Journal of Management World **2025**, 3: 209-217
DOI: 10.53935/jomw.v2024i4.1109

Logistics Network Design for Sustainable Supply Chains: Evaluating Trade-Offs between Cost and Environmental Impact

Jannatul Ferdous[1*]

[1]Management Science and Supply Chain Management, Wichita State University, US; jannattushti2828@gmail.com (J.F.).

Abstract. Logistics network design leads to critical components in supply chain sustainability specifically in the United States since businesses aim to achieve reduced operational expenses together with decreased environmental impact. Since their initial inception as traditional transportation systems, logistics networks have gradually developed into worldwide systems which offer efficiency but cause raised environmental emissions and energy utilisation. The study evaluated the trade-offs between cost efficiency and environmental sustainability in logistics network design, particularly examining how different operational decisions affect both logistics cost and carbon emissions. A primary quantitative approach was adopted by the research, which utilised data obtained from 380 representatives of logistics companies operating in the USA, and a survey questionnaire was utilised. SmartPLS software analysed direct and indirect relationships between independent and dependent variables during the data evaluation process. Sustainable logistics procedures decrease environmental damage, but expenses typically rise in the process. The examination discovered that inventory management, together with sustainability initiatives, create a major influence over carbon emissions and logistics expenses. Transportation mode selection demonstrated better effectiveness in lowering environmental emissions than it did in cutting costs down. The research established that organisations need to find effective ways to achieve financial efficiency while promoting sustainability. Strategic decisions made by companies need to maintain sustainability steps while avoiding competitive setbacks through an understanding that sustainable logistics practices generate lasting advantages. The sustainability of business logistics networks requires top priority while policymakers need to back sustainable logistics programs with both incentives and rules. More research is necessary to determine multiple variables that affect logistics network design.

Keywords: Carbon Emissions, Cost-efficiency, Environmental Sustainability, Logistics Costs, Logistics network design, Sustainable Supply Chain, Transportation Model Selection,

1. INTRODUCTION

Logistics network design plays a key role in shaping the sustainability of supply chains. As per Keramydas et al. (2017), the modern business environment demands that firms achieve operational effectiveness and environmental accountability. Supply chains generate substantial global carbon emissions, while the design structure of logistics systems creates direct outcomes for operationally released pollution into the environment. The proper arrangement of a logistics network delivers quick and efficient delivery of goods through supplier-consumer routes while prioritising environmental sensitivity (López-Castro & Solano-Charris, 2021). A sustainable logistics network design minimises environmental impacts through its design process to achieve or exceed operational performance targets.

Over the years, logistics systems have evolved from traditional point-to-point transportation operations into modern complex diverse network systems that frequently extend across national borders (Fazili, Venkatadri, Cyrus, & Tajbakhsh, 2017). These networks now display higher, easy-to-identify inefficiencies that produce greater resource usage, increased emission levels, and increased total expenses. As sustainability becomes increasingly important for businesses, it has added a critical element to logistics network development processes (Strandhagen et al. 2017). In the United States, businesses operate under dual requirements to reduce both operating expenses and their environmental emissions as they fulfil government standards and social expectations toward responsible environmental care (Ahmad et al. 2023). The main challenge for firms in the USA is to balance cost-efficiency and environmental sustainability. The activities within logistics networks produce major carbon emissions, energy usage, and waste production that result in global climate change. Stakeholders now focus on using logistics networks to decrease environmental impact while simultaneously achieving or surpassing regular supply chain performance results. As per Keerthana et al. (2023), the USA maintains a central role in world trade and commerce, thus showing substantial growth in consumption activities along with transportation-based emissions. Businesses conducting operations within the USA face mounting pressure from three sectors to lower their environmental impact. Despite market changes, organisations need to maintain competitive business by optimising their supply chains (Jangid, 2023).

Moreover, cost-effective logistics network design for American businesses represents the primary operational problem that must consider environmental consequences (Keramydas et al. 2017). According to Mittal, Krejci, & Craven (2018), logistics strategies in the past emphasised cost reduction through industry standards such as single centralised operation points and long-distance transportation and bulk shipping methods. These cost-reducing logistics strategies produce major negative environmental impacts because they cause elevated fuel usage and carbon emissions, together with heightened energy consumption at large centralised distribution centers. Any company that adopts cost-saving approaches through the least expensive transportation choices and non-environmental energy systems creates worse environmental harm while increasing its climate impact (Lundgren & Haavikko, 2023).

* Correspondence: jannattushti2828@gmail.com

Sustainable logistics operations that focus on reducing carbon emissions, adopting renewable energy, and minimising waste often incur higher costs (Khan et al. 2022). For instance, the implementation of electric vehicles, alternative fuel systems and energy-efficient warehouse solutions requires companies to allocate large capital investments before and during operation. According to Zowada and Ciesielska (2024), the challenge for organisations, especially small- and medium-sized enterprises, stems from their requirement to determine the investment level for sustainable logistics solutions versus the need to preserve operational efficiency. The growing need to comply with sustainability standards through environmental regulations and customer sustainability expectations forces businesses to fulfil emission reduction requirements while attaining sustainability certifications. The increased market interest in environmentally friendly products drives businesses to adopt sustainable approaches, while sustainable practices require proper planning with innovative investments for financial success (Lopes et al. 2022). Organisations need to discover methods to decrease emissions, enhance energy efficiency, minimise waste, and maintain affordable operations during their constant effort to maintain competitive advantage, regulatory compliance, and consumer satisfaction (Jangid, 2020). In this case, the study aims to explore and evaluate the trade-offs between cost-efficiency and environmental sustainability in logistics network design with a particular focus on companies operating in the USA. It examines the key factors affecting the cost and environmental impact of logistics networks in the USA. It assesses the trade-offs between cost-effectiveness and environmental sustainability in logistics network design.

The findings from the study possess significant implications for academic research and practical business applications. The study's findings will produce significant consequences affecting future logistics network development within the United States. Corporate strategy must incorporate sustainability as a key factor, so businesses will need to develop creative solutions to unite environmental priorities with their logistics execution without causing financial loss. Additionally, the findings from the study establish the fundamental structure for researchers to create new models as well as methodologies which optimise logistics networks. The findings may serve as a foundation for businesses, enabling better network logistical decisions between cost-effectiveness and environmental sustainability. Policy-making institutions and industry leaders can use this research to grasp the environmental obstacles and business prospects that emerge from integrating sustainability into their logistics systems. The recommendations from the study may lead to a transformation of logistics networks structured with companies prioritising sustainable practices. The transition will help companies choose cleaner technologies while enhancing transportation system efficiency and adopting superior waste management systems. The implemented changes will eventually result in major greenhouse gas emission reduction while simultaneously decreasing resource usage and supply chain ecological impact. The combination of competitive challenges and sustainability needs will be resolved through this research, which forces businesses to adopt ecologically responsible logistics approaches that balance financial performance.

2. METHODOLOGY

The study utilises primary quantitative research methods to analyse the relationship between sustainable supply chain network design and its linked environmental results and cost factors. The research investigates how different independent variables, including Transportation Mode Selection, Warehouse Location and Distribution Centers, Inventory Management and Optimization, Sustainability Initiatives (Green Technologies) and Total Logistics Cost and Carbon Emissions (CO_2), are dependent variables. The research design provides companies with a precise view of the trade-offs they experience during the optimisation of their logistics networks for both cost reduction and environmental performance. The research adopted a primary quantitative research approach through data collection from USA-based firms. This research has used a convenience sampling method to collect data from businesses that operate in logistics and supply chain management. The main justification for choosing convenience sampling is that it allowed the researcher to choose participants based on their accessibility and availability, thus achieving both practicality and high efficiency in data collection (Golzar, Noor, & Tajik, 2022).

The research survey collects data from 380 representatives across different logistics companies who hold positions as supply chain managers, logistics coordinators or operations managers. It utilises a structured survey as its data collection method, which is distributed electronically to the selected firms. The research instrument comprises questions about transportation choice along with warehouse placements, distribution points, inventory processes, and sustainable practices like green technologies, including electric vehicles with renewable power and efficient warehouse infrastructure. Survey participants submitted quantitative information regarding their logistics expenses from transportations and storage facilities and inventory management combined with emission data from their logistics systems. The research survey obtained vital details about how well sustainability initiatives align with their supply chain operational framework.

Moreover, the analysis of these variables relied on SmartPLS because it serves as an appropriate statistical method to solve complex models containing multiple variables. SmartPLS provides researchers with a valuable method to study direct impacts as well as indirect effects between independent and dependent variables within structural models (Ramayah et al. 2018). The analysis through PLS techniques enables evaluation of how logistics network design elements affect total logistics cost alongside carbon emission levels. The selected method proves ideal specifically because it enables researchers to construct models for intricate relationships when working with datasets that contain multiple predictor variables. PLS enables researchers to measure variable correlations along with their directional influences, thus producing comprehensive results about how different logistics operation factors affect cost-outcomes and environmental effects.

The research investigation includes transportation mode selection as an independent variable that represents the decision making process for organizational logistics transportation by companies among the available options (road, rail, air, sea). The selected transportation method remains essential for both cost and environmental outcomes due to different transportation systems displaying unique patterns of fuel usage and emission releases and operational expenses. Warehouse location and distribution centers represent a critical independent variable that affects transportation expenses yet controls energy consumption based on central or decentralized distribution methods. The optimization along with management of inventory stands as an important independent variable which leads to lower transportation expenses combined with better warehouse efficiency and diminished energy usage. The implementation of sustainability initiatives containing electric vehicles and renewable energy sources and energy-efficient facilities will decrease carbon emissions but increase logistics costs since initial investments are higher. The research investigates two dependent variables: total logistics cost as well as carbon emissions (CO_2). The total logistics cost includes both direct expenses and supporting costs that stem from transportation activities and warehousing requirements, inventory management needs and sustainability practice implementation expenses. Total carbon emissions of CO_2 serve as principal environmental indicators to measure the greenhouse gas output generated by logistics processes.

3. RESULTS

3.1. Measurement Model Using Confirmatory Factor Analysis

Table 1: Relaibility and convergent validity testing.

Constructs	Indicators	Factor Loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
Carbon Emission	CE1	0.831	0.901	0.902	0.772
	CE2	0.892			
	CE3	0.889			
	CE4	0.902	0.883	0.883	0.811
Inventory Management and Optimisation	IMO1	0.893			
	IMO2	0.925			
	IMO3	0.883	0.901	0.903	0.835
Sustainability Initiatives	SI1	0.907			
	SI2	0.934			
	SI3	0.900	0.894	0.905	0.825
Total Logistics Costs	TLC1	0.911			
	TLC2	0.933			
	TLC3	0.881	0.851	0.854	0.771
Transportation Mode Selection	TMS1	0.877			
	TMS2	0.905			
	TMS3	0.851			
Warehouse location and distribution centers	WLDC1	0.822	0.811	0.8183	0.727
	WLDC2	0.903			
	WLDC3	0.831			

The research by Brown (2015) demonstrates that principal component analysis serves as a vital tool to validate constructs through discriminant and convergent assessment in addition to reliability evaluation. The study measured latent variable reliability by using Cronbach's alpha and composite reliability and Kline (2023) suggested a minimum threshold of 0.7 as the standard. The data in Table 3 demonstrates the internal measurement quality of the applied items through reliability and convergent validity assessment. The measurement tools achieved excellent internal consistency based on Cronbach's alpha because Carbon Emission (0.883), Inventory Management and Optimisation (0.901), Sustainability Initiatives (0.894), and Total Logistics Costs (0.851) surpassed the essential threshold of 0.7. The construct reliability values which exceed 0.7 confirm the reliability of Carbon Emission (0.902), Inventory Management and Optimisation (0.903), Sustainability Initiatives (0.905), and Total Logistics Costs (0.854). Analysis of factor loadings validated the constructs according to Latan, Noonan and Matthews (2017) who established that valid indicators should exceed values of 0.6. The measurement items in Table 3 fulfill the validity criteria because their factor loadings for Carbon Emission (0.831) Inventory Management and Optimisation (0.883) Sustainability Initiatives (0.900) and from Total Logistics Costs (0.881) exceeded the 0.6 threshold. The verification procedure shows that every indicator properly reflects its underlying hidden construct. The research achieves robust convergent validity based on Average Variance Extracted (AVE) results because all constructs exceed the required threshold of 0.5: Carbon Emission (0.772) and Inventory Management and Optimisation (0.835) and Sustainability Initiatives (0.825) and Total Logistics Costs (0.771). The measurement model displays reliable and valid characteristics because of these results which accurately represent the study constructs.

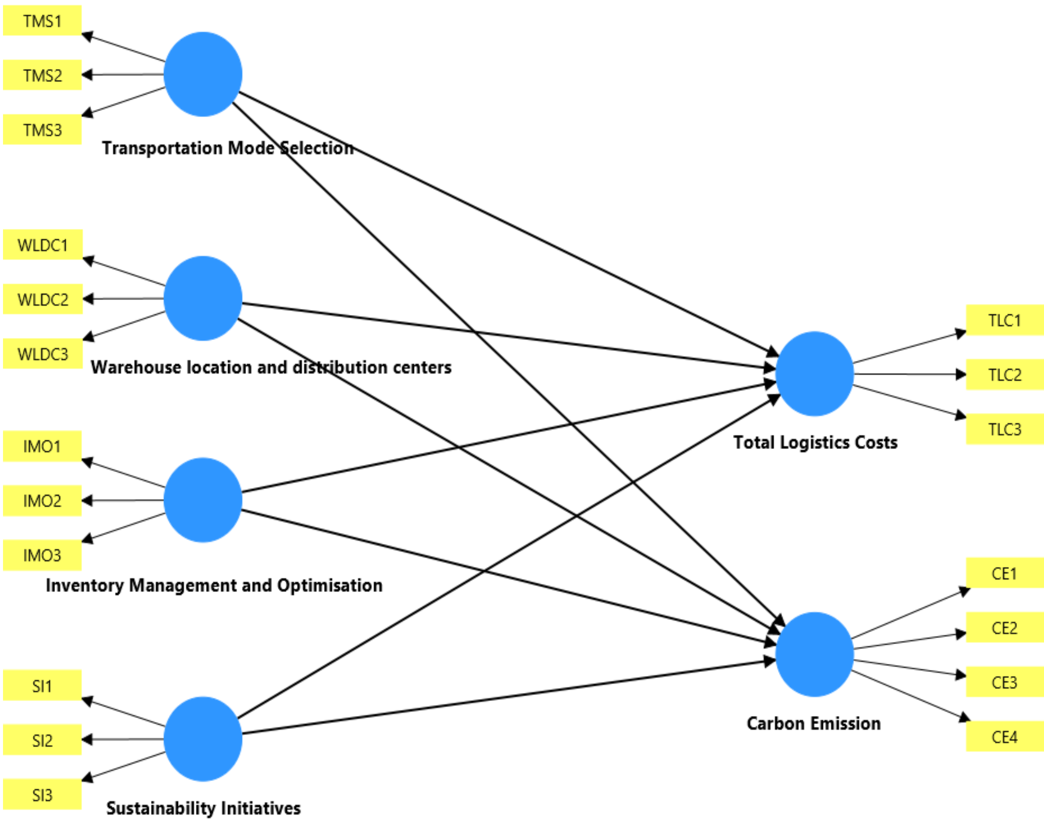

Figure 1: Measurement Model.

Table 1: Discriminant Validity.

	Carbon Emission	Inventory Management and Optimisation	Sustainability Initiatives	Total Logistics Costs	Transportation Mode Selection	Warehouse location and distribution centers
Carbon Emission						
Inventory Management and Optimisation	0.500					
Sustainability Initiatives	0.518	0.733				
Total Logistics Costs	0.918	0.495	0.477			
Transportation Mode Selection	0.312	0.718	0.614	0.276		
Warehouse location and distribution centers	0.400	0.550	0.467	0.343	0.620	

The Heterotrait-Monotrait (HTMT) ratio served as the assessment tool for discriminant validity in this research study. Wong (2011) defines valid discriminant validity as values under 0.85 in HTMT ratios because these criteria establish distinct constructs that avoid multicollinearity issues through minimal correlation. The data in Table 4 proves the model discriminant validity because all HTMT ratios remain under the critical threshold value of 0.85. The significant relationship between Carbon Emission and Total Logistics Costs (0.918) and Inventory Management and Optimisation and Transportation Mode Selection (0.718) remains distinct enough to maintain separate construct recognition. The correlation levels between Sustainability Initiatives and Total Logistics Costs (0.477) and Carbon Emission (0.518) establish meaningful relationships yet preserve the unique qualities of each construct. The relationships between Transportation Mode Selection and Warehouse Location and Distribution Centers with other constructs are moderate to low as measured by 0.312 (Carbon Emission), 0.618 (Warehouse Location and Distribution Centers), and 0.620 (Transportation Mode Selection). This indicates that these constructs maintain individual identity despite their relationships. The constructs measured in this model produce individual and separate data points. The HTMT analysis demonstrates that each construct maintains its uniqueness and makes unique contributions to the model according to the recommendations of Rönkkö and Cho (2022).

3.2. Path Analysis

Table 2: Structural Model.

	Sample mean (M)	T statistics	P values
Inventory Management and Optimisation -> Carbon Emission	0.251	3.439	0.001
Inventory Management and Optimisation -> Total Logistics Costs	0.309	3.921	0.000
Sustainability Initiatives -> Carbon Emission	0.305	3.681	0.000
Sustainability Initiatives -> Total Logistics Costs	0.263	3.055	0.002
Transportation Mode Selection -> Carbon Emission	-0.134	1.986	0.047
Transportation Mode Selection -> Total Logistics Costs	-0.156	2.120	0.034
Warehouse location and distribution centers -> Carbon Emission	0.177	2.683	0.007
Warehouse location and distribution centers -> Total Logistics Costs	0.129	1.820	0.069

The structural model analysis identifies the connections between logistics network design variables and their effects on Carbon Emissions together with Total Logistics Costs. Path analysis is still essential for identifying the magnitudes of variable correlations, even though Hair Jr et al. (2017) bootstrapping is a crucial method for assessing the importance of these interactions. Table 2 shows that the relationships between independent and dependent variables present significant findings that explain the trade-off dynamics. Inventory Management and Optimisation creates positive effects on Carbon Emission (0.251) as well as Total Logistics Costs (0.309). Increased operational efficiency resulting from improved inventory management apparently generates more emissions while elevating costs because transportation needs and warehouse operations increase.

Moreover, the analysis reveals the difficulty that businesses encounter when they attempt to improve inventory management alongside sustainable goal achievement. The positive correlation between Sustainability Initiatives leads to increased Carbon Emission (0.305) and Total Logistics Costs (0.263) values, which indicates this area of difficulty. The implementation of sustainability practices, which includes green technologies and renewable energy solutions, demands considerable investments that drive up operation costs. The pursuit of sustainability demands organisations to make decisions that often create conflicting relationships with operational expenses. Transportation Mode Selection, in contrast, exhibits a negative relationship with both Carbon Emission (-0.134) and Total Logistics Costs (-0.156). Using electric vehicles and alternative fuel options as transportation choices will produce simultaneous reductions in expenses and environmental emissions. This connection between transportation decisions and emissions reduction and cost reduction remains weak compared to other elements in the analysis. The table also indicates that warehouse locations and distribution centers create higher carbon emissions since they positively impact carbon emissions (0.177). The impact of warehouse decisions on Total Logistics Costs proves to be marginally significant at 0.129, even though they affect emissions to some extent. Companies need to manage their logistics network choices with precision to obtain the dual benefits of environmental sustainability and cost-effectiveness.

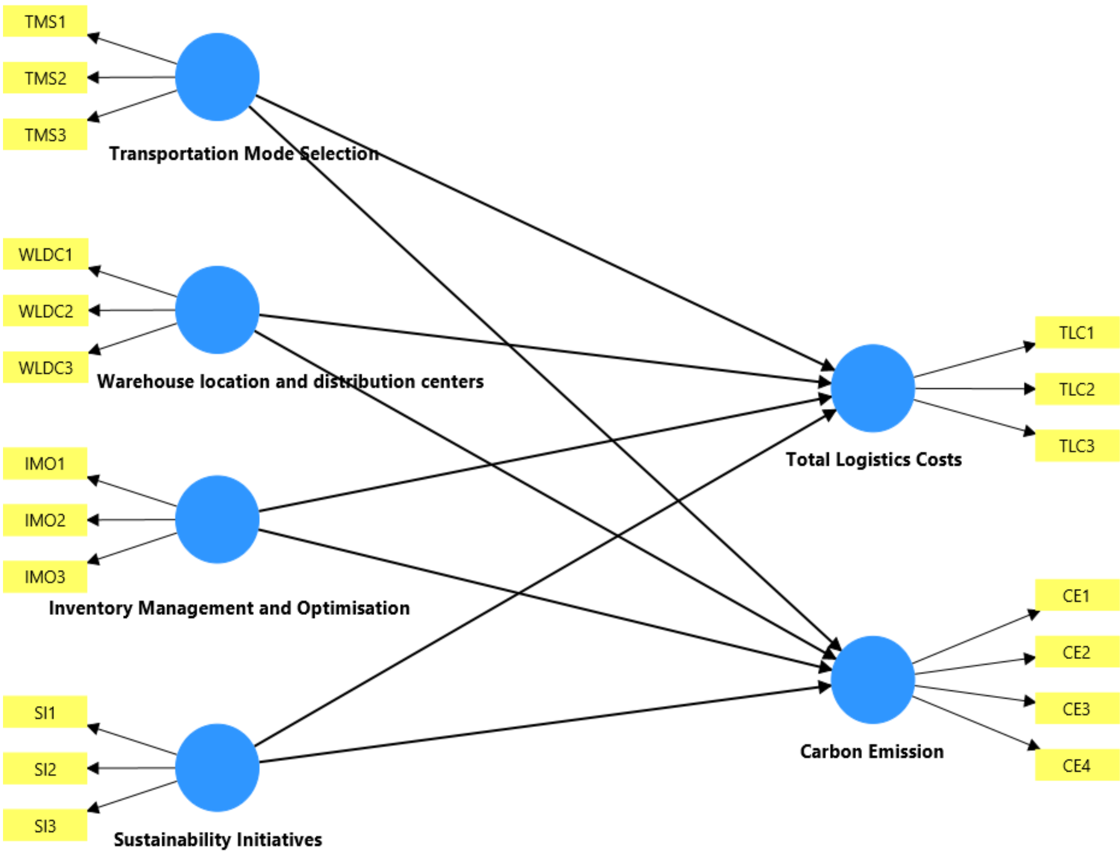

Figure 2: Path Analysis.

3.3. Model Explanatory Power

Table 3: Predictive Relevance and Quality Assessment.

	R-square	R-square adjusted
Carbon Emission	0.278	0.271
Total Logistics Costs	0.251	0.243

The constructs measured in this study reveal that they can explain 27.8% of Carbon Emissions variance according to the R-squared value of 0.278. The operational model successfully explains a moderate degree of environmental aspects affecting carbon emissions in logistics networks. A significant amount of variance exists in carbon emissions since the model explains 27.8% of the total variance while 72.2% remains unexplained based on the analysis. The model reveals that Total Logistics Costs contain 25.1% variable variance based on its R-squared value of 0.251. The model successfully identifies major elements that determine logistics costs, yet there remains 74.9% of variance, which stems from unknown external factors that this study did not measure. The adjusted R-squared statistics of 0.271 reflect Carbon Emission modeling performance, and 0.243 assess Total Logistics Costs modeling efficiency after factoring in predictor number effects. Further study should be conducted to identify extra variables which explain the unmeasured portion of carbon emissions and logistics costs based on the current findings.

Table 5.

Hypothesis	Variable	Result
H1	Inventory Management & Optimization → Carbon Emission	Accepted
H2	Inventory Management and Optimization → Total Logistics Costs	Accepted
H3	Sustainability Initiatives → Carbon Emission	Accepted
H4	Sustainability Initiatives → Total Logistics Costs	Accepted
H5	Transportation Mode Selection → Carbon Emission	Accepted
H6	Transportation Mode Selection → Total Logistics Costs	Accepted
H7	Warehouse Location & Distribution Centers → Carbon Emission	Rejected
H8	Warehouse Location & Distribution Centers → Total Logistics Costs	Rejected

4. DISCUSSION

The study aimed to explore and evaluate the trade-offs between cost-efficiency and environmental sustainability in logistics network design with a particular focus on companies operating in the USA. It examines the cost and environmental impact of logistics networks in the USA and assesses the trade-offs between cost-effectiveness and environmental sustainability in logistics network design. The research results support findings made by Keramydas et al. (2017) and Mittal et al. (2018) demonstrating that operational performance optimisation through cost-cutting strategies has created greater environmental problems. The study results indicate that network development strategies optimised for inventory control alongside transportation system selection and ecological initiatives enhance operational capabilities at the expense of rising operational expenses and heightened environmental impact. The study findings also indicate that network development strategies optimised for inventory control and transportation systems, as well as sustainable initiatives, enhance operational capabilities at the expense of rising operational expenses and increased environmental impact.

The positive results between supply chain inventory management approaches and their impact on both carbon emissions and logistics costs demonstrate that improving warehouse function usually drives increased shipping requirements which subsequently results in elevated environmental effects and logistics expenses. The research supports Strandhagen et al. (2017) who claimed that contemporary logistics systems are inadequately designed because they fail to consider environmental effects from making efficiency-driven choices.

The analysis indicates that sustainability programs with green technologies and renewable power systems help decrease carbon pollution yet elevate logistic expenses because of necessary major financial commitments at the start. The research by Khan et al. (2022) supports these findings because sustainable logistics solutions necessitate significant upfront costs to achieve their long-term environmental impacts. The research reveals that attaining sustainability requires people to make challenging decisions. The selection of electric vehicles through transportation mode demonstrates dual benefits in emission control and logistics cost reduction yet shows a weaker relationship than inventory management and sustainability initiatives. The research indicates that warehouse and inventory decisions produce more significant effects than transportation mode decisions when it comes to decreasing overall costs and emissions. An improvement in transportation efficiency cannot guarantee meaningful carbon emission reductions, according to Lundgren and Haavikko (2023). The research by López-Castro and Solano-Charris (2021) has been confirmed through findings which demonstrate that warehouse locations in central positions produce elevated carbon emissions due to extended delivery distances. According to the research findings, warehouse location choices affect logistics expenses, but their environmental impact remains stronger than cost-related effects. Businesses need to examine environmental concerns in their logistics network design processes because minor modifications in warehouse layouts produce notable effects on logistics system carbon emissions. Fazili et al. (2017) confirmed in their study that physical logistics network design elements determine operational efficiency together with environmental sustainability.

The structural model effectively predicts how carbon emissions, together with total logistics costs, vary according to research results. The model manages to identify a moderate percentage of variance, yet it leaves substantial unexplained variance in carbon emissions measurements. The study demonstrates that inventory management, along with sustainability measures and transportation method choices, drive emissions and cost reductions, but other missing variables beyond the model play a role in environmental and financial outcomes. Research by Ahmad et al. (2023) and Keerthana et al. (2023) focuses on how external variables from the U.S. logistics market affect both environmental results and costs from logistics operations. Future research should focus on external factors to create a complete understanding of all elements that impact logistics network performance as indicated by unexplained data variation. The study validates the necessity for U.S. organizations to maintain an equilibrium between minimising operational expenses and minimising environmental impact throughout their logistics networks design process. Businesses now face dual expectations from regulatory bodies and customers about decreasing their environmental influence, so they must create sustainable logistics strategies that keep them competitive. The research results create a practical guideline for companies to improve supply chain management systems which achieve economic efficiency along with environmental achievement targets. According to Zowada and Ciesielska (2024), small- and medium-sized enterprises need custom strategies because they face specific challenges when it comes to implementing sustainable logistics solutions due to resource limitations.

5. CONCLUSION

The research determined that designing sustainable supply chain logistics networks in the U.S. demands an optimal management of operational expenses alongside environmental conservation practices. The research uncovered a direct link between conventional delivery techniques, which aim to decrease operational costs and higher environmental pollution, together with resource depletion. Three elements of inventory management and transportation systems and sustainable initiatives emerged as critical drivers that influence how much logistics costs and environmental effects become. The study demonstrated that sustainable logistics practices using green technologies act positively for environmental protection, but they create financial challenges through necessary initial investments. The performance evaluation revealed electric vehicles as an attractive transportation option to decrease emissions, even though their influence on cost savings remained comparatively lower than inventory optimisation combined with warehouse operation improvements. This research pointed out that companies must base their strategic choices on information-driven decisions between operational performance improvements and sustainability outcomes. The study established that businesses must strategically include sustainability into their logistics networks to fulfill regulatory standards and consumer demands, together with reaching sustainable environmental and financial outcomes.

Based on the results of the analysis, businesses should finance advanced green technologies that involve electric vehicles, renewable energy systems, and energy-efficient infrastructure. Businesses need to incur higher upfront costs to obtain innovative systems which decrease emissions and operational costs at a long-term level. Companies need to team up with different industry members to learn from one another about the best sustainable logistics implementation strategies. The joint effort between businesses would lower the costs for each entity while simultaneously increasing environmental benefits for the entire group. Small and medium-sized enterprises can gain vital resources through strategic partnerships with big corporations, together with industry consortium membership, to obtain technology and expertise normally inaccessible at their scale. Businesses can achieve market competitiveness by achieving sustainability targets simultaneously with minimizing their environmental effect through these steps.

6. LIMITATIONS AND FUTURE DIRECTIONS

The research depends heavily on data from the United States territory, which may not capture worldwide logistics operations properly. The environmental effects of logistics systems change depending on regional characteristics because regulations and infrastructure and consumer demands affect the results. Research expansion should include multinational data collection to deliver a complete understanding of these elements in different worldwide settings. The study omitted the evaluation of factors like technological development and supply chain disruption along with changes in external economic situations, which might affect logistics performance substantially.

Future investigations need to broaden their research scope to include logistics networks from different regions since environmental practices and cost strategies demonstrably differ across nations. Longitudinal studies would show the sustainable practice developments in addition to their evolving impact on operations across time. Expert interviews and case studies through qualitative research methods will boost the comprehension of choice-making activities that direct logistics network planning. An assessment of circular economy logistics practices, together with investigations into worldwide supply chain disturbances, will generate a thorough understanding of sustainable logistics accomplishment through cost efficiency preservation.

REFERENCES

Ahmad, K., Younas, Z. I., Manzoor, W., & Safdar, N. (2023). Greenhouse gas emissions and corporate social responsibility in USA: A comprehensive study using dynamic panel model. *Heliyon*, *9*(3), e13979–e13979. https://doi.org/10.1016/j.heliyon.2023.e13979

Brown, T. A. (2015). Confirmatory factor analysis for applied research. Guilford publications. Available at: https://books.google.com.pk/books?hl=en&lr=&id=tTL2BQAAQBAJ&oi=fnd&pg=PP1&dq=Brown,+T.A.,+2015.+Confirmatory+factor+analysis+for+applied+research.+Guilford+publications&ots=amSvmL_I9D&sig=husYYgHO1M6Mvae8U8McGlkyfqo&redir_esc=y#v=onepage&q=Brown%2C%20T.A.%2C%202015.%20Confirmatory%20factor%20analysis%20for%20applied%20research.%20Guilford%20publications&f=false

Fazili, M., Venkatadri, U., Cyrus, P., & Tajbakhsh, M. (2017). Physical Internet, conventional and hybrid logistic systems: a routing optimisation-based comparison using the Eastern Canada road network case study. International Journal of Production Research, 55(9), 2703-2730. https://doi.org/10.1080/00207543.2017.1285075

Golzar, J., Noor, S., & Tajik, O. (2022). Convenience sampling. International Journal of Education & Language Studies, 1(2), 72-77. Available at: https://www.ijels.net/article_162981_06fc448b8914d42316b8d44829c88188.pdf

Hair Jr, J. F., Matthews, L. M., Matthews, R. L., & Sarstedt, M. (2017). PLS-SEM or CB-SEM: updated guidelines on which method to use. International Journal of Multivariate Data Analysis, 1(2), 107-123. https://doi.org/10.1504/IJMDA.2017.087624

Jangid, J (2023). Enhancing Security and Efficiency in Wireless Mobile Networks through Blockchain. *International Journal of Intelligent Systems and Applications in Engineering*, *11*(4), 958–969. https://ijisae.org/index.php/IJISAE/article/view/7309

Jangid, J. (2020). Efficient Training Data Caching for Deep Learning in Edge Computing Networks. International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN, 2456-3307. https://doi.org/10.32628/CSEIT20631113

Keerthana, K. B., Wu, S.-W., Wu, M.-E., & Kokulnathan, T. (2023). The United States Energy Consumption and Carbon Dioxide Emissions: A Comprehensive Forecast Using a Regression Model. *Sustainability*, *15*(10), 7932. https://doi.org/10.3390/su15107932

Keramydas, C., Mallidis, I., Dekker, R., Vlachos, D., & Iakovou, E. (2017). Cost and environmental trade-offs in supply chain network design and planning: the merit of a simulation-based approach. Journal of Simulation, 11(1), 20-29. https://doi.org/10.1057/s41273-016-0031-z

Khan, S. A. R., Yu, Z., Umar, M., Zia-ul-haq, H. M., Tanveer, M., & Janjua, L. R. (2022). Renewable energy and advanced logistical infrastructure: Carbon-free economic development. Sustainable Development, 30(4), 693-702. DOI: 10.1002/sd.2266

Kline, R. B. (2023). Principles and practice of structural equation modeling. Guilford publications. Available at: https://books.google.com.pk/books?hl=en&lr=&id=t2CvEAAAQBAJ&oi=fnd&pg=PP1&dq=Kline,+R.B.,+2023.+Principles+and+practice+of+structural+equation+modeling.+Guilford+publications.&ots=sWVDT2eWcP&sig=pXfYlqEWE8tPPtZskuoaOKr8AvU&redir_esc=y#v=onepage&q=Kline%2C%20R.B.%2C%202023.%20Principles%20and%20practice%20of%20structural%20equation%20modeling.%20Guilford%20publications.&f=false

Latan, H., Noonan, R., & Matthews, L. (2017). Partial least squares path modeling. Partial least squares path modeling: basic concepts, methodological issues and applications. https://doi.org/10.1007/978-3-031-37772-3

Lopes, J. M., Gomes, S., Pacheco, R., Monteiro, E., & Santos, C. (2022). Drivers of sustainable innovation strategies for increased competition among companies. Sustainability, 14(9), 5471. https://doi.org/10.1007/s10551-015-2670-9

López-Castro, L. F., & Solano-Charris, E. L. (2021). Integrating resilience and sustainability criteria in the supply chain network design. A systematic literature review. Sustainability, 13(19), 10925. https://doi.org/10.3390/su131910925

Lundgren, A., & Haavikko, E. (2023). The Role of Transport Purchasing Companies in the Reduction of Freight Transport Emissions:

The Opportunities and Barriers of Environmentally Friendly Freight Transport. Available at: https://www.diva-portal.org/smash/get/diva2:1772280/FULLTEXT01.pdf

Mittal, A., Krejci, C. C., & Craven, T. J. (2018). Logistics best practices for regional food systems: A review. Sustainability, 10(1), 168. https://doi.org/10.3390/su10010168

Ramayah, T. J. F. H., Cheah, J., Chuah, F., Ting, H., & Memon, M. A. (2018). Partial least squares structural equation modeling (PLS-SEM) using smartPLS 3.0. An updated guide and practical guide to statistical analysis, 1(1), 1-72. Available at: https://www.researchgate.net/profile/Hiram-Ting/publication/341357609_PLS-SEM_using_SmartPLS_30_Chapter_13_Assessment_of_Moderation_Analysis/links/5ebc2be6a6fdcc90d674eb9c/PLS-SEM-using-SmartPLS-30-Chapter-13-Assessment-of-Moderation-Analysis.pdf

Rönkkö, M., & Cho, E. (2022). An updated guideline for assessing discriminant validity. Organisational research methods, 25(1), 6-14. https://doi.org/10.1177/1094428120968614

Strandhagen, J. O., Vallandingham, L. R., Fragapane, G., Strandhagen, J. W., Stangeland, A. B. H., & Sharma, N. (2017). Logistics 4.0 and emerging sustainable business models. Advances in Manufacturing, 5, 359-369. Available at: https://www.researchgate.net/profile/Giuseppe-Fragapane/publication/321253670_Logistics_40_and_emerging_sustainable_business_models/links/63e9057ce2e1515b6b90211b/Logistics-40-and-emerging-sustainable-business-models.pdf

Wong, K. K. K. (2011). Book review: Handbook of partial least squares: Concepts, methods and applications. International Journal of Business Science and Applied Management, 6(2), 52-54. DOI: 10.69864/ijbsam.6-2.72

ZOWADA, K., & CIESIELSKA, A. (2024). TOWARDS SUSTAINABLE LOGISTICS: THE CASE OF SMALL AND MEDIUM-SIZED ENTERPRISES. Scientific Papers of Silesian University of Technology. Organization & Management/Zeszyty Naukowe Politechniki Slaskiej. Seria Organizacji i Zarzadzanie, (209). Available at: https://managementpapers.polsl.pl/wp-content/uploads/2025/01/209-Zowada-Ciesielska.pdf