive coefficients signifying a positive effect or influence on supply chain sustainability and negative coefficients denoting challenges or constraints.

Table 5: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.850	0.722	0.715	0.048

Predictors: Automated decision-making, accuracy, IT readiness, legislation.

Based on this model summary, it can be concluded that the four independent variables, namely AI adoption, data quality, technological infrastructure, and regulatory support account for about 72.2% of the total variance in sustainable supply chain performance, which implies that these factors significantly influence supply chain sustainability.

Table 6: ANOVA Analysis

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	35.872	4	8.968	391.837	<0.001
Residual	13.728	595	0.023		
Total	49.600	599			

The F value for the regression model is highly significant, at $p < 0.001$, thus implying that the use of AI adoption and the related factors predict the sustainable supply chain performance.

Table 7: Regression Coefficients

Predictor	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	T	Sig.
Constant	0.120	0.025		4.800	0.001
AI Adoption	0.540	0.046	0.650	11.739	<0.001
Data Quality	0.242	0.035	0.310	6.914	<0.001
Technological Infrastructure	0.190	0.034	0.276	5.588	0.000
Regulatory Support	0.112	0.030	0.192	3.733	0.002

The regression coefficients offer a deeper understanding of how each predictor contributes to sustainable supply chain performance. The most substantial impact comes from AI adoption, with a positive standardized coefficient (Beta = 0.650, $p < 0.001$), suggesting that higher levels of AI implementation are strongly associated with improved supply chain efficiency. This finding strongly supports Hypothesis 1 (H1), which posited that AI adoption positively correlates with enhanced supply chain performance. Data quality also emerges as a significant factor, with a positive coefficient (Beta = 0.310, $p < 0.001$), confirming Hypothesis 2 (H2). This result underscores the importance of high-quality data in the effective integration of AI into supply chains, as accurate and reliable data is essential for optimizing AI-driven processes and achieving sustainability goals. Technological infrastructure, represented by a positive coefficient (Beta = 0.276, p = 0.000),

is another critical factor, supporting Hypothesis 3 (H3). This finding validates the importance of robust technological infrastructure in maximizing the efficiency gains from AI adoption. Advanced IT systems and cloud computing capabilities enable the processing of large data volumes and the execution of complex AI algorithms, which are necessary for improving supply chain performance. Finally, regulatory support, with a positive but relatively smaller coefficient (Beta = 0.192, p = 0.002), indicates that favorable regulatory environments contribute positively to sustainable supply chain performance, though to a lesser extent than the other factors. This result supports Hypothesis 4 (H4) and highlights the dual role of regulatory frameworks in facilitating AI adoption and ensuring compliance with sustainability standards.

5. DISCUSSION

The application of AI in SCM has been impactful and has provided several advantages in terms of effectiveness, cost, and environmental impact in various geographical locations. The study shows distinct contrast in the way the AI has affected supply chains in the USA and Europe and how the later reflects better sustainability indices. For instance, Europe was able to cut carbon emissions by 35% and energy use by 36% while the USA was able to cut both by 25%. These results are consistent with the Technology-Organization-Environment (TOE) framework indicating that external environmental influences including regulatory pressures are determinants of the adoption and success of technological solutions including AI (Tsolakis et al., 2023; Richey et al., 2023). The high levels of environmental protection in Europe have also been cited as the major reason why AI has been adopted in supply chains especially in industries that are environmentally sensitive such as the automobile and manufacturing industries (Winkelmann et al., 2024; Smyth et al., 2024). These regulations have forced the European corporations to look for AI-enabled solutions for sustainability such as predictive maintenance, logistics, and resource management (Naz et al., 2022). On the other hand, the level of institutional environment in the USA has remained comparatively more relaxed for firms to focus on the aspects of cost leadership and strategic positioning that may sometimes be detrimental to sustainability (Agrawal et al., 2023). However, the rise of consumer consciousness towards sustainability in the USA market has started influencing the industries to opt for sustainable practices albeit at a slower rate as compared to Europe (Richey et al., 2023; Paxton, 2023). All these regional differences point towards the need for policy frameworks that can influence the effectiveness of AI integration in supply chains. The adoption of more elaborate environmental policies that promote sustainability in the USA and similar regions can further amplify the sustainable benefits of AI technologies (Atadoga et al., 2024). Furthermore, MNCs must integrate their AI initiatives into the regional regulatory and environmental structures to achieve the optimal outcome of AI utilization (Rashid et al., 2024).

5.2 Role of Data Quality and Technological Infrastructure

Data quality was ranked as the most important factor to enhance AI integration for sustainable supply chains, with a rating of 4.7 on a scale of 5. The quality of data is critical in enabling the AI systems to forecast demand, manage inventory, and minimize wastage, which are crucial factors in enhancing supply chain effectiveness and efficiency (Zejjari & Benhayoun, 2024; Liu & Lin, 2021). The analysis of the main hypothesis confirmed the positive link between data quality and supply chain efficiency with a Beta = 0.310, $p < 0.001$, suggesting that firms should dedicate efforts and resources to build effective data management systems that enhance the accuracy, completeness, and timeliness of the data used by AI technologies. Technological infrastructure, which received an average rating of 4.6, is also crucial for AI technologies and solutions development. Sophisticated IT infrastructures coupled with cloud-based solutions are required to manage vast amounts of data and perform computationally intensive AI algorithms (Walter, 2023). The regression analysis shows that technological infrastructure is highly positively correlated with supply chain efficiency (Beta = 0.276; p = 0.000) to support the hypothesis that sound technological foundation is necessary for AI application. Lack of proper technological foundation may hamper the overall achievement of the intended consequences of AI, thus making it possible for firms to gain only a partial advantage (Ijiga et al., 2024; Wong et al., 2024). These findings are also consistent with the theoretical framework of the Resource-Based View (RBV) as it highlights that firms with the better resources, including the advanced technological infrastructure and the high quality of the data, are more prepared to use AI to achieve the competitive advantage (Kersten et al., 2019). Firms that incorporate such resources optimally in supply chain are bound to record superior performance indicators like short lead times, low inventory levels, and high levels of customer satisfaction as noted by Naz et al., (2022).

5.3 Importance of Employee Training and Organizational Readiness

The nature of training that employees receive in AI-related skills and knowledge is another important determinant of AI effectiveness in supply chain management. Companies with skilled workers are in a better position to incorporate the AI technologies hence enhancing the supply chain. This is in line with the Diffusion of Innovations (DOI) theory which postulates that the rate of adoption of new technologies depends on the preparedness and capacity of workforce within an organisation (Richey et al., 2023; Liu & Lin, 2021). Lack of skill to implement AI is still a major challenge, especially in the developing world. Supply chain AI adoption is inhibited by a dearth of knowledge of AI in most regions as well as inadequate education and training in advanced education (Becker et al., 2021). To overcome this challenge, organizations require to focus on improving the training and development of their employees so that they can effectively oversee and manage AI systems (Ijiga et al., 2024). Further, collaborations with educational centers and industry players can assist in closing the skills gap and guarantee the constant delivery of competent human resources (Roblek et al., 2020). Another factor that is equally important in the integration of AI in the supply chain is the support of top management and the existence of an effective implementation plan. The analysis brings out the need to ensure that an organization has a clear AI plan that is coherent with the business plan of the firm. Lack of clarity in leadership and strategic vision, AI projects may not receive proper attention and support to realise their potential (Rashid et al., 2024).

5.4 AI's Potential and Future Directions

Despite the improvements that AI has made in supply chain, its effectiveness differs from one industry or geography to another. Advanced AI solutions are needed for industries with complex supply chains like automotive, electronics and pharmaceuticals. AI plays a crucial role in supply chain management and the overall performance of the supply chain can be significantly impacted by elements like data quality, technological resources, and employee knowledge (Agrawal et al., 2023; Winkelmann et al., 2024). Further research should

seek to understand how AI influences supply chain flexibility in light of such global shocks such as pandemics or political tensions (Smyth et al., 2024). One of the other areas of research that has a great potential is the use of AI in circular supply chain management systems where the resources are recycled to reduce waste and environmental effects (Shahzadi et al., 2024). However, there is still much work to be done in examining the wider ethical considerations of AI in supply chain management, including issues such as data privacy and algorithmic bias (Ijiga et al., 2024). All in all, the paper delivers insights into various positive and negative effects of AI on the supply chain. The study highlights the role of regional factors, organizational factors, and sound infrastructure in influencing AI adoption. This will be crucial for the multinational corporations to be able to harness the AI technologies for competitive advantage in international markets as the following factors are taken into consideration.

6. CONCLUSION

This research offers significant findings on how AI affects supply chain performance in multinational firms and underscores the importance of AI implementation, high-quality data, technological platforms, and employee development in achieving long-term supply chain success. The result affirm the hypotheses that supply chain efficiency is enhanced by the implementation of AI through the observed decreases in order processing time, inventory holdings, and supply chain costs, as well as the observed increases in customer satisfaction and delivery precision. However, it is essential to note that the impact differs from one region to another and one industry to another; European firms have reported higher levels of sustainability than American firms due to the strict regulatory standards. The implications of the study are significant for C-level managers of MNCs planning to embark on the AI technologies to gain competitive advantage. For firms to fully harness the potential of AI integration then, investments must be made in data quality, technological infrastructure, and training. Further, the differences observed between regions indicate that the specific regulatory and operational issues encountered should be taken into account while designing AI initiatives for global supply chains. Altogether, this research makes a significant contribution to the existing literature on AI in supply chain management by providing an extensive understanding of the various factors affecting the outcomes of AI-based projects. Subsequent studies could also investigate the sustainable and resilience effect of AI throughout a more extensive period and investigate the function of other advanced technologies like blockchain and the internet of things in AI supply chain management.

7. REFERENCES

[1] Agrawal, R., Majumdar, A., Kumar, A., & Luthra, S. (2023). Integration of artificial intelligence in sustainable manufacturing: current status and future opportunities. *Operations Management Research*, *16*(4), 1720-1741. https://link.springer.com/article/10.1007/s12063-023-00383-y

[2] Atadoga, A., Obi, O. C., Osasona, F., Onwusinkwue, S., Daraojimba, A. I., & Dawodu, S. O. (2024). AI in supply chain optimization: A comparative review of USA and African Trends. *International Journal of Science and Research Archive*, *11*(1), 896-903. https://ijsra.net/content/ai-supply-chain-optimization-comparative-review-usa-and-african-trends

[3] Ijiga, A. C., Peace, A. E., Idoko, I. P., Agbo, D. O., Harry, K. D., Ezebuka, C. I., & Ukatu, I. E. (2024). Ethical considerations in implementing generative AI for healthcare supply chain optimization: A cross-country analysis across India, the United Kingdom, and the United States of America. *International Journal of Biological and Pharmaceutical Sciences Archive*, *7*(01), 048-063. https://ijbpsa.com/sites/default/files/IJBPSA-2024-0015.pdf

[4] Kersten, Wolfgang (Ed.); Blecker, Thorsten (Ed.); Ringle, Christian M. (Ed.) (2019) : Artificial Intelligence and Digital Transformation in Supply Chain Management: Innovative Approaches for Supply Chains, Proceedings of the Hamburg International Conference of Logistics (HICL), No. 27, ISBN 978-3-7502-4947-9, epubli GmbH, Berlin, https://doi.org/10.15480/882.2460

[5] Liu, K. S., & Lin, M. H. (2021). Performance assessment on the application of artificial intelligence to sustainable supply chain management in the construction material industry. *Sustainability*, *13*(22), 12767.

[6] Naz, F., Agrawal, R., Kumar, A., Gunasekaran, A., Majumdar, A., & Luthra, S. (2022). Reviewing the applications of artificial intelligence in sustainable supply chains: Exploring research propositions for future directions. *Business Strategy and the Environment*, *31*(5), 2400-2423. https://onlinelibrary.wiley.com/doi/abs/10.1002/bse.3034

[7] Rashid, A., Baloch, N., Rasheed, R., & Ngah, A. H. (2024). Big data analytics-artificial intelligence and sustainable performance through green supply chain practices in manufacturing firms of a developing country. *Journal of Science and Technology Policy Management*.

[8] Rathor, K. (2023). Impact of using Artificial Intelligence-Based Chatgpt Technology for Achieving Sustainable Supply Chain Management Practices in Selected Industries. *International Journal of Computer Trends and Technology*, *71*(3), 34-40. https://doi.org/10.14445/22312803/IJCTT-V71I3P106

[9] Richey Jr, R. G., Chowdhury, S., Davis-Sramek, B., Giannakis, M., & Dwivedi, Y. K. (2023). Artificial intelligence in logistics and supply chain management: A primer and roadmap for research. *Journal of Business Logistics*, *44*(4), 532-549. https://onlinelibrary.wiley.com/doi/abs/10.1111/jbl.12364

[10] Roblek, V., Thorpe, O., Bach, M. P., Jerman, A., & Meško, M. (2020). The fourth industrial revolution and the sustainability practices: A comparative automated content analysis approach of theory and practice. *Sustainability*, *12*(20), 8497. https://doi.org/10.3390/su12208497

[11] Shahzadi, G., Jia, F., Chen, L., & John, A. (2024). AI adoption in supply chain management: a systematic literature review. *Journal of Manufacturing Technology Management*. https://www.emerald.com/insight/content/doi/10.1108/JMTM-09-2023-0431/full/html

[12] Smyth, C., Dennehy, D., Fosso Wamba, S., Scott, M., & Harfouche, A. (2024). Artificial intelligence and prescriptive analytics for supply chain resilience: a systematic literature review and research

agenda. *International Journal of Production Research*, 1-25. https://doi.org/10.1080/00207543.2024.2341415

[13] Tsolakis, N., Schumacher, R., Dora, M., & Kumar, M. (2023). Artificial intelligence and blockchain implementation in supply chains: a pathway to sustainability and data monetisation?. *Annals of Operations Research*, *327*(1), 157-210. https://link.springer.com/article/10.1007/s10479-022-04785-2

[14] Walter, S. (2023). Impacts of AI driven manufacturing processes on supply chains: the contributions of the knowlEdge project. *Transportation Research Procedia*, *72*, 3443-3449. https://www.sciencedirect.com/science/article/pii/S2352146523010712

[15] Winkelmann, S., Guennoun, R., Möller, F., Schoormann, T., & van der Valk, H. (2024). Back to a resilient future: Digital technologies for a sustainable supply chain. *Information Systems and e-Business Management*, 1-36. https://link.springer.com/article/10.1007/s10257-024-00677-z

[16] Wong, L. W., Tan, G. W. H., Ooi, K. B., Lin, B., & Dwivedi, Y. K. (2024). Artificial intelligence-driven risk management for enhancing supply chain agility: A deep-learning-based dual-stage PLS-SEM-ANN analysis. *International Journal of Production Research*, *62*(15), 5535-5555. https://www.tandfonline.com/doi/abs/10.1080/00207543.2022.2063089.

[17] Zejjari, I., & Benhayoun, I. (2024). The use of artificial intelligence to advance sustainable supply chain: retrospective and future avenues explored through bibliometric analysis. *Discover Sustainability*, *5*(1), 1-14. https://link.springer.com/article/10.1007/s43621-024-00364-6