

The Influence of Green Logistic Practices on Supply Chain Sustainability of Manufacturing Companies in Western Kenya.

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Abstract: The manufacturing sector in Kenya plays a vital role in economic growth, employment creation, and industrial development. However, it faces persistent environmental and operational challenges due to inefficient logistics systems, resource-intensive production, and inadequate sustainability practices. This study evaluated how green logistic practices influence the supply chain sustainability of sugar companies in western Kenya. Specifically, it evaluated the effects of eco-friendly packaging on supply chain sustainability of sugar companies in western Kenya, examined the effect of green transportation on supply chain sustainability of sugar companies in western Kenya, evaluated the effect of green warehousing on supply chain sustainability of sugar companies in western Kenya, and to examine the effect of reverse logistics on supply chain sustainability of sugar companies in western Kenya. The study was anchored on natural resource-based theory. The study adopted a positivist philosophy and a descriptive and explanatory research design. The target population included factory managers, supply chain managers, operations supervisors, production managers, quality assurance managers, logistics personnel and warehouse managers. Data was collected through structured questionnaires and analyzed with help SPSS, employing descriptive statistics consisting of frequencies and percentages, correlation, and multiple regression analysis. Results were presented in tables. The study results found that green logistics practices have a significant and positive effect on supply chain sustainability among sugar manufacturing companies in Western Kenya. The regression results indicated that eco-friendly packaging ($\beta = 0.657$, $p = 0.001$), green transportation ($\beta = 0.598$, $p = 0.000$), green warehousing ($\beta = 0.682$, $p = 0.000$), and reverse logistics ($\beta = 0.471$, $p = 0.007$) all positively and significantly influence supply chain sustainability. Among these, green warehousing emerged as the strongest predictor. The model explained 62.3% of the variation in supply chain sustainability ($R^2 = 0.623$), indicating a strong explanatory power. Overall, the findings demonstrate that the adoption of integrated green logistics practices substantially enhances environmental and operational sustainability performance. The study recommends that sugar manufacturing firms should adopt an integrated green logistics strategy by strengthening eco-friendly packaging, enhancing green transportation systems, investing in energy-efficient warehousing, and improving reverse logistics practices. Firms should prioritize sustainable packaging materials, optimize transport operations, adopt renewable energy and automation in warehouses, and establish efficient product return and recycling systems. Additionally, policymakers should support these initiatives through environmental regulations, incentives, and infrastructure development to promote sustainable supply chain practices.

I. Introduction

Sustainable development has become a central concern for governments, industries, communities, and global institutions as the world grapples with the environmental consequences of industrialization, rising carbon emissions, resource depletion, and the degradation of natural ecosystems. The logistics and supply chain sector which is responsible for the movement, storage, and flow of goods, plays a significant role in these environmental challenges due to its heavy dependence on transportation, warehousing, packaging, distribution, and energy-intensive operations (Pham, Dinh, Pham, & Kozak, 2023).

In response to these concerns, the concept of green logistics has emerged as a strategic approach aimed at minimizing the ecological footprint of logistics and supply chain activities while enhancing operational efficiency, competitiveness, and long-term sustainability. Green logistics emphasizes reducing waste, lowering carbon emissions, optimizing resource use, adopting cleaner technologies, and integrating environmentally conscious practices throughout the supply chain (Nikseresht, Golmohammadi, & Zandieh, 2024).

Ding (2023) argues that green logistics emerged in the late 1980s and early 1990s as global awareness of environmental degradation intensified and industries began to face pressure to reduce ecological damage caused by logistics activities. Traditional logistics had long focused on cost minimization, speed, and efficiency, with little consideration for environmental impacts such as carbon emissions, air pollution, excessive energy consumption, and waste generation. However, the rise of environmental movements, stricter government regulations, and international agreements on climate change prompted a shift toward environmentally conscious logistics practices (Liu, 2021).

Further, Nicoletti and Appolloni (2024) added that during the early 1990s, the proliferation of environmental management systems such as ISO 14001 encouraged firms worldwide to integrate sustainability into their operations, including transportation, warehousing, and packaging. At the same time, academic research began emphasizing the importance of reducing the ecological footprint of supply chains, giving rise to formal definitions and frameworks for green logistics. By the 2000s, the focus expanded to include reverse logistics, recycling, eco-design, and closed-loop supply chains as companies recognized the cost-saving and competitive benefits of sustainability-oriented practices (Mumcu, 2025).

UNDP, (2021) reported that the adoption of green logistics accelerated further in the 2010s due to technological advancements, including energy-efficient vehicles, digital route optimization, renewable energy in warehousing, and smart supply chain systems. Global sustainability agendas such as the United Nations Sustainable Development Goals (SDGs) and the Paris Climate Agreement reinforced the responsibility of industries to reduce environmental harm. As consumer awareness grew, companies faced increasing pressure to improve environmental performance, leading to broader adoption of eco-friendly logistics practices across sectors (UNDP, 2021).

In developing regions such as Africa, green logistics gained prominence as governments and industries sought to address pollution, inefficient resource use, and climate-related risks. In Kenya, organizations such as the National Environment Management Authority (NEMA) and the Kenya Association of Manufacturers (KAM) have increasingly promoted green supply chain practices through environmental compliance standards, industrial policies, and sustainability initiatives (Mwangi, 2023; KAM, 2021). Today, green logistics is recognized as a critical component of sustainable supply chain management, driven by regulatory requirements, competitiveness, technological innovation, and societal expectations for environmentally responsible business operations.

Sustainability within supply chains encompasses economic resilience, environmental protection, and social responsibility. For firms, sustainability involves reducing environmental risks, improving resource efficiency, and enhancing stakeholder relations while ensuring stable financial performance. Green logistics practices contribute to sustainability by minimizing waste, lowering emissions, reducing costs, and improving brand reputation. Therefore, according to Pham et al. (2023), green logistics is an environmental management approach that integrates ecological considerations into logistics decisions, activities, and systems such as including transportation, warehousing, inventory management, packaging, and distribution, with the objective of reducing environmental degradation and promoting sustainable supply chain performance (Aldakhil, Nassani, Awan, Abro, & Zaman, 2018).

Sustainable procurement is the process whereby economic development, social development and environmental protection are balanced against business needs. The benefits of adopting a sustainable procurement policy as a cost control, improved internal and external standards through performance assessment and compliance with environmental and social legislation (McKinnon, Browne, Whiteing, & Piecyk, 2015). Green procurement attributes contribute to performance excellence. Competence of the staff members on green procurement concepts was essential contributor to the effects of green procurement to performance (Nikseresht, Golmohammadi, & Zandieh, 2024).

The adoption of green logistics initiatives including the use of route optimization, eco-friendly packaging, recycling programs, renewable energy in warehousing, and digitalization of supply chain processes, presents an opportunity for firms to balance economic growth with environmental stewardship (Agyabeng-Mensah et al, 2020). Yet, despite the potential benefits, research suggests that the uptake of green logistics practices among manufacturing firms in developing regions remains relatively low. Factors such as high implementation costs, limited technological capability, weak enforcement of environmental regulations, inadequate managerial awareness, and lack of institutional support hinder the widespread adoption of green logistics strategies. Moreover, logistical inefficiencies and infrastructure gaps, such as poorly maintained road networks and limited access to modern logistics facilities, create additional constraints for firms seeking to transition toward sustainable supply chain models (Tamulis, Guzavičius, & Žalgirytė, 2020).

Globally, green logistics has evolved into a global priority as countries, industries, and international organizations respond to increasing environmental concerns, climate change, and the demand for sustainable economic development. Logistics and supply chain operations contribute significantly to greenhouse gas emissions, resource depletion, urban congestion, and waste generation. According to the International Transport Forum (2021), freight transport alone accounts for nearly 8% of global CO₂ emissions, making logistics a critical area for sustainability interventions. As a result, green logistics, strategies that aim to minimize the ecological footprint of logistics activities, has become central to sustainable supply chain management worldwide (International Transport Forum, 2021).

Governments across Europe, North America, and Asia have implemented stringent policies targeting emissions, waste management, and energy efficiency in logistics. The European Union's Green Deal, for example,

aims to reduce transport-related emissions by 90% by 2050, pushing companies toward low-carbon logistics solutions. Similarly, the Paris Climate Agreement obligates countries to adopt measures that reduce global warming, forcing industries to integrate sustainability into their supply chains (United Nations Environment Programme, 2021).

In Africa, the push toward greener supply chains have been motivated by increasing pressure from regulatory frameworks, global sustainability standards, stakeholder expectations, and rising awareness of environmental conservation. Kenya's Vision 2030 and subsequent industrialization strategies underscore the need for sustainable growth through clean production, responsible resource utilization, and the adoption of modern technologies that support environmental protection. Additionally, international frameworks such as the Paris Climate Agreement and the Sustainable Development Goals (SDGs), especially SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action), further compel manufacturing firms to embed sustainability into their logistics and supply chain activities. As global supply chains become more interconnected, Kenyan manufacturing firms increasingly face demands from international markets to comply with environmentally sound practices in order to remain competitive (KAM, 2021).

The manufacturing sector in Western Kenya specifically tea manufacturers and sugar factories plays a critical role in regional economic development. The region's manufacturing companies depend heavily on logistics operations such as transportation of raw materials from agricultural zones, cross-county distribution of finished products, storage and warehousing, and last-mile delivery to rural and urban markets. However, these operations are often characterized by inefficiencies, reliance on fossil fuels, poor infrastructure, outdated technologies, and inadequate environmental management systems (KAM, 2021). These challenges contribute to high greenhouse gas emissions, air and noise pollution, excessive waste generation, unsafe disposal practices, and escalating operational costs. As environmental concerns continue to gain prominence, these shortcomings threaten the long-term sustainability, competitiveness, and regulatory compliance of manufacturing firms in the region (NEMA, 2023).

In Western Kenya, the logistical environment presents unique challenges that influence sustainability outcomes. The region's manufacturing companies operate within a supply chain ecosystem that includes smallholder farmers, distributors, transporters, wholesalers, and retailers, many of whom lack sophisticated environmental management systems. As a result, supply chain activities such as transportation, storage, and packaging often contribute to significant environmental impacts (NEMA, 2023). For instance, heavy reliance on diesel-powered transportation fleets increases carbon emissions, while inadequate waste management systems lead to improper disposal of industrial by-products. Furthermore, fluctuating fuel prices and inefficiencies in transportation routes drive operational costs upward, reducing profitability and weakening firms' ability to invest in green technologies. These challenges underscore the need for empirical research examining the relationship between green logistics adoption and supply chain sustainability in the regional manufacturing context (Kuteyi & Winkler, 2022; Mulemba, Ouma, & Atieno, 2022).

Sustainability within supply chains encompasses economic resilience, environmental protection, and social responsibility. For manufacturing firms, sustainability involves reducing environmental risks, improving resource efficiency, and enhancing stakeholder relations while ensuring stable financial performance. Green logistics practices contribute to sustainability by minimizing waste, lowering emissions, reducing costs, and improving brand reputation. However, the extent to which these benefits are realized among manufacturing companies in Western Kenya remains insufficiently documented. Existing studies in Kenya have primarily focused on supply chain management, environmental practices, and manufacturing competitiveness at the national level, with limited emphasis on region-specific dynamics affecting sustainability outcomes in Western Kenya. This gap in knowledge warrants a comprehensive investigation to determine how green logistics practices influence supply chain sustainability within the region's manufacturing sector (Mwangi, 2023).

Moreover, as customers and communities become increasingly environmentally conscious, firms face growing pressure to adopt greener production and distribution methods. Regulatory bodies such as the National Environment Management Authority (NEMA) and county governments have also strengthened environmental compliance requirements, further compelling firms to reconsider their logistics strategies (NEMA, 2023). Manufacturing companies that fail to comply risk penalties, reputational damage, and declining market share, particularly as global markets shift toward sustainable sourcing. Therefore, understanding the drivers, implementation levels, and sustainability outcomes of green logistics in Western Kenya is crucial for shaping policy interventions, guiding managerial decision-making, and promoting environmentally responsible industrial growth.

1.2 Study Objectives

1.2.1 Main Objective

The main objective of the study is to evaluate the effect of green logistics and supply chain sustainability of sugar manufacturing companies in western Kenya.

1.2.2 Specific Objectives

The specific objectives of the study were;

- i. To determine the influence of eco-friendly packaging on supply chain sustainability of manufacturing companies in western Kenya.
- ii. To evaluate the impact of green transportation on supply chain sustainability of manufacturing companies in western Kenya.
- iii. To examine the impact of green warehousing on supply chain sustainability of manufacturing companies in western Kenya.
- iv. To evaluate the impact of reverse logistics on supply chain sustainability of manufacturing companies in western Kenya.

1.3 Hypotheses

H₀₁: Eco-friendly Packaging has no significant effect on supply chain sustainability of manufacturing companies in western Kenya.

H₀₂: Green transportation has no significant effect on supply chain sustainability of manufacturing companies in western Kenya.

H₀₃: Green warehousing has no significant effect on supply chain sustainability of manufacturing companies in western Kenya.

H₀₄: Reverse logistics has no significant effect on supply chain sustainability of manufacturing companies in western Kenya.

II. Literature Review

2.1 Theoretical Literature Review

The theoretical literature reviewed outlines the key theories that explain how green logistics practices influence supply chain sustainability. It presented the conceptual foundations that guide the study, clarifies the relationships among variables, and provides a framework for interpreting empirical findings. These theories help establish the rationale for examining green logistics within sugar manufacturing firms in Western Kenya. The study was anchored on natural resource-based view (NRBV) theory.

2.1.1 Natural Resource-Based View (NRBV) Theory

The Natural Resource-Based View (NRBV) Theory, proposed by Hart (1995), extends the traditional resource-based view by explicitly incorporating environmental considerations into organizational strategy. Unlike the classical RBV, which emphasizes internal resources as sources of competitive advantage, the NRBV argues that long-term competitiveness increasingly depends on a firm's ability to develop capabilities that support environmental sustainability (Hart & Dowell, 2011). This framework acknowledges that global environmental pressures, stakeholder expectations, and regulatory demands have fundamentally reshaped the operational landscape, compelling firms to integrate natural resource management into strategic decision-making (McDougall, Wagner, & MacBryde, 2019).

The NRBV focuses on three central strategic capabilities: pollution prevention, product stewardship, and sustainable development. Pollution prevention refers to internal efficiency measures that minimize waste, reduce emissions, and promote eco-efficiency. This capability suggests that organizations can lower operational costs and improve resource utilization by adopting cleaner production processes. In the context of green logistics, pollution prevention is reflected through practices such as green transportation, fuel-efficient routing, and eco-friendly packaging, approaches that reduce environmental footprint while enhancing supply chain efficiency (Johnson-Hall & Hall, 2022).

Product stewardship represents a broader, externally oriented capability that requires organizations to consider environmental impacts throughout the entire product lifecycle. This involves collaboration with suppliers, customers, and other stakeholders to ensure sustainability from production to disposal. Green warehousing practices, such as optimized energy use, recycling systems, and environmentally conscious storage technologies, are aligned with product stewardship, as they collectively support responsible resource management along the supply chain (Samadhiya, Agrawal, Kumar, & Garza-Reyes, 2023). Reverse logistics, including recycling, reprocessing, and recovery of materials, also embodies stewardship by closing the loop on product flows and reducing waste generation.

The third capability, sustainable development, emphasizes long-term, system-wide strategies that support economic growth while preserving environmental and social well-being. This capability is especially significant for industries with heavy resource dependence, such as sugar manufacturing. Sustainable development requires firms to integrate environmental priorities into core strategies, invest in cleaner technologies, adopt regenerative supply chain practices, and build resilience against ecological risks (Lau & Wong, 2024). In the context of Western Kenya’s sugar manufacturing sector, sustainable development may involve integrating environmentally friendly logistics practices to enhance supply chain sustainability under changing environmental regulations and climate conditions.

NRBV provided a strong theoretical grounding for understanding why and how firms adopt green logistics practices. It suggested that environmentally conscious logistics systems can become unique capabilities that are valuable, rare, and difficult for competitors to imitate. Over time, these capabilities contribute not only to environmental performance but also to economic and operational sustainability. They helped firms reduce costs associated with waste disposal, energy consumption, regulatory compliance, and supply chain disruptions.

For sugar manufacturing companies in Western Kenya, NRBV offers a meaningful lens for evaluating the strategic importance of green logistics in driving supply chain sustainability. These companies operate in an environment where sustainability concerns are rising due to climate change impacts, soil degradation, water scarcity, and stricter environmental regulations. NRBV explains that developing strong green logistics capabilities allows organizations to navigate these challenges while strengthening competitive advantage. For instance, green transportation reduces carbon emissions and fuel costs; eco-friendly packaging minimizes waste; green warehousing lowers utility expenses and enhances efficiency; and reverse logistics supports circular economy principles that help firms re-capture value from returns and waste.

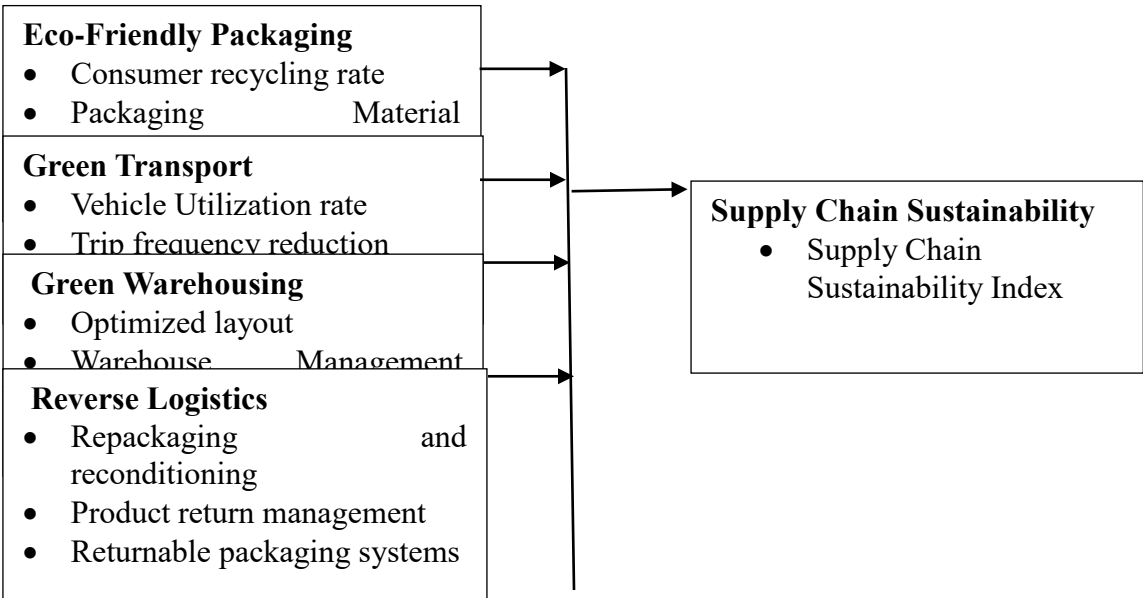
In summary, the Natural Resource–Based View positions environmental practices not as optional corporate responsibilities but as integral components of organizational strategy. It provided a theoretical foundation that links green logistics practices to long-term supply chain sustainability. By applying NRBV, this study demonstrated how sugar manufacturing firms in Western Kenya can leverage environmentally oriented logistics capabilities to enhance sustainability performance, operational resilience, and competitive advantage in an increasingly ecological-conscious business environment.

2.3 Conceptual Framework

The conceptual framework of this study illustrated how green logistics practices, eco-friendly packaging, green transportation, green warehousing, and reverse logistics, affect supply chain sustainability in sugar manufacturing companies in Western Kenya. Grounded in the natural resource-based view, ecological modernization, and institutional theories, it guides the study by showing the relationship between independent variables (green logistics) and the dependent variable (supply chain sustainability), providing a foundation for data collection and analysis.

**Independent Variables
Green Logistics**

**Dependent Variable
Supply Chain Sustainability**



2. 4 Empirical Literature Review

The empirical literature review focused on examining previous research studies that have investigated the relationships between green supply chain practices and supply chain sustainability. It provides evidence-based insights into how specific practices, including eco-friendly packaging, green transport, green warehousing, and reverse logistics, influence the environmental, social, and economic performance of supply chains. This section emphasizes studies that have employed quantitative and qualitative methodologies to measure sustainability outcomes, highlighting the indicators and tools, such as the Supply Chain Sustainability Index (SCSI), used to operationalize these variables. By analyzing existing empirical findings, this review identifies patterns, relationships, and gaps in knowledge, offering a foundation for the current study.

2.4.1 Eco-Friendly Packaging and Supply Chain Sustainability

Several empirical studies have investigated the role of eco-friendly packaging in promoting supply chain sustainability, employing diverse methodological approaches and highlighting key research gaps. Ker, Sen, and Rajendran (2019) conducted a quantitative study in the fast-moving consumer goods (FMCG) sector using survey data from supply chain managers to assess the benefits of eco-friendly packaging. Their study revealed significant improvements in environmental performance and operational efficiency; however, the research was limited to a single sector, leaving cross-industry generalizability untested.

Moustafa, et al., (2019) employed a materials engineering approach, combining laboratory experiments and life-cycle assessment to evaluate eco-friendly polymer composites for green packaging. While the study provided technical insights into material sustainability, it lacked empirical evidence on market adoption and operational impacts in real-world supply chains. In examining consumer behavior, Koch, Frommeyer, and Schewe (2022) applied a mixed-methods design, including surveys and experimental choice modeling in online retail, showing that environmental consciousness and perceived quality influence eco-friendly packaging adoption. However, the study focused primarily on consumer motives, with limited consideration of supply chain performance outcomes.

Safaei (2020) conducted a case study approach in the pharmaceutical and food supply chain, combining interviews and document analysis to extract green marketing strategies linked to eco-friendly packaging. While this provided rich qualitative insights, the findings were context-specific and lacked quantitative measures to evaluate environmental or operational impacts. A systematic review by Morashti, An, and Jang (2022) synthesized empirical and theoretical studies on sustainable packaging, identifying benefits such as waste reduction and resource efficiency, but highlighted the absence of integrated frameworks linking packaging practices to measurable supply chain sustainability indices.

Govere, et al., (2024) explored eco-friendly packaging in transportation systems using secondary data analysis, demonstrating environmental benefits through reduced fuel consumption; however, the study did not incorporate firm-level operational or financial performance measures. Finally, Choi and Lee (2020) used market-level sales data to evaluate the economic impact of eco-packaging, revealing brand and revenue benefits, but the study did not address environmental metrics or longitudinal sustainability outcomes. Collectively, while these studies confirm the positive role of eco-friendly packaging, gaps remain in integrating quantitative, environmental, social, and economic measures within a single study, particularly in manufacturing contexts such as sugar firms, highlighting the need for research that links packaging practices to composite supply chain sustainability indices.

2.4.2 Green Transport and Supply Chain Sustainability

Empirical research on green transportation has consistently emphasized its role in enhancing environmental, social, and economic sustainability within supply chains sustainability. Shah, et al., (2021) conducted a comprehensive review of current barriers, strategies, and innovative technologies in green transportation, identifying key challenges such as high implementation costs and lack of policy support. While informative, the study was largely conceptual and did not empirically measure operational or environmental outcomes. Abdel and Abd-El-Monem (2020) applied a case study methodology in Greater Cairo, Egypt, using surveys and observational data to examine the effects of sustainable transportation practices on urban quality of life, demonstrating reductions in emissions and improvements in traffic efficiency; however, their findings were geographically limited and may not generalize to manufacturing supply chains.

Rehman, Islam, and Miao (2023) employed a quantitative analysis of the top ten energy transition nations, using cross-country panel data to assess the environmental impact of green transportation, revealing significant reductions in carbon emissions and fuel consumption, yet the study did not examine firm-level operational efficiency or supply chain-specific outcomes. Ma, Jia, Sun, and Kuang (2022) used spatio-temporal analysis to evaluate comprehensive transportation green efficiency in China, highlighting dynamic trends in energy usage and environmental performance; however, this macro-level approach overlooked organizational-level logistics decisions.

Saada (2021) explored green transportation within green supply chain management frameworks, combining literature review with case illustrations, but empirical testing of measurable sustainability indicators was limited. Chen and Anandhan (2020) applied performance-based evaluation in smart city transportation management systems, using quantitative performance metrics to identify operational inefficiencies and opportunities for emission reduction; nevertheless, the study did not extend to manufacturing or product distribution networks.

Vukic, Poletan, Guidi, and Oblak (2020) developed a model for determining optimal green transport routes using data envelopment analysis (DEA), offering practical guidance for logistics optimization, but the focus was on route selection rather than broader supply chain sustainability outcomes. Collectively, these studies demonstrate that green transportation positively influences environmental performance and operational efficiency, but gaps remain in integrating green transport practices into composite supply chain sustainability measures at the firm level, particularly in manufacturing sectors such as sugar production, where both logistics efficiency and environmental impact need to be quantified simultaneously.

2.4.3 Green Warehousing and Supply Chain Sustainability

Empirical studies have highlighted the pivotal role of green warehousing in promoting supply chain sustainability through energy efficiency, logistics optimization, and environmental performance. Agyabeng-Mensah, et al., (2020) conducted a quantitative study using survey data from logistics and warehouse managers, demonstrating that green warehousing practices positively influence economic performance and social values, while enhancing overall supply chain sustainability. However, the study primarily focused on managerial perceptions rather than measurable operational metrics.

Perotti and Colicchia, (2023) developed a conceptual framework based on a systematic literature review, emphasizing energy efficiency and environmental impact reduction in warehouses, but their work lacked empirical testing in operational settings. Atashi-Khoei (2021) provided an overview of green logistics applications, including warehousing, using case study analysis to highlight practical applications of sustainability practices; however, quantitative measurement of performance outcomes was limited. Meng, Wang, He, and Zhao (2025) applied deep learning techniques for warehouse site selection optimization and path planning, providing a data-driven approach to improve logistics efficiency and reduce energy consumption, yet the study did not incorporate social or economic dimensions of sustainability.

Mashud, Roy, Chakraborty, Tseng, and Pervin (2022) developed a model balancing ordering cost reduction, product deterioration, and carbon emissions in sustainable green warehouses, employing quantitative optimization methods, but the study was highly technical and context-specific. Muttaqin, Margareta, and Zahira (2022) designed a green warehouse performance monitoring system using the Analytical Hierarchy Process (AHP) and Supply Chain Operations Reference (SCOR) framework, enabling systematic assessment of sustainability metrics; however, broader empirical validation across industries was lacking.

Sandra, et al., (2024), proposed a decision support system for green warehouse appraisal and selection, integrating quantitative sustainability indicators, but the implementation focused on theoretical modeling rather than real-world operational outcomes. Collectively, these studies affirm that green warehousing enhances environmental, economic, and social dimensions of supply chain sustainability, yet gaps remain in integrating all dimensions into a composite sustainability index and in empirical application within specific manufacturing sectors, highlighting the need for comprehensive, context-specific research.

2.4.4 Reverse Logistics and Sustainable Supply Chain

Empirical research on reverse logistics highlights its critical role in enhancing supply chain sustainability by improving resource efficiency, reducing waste, and supporting environmental and economic performance. Yang, et al., (2024) conducted a quantitative study using survey data from manufacturing firms to examine how reverse logistics and sustainable supply chain initiatives influence sustainability performance, with organizational learning capability as a moderating variable. The study demonstrated that reverse logistics significantly improves environmental and operational outcomes, yet it focused on managerial perceptions rather than measurable operational metrics.

Aćimović, Mijušković, and Rajić, (2020) applied a cross-sectional survey approach with Serbian consumers to assess the impact of reverse logistics on green supply chain competitiveness, showing that effective product returns and recycling practices enhance consumer trust and market performance; however, firm-level operational impacts were not fully analyzed. Melo, et al., (2021) conducted a systematic literature review to develop frameworks integrating reverse logistics with sustainable design, providing theoretical insights but lacking empirical validation in real-world supply chains.

Beiler, et al., (2020) performed an exploratory case study of a Brazilian beverage company, analyzing the implementation of reverse logistics processes such as product returns, packaging recovery, and recycling; while

offering rich operational insights, the study was context-specific and limited in generalizability. Mbago, et al., (2025) applied case study methodology in recycling firms to assess the implementation of reverse logistics practices, highlighting operational efficiencies and environmental benefits, but broader quantitative measures of supply chain sustainability were not incorporated.

Adesoga, et al., (2024) reviewed reverse logistics practices across multiple industries, identifying positive effects on waste reduction and resource recovery, though empirical evidence linking these practices to composite sustainability indices was limited. Offei (2025) analyzed the influence of reverse logistics on green supply chain management using mixed methods, demonstrating improvements in environmental compliance and cost reduction, yet the study did not integrate social sustainability metrics. Collectively, these studies confirm that reverse logistics enhances supply chain sustainability, but gaps remain in quantitatively linking operational practices, environmental impact, and broader social and economic outcomes, particularly in sector-specific contexts such as manufacturing and sugar firms, highlighting the need for comprehensive empirical studies that measure all dimensions of sustainability.

III. Study Methodology

3.1 Research Philosophy

The research philosophy adopted in this study is positivism, which is grounded in the belief that reality is objective and can be measured empirically through observable phenomena. Positivist philosophy emphasizes the collection of quantitative data, the use of structured instruments, and statistical analysis to establish causal relationships between variables. In the context of this study, positivism allowed for a systematic examination of the influence of green supply chain practices, eco-friendly packaging, green transport, green warehousing, and reverse logistics, on supply chain sustainability (Mugenda & Mugenda, 2003).

Adopting a positivist approach ensured that the study produced objective, reliable, and generalizable findings, minimizing researcher bias. It also supported the use of structured questionnaires and standardized metrics for data collection, facilitating the quantification of sustainability outcomes across multiple dimensions: environmental, social, and economic. Furthermore, positivism aligned with the study's goal of testing theoretical relationships identified in the literature review, enabling empirical validation of how green supply chain practices impact the overall sustainability of manufacturing supply chains, particularly within the sugar industry.

3.2 Research Design

The study adopted descriptive and explanatory research, aimed at empirically examining the effect of green supply chain practices on supply chain sustainability in sugar manufacturing firms. The descriptive component of the design enabled the study to systematically describe the current status of green supply chain practices and sustainability performance among sugar firms. Key indicators, such as packaging recyclability, vehicle utilization rate, warehouse energy efficiency, and effectiveness of reverse logistics processes, are quantified to provide a clear picture of existing practices. The explanatory component focused on establishing causal relationships, analyzing how each green supply chain practice influences overall supply chain sustainability. Multiple regression analysis and correlation techniques was employed to test hypotheses and determine the strength and direction of relationships between variables. This research design was suitable for achieving the study's objectives because it combines empirical measurement, statistical rigor, and practical relevance, providing both descriptive insights and analytical understanding of the impact of integrated green supply chain practices on sustainability outcomes in the sugar manufacturing sector.

3.3 Target Population

The target population for this study comprised 14 sugar manufacturing firms operating within Western Kenya presented in Appendix III, as these firms represent the industry context in which green supply chain practices and sustainability performance are being assessed. The population included factory managers, supply chain managers, operations supervisors, production managers, quality assurance managers, logistics personnel, and warehouse managers who are directly involved in implementing and monitoring green practices such as eco-friendly packaging, green transport, green warehousing, and reverse logistics.

These individuals were considered key informants because they possess firsthand knowledge and experience regarding operational processes, sustainability initiatives, and performance metrics within their organizations. Focusing on this population ensures that the data collected are both relevant and reliable, reflecting the actual implementation of green supply chain practices and their influence on environmental, social, and economic outcomes.

The study targeted all registered sugar manufacturing firms within the specified region, providing a defined and accessible population for data collection. The choice of this population is justified by the study's aim to

empirically assess the impact of integrated green supply chain practices on the Supply Chain Sustainability Index (SCSI), and the critical role these firms play in the local economy and environmental management.

Table 3.1: Target Population

Target Population	Number
Factory Manager	14
Supply Chain Managers	14
Production Managers	14
Operations Supervisors	14
Logistics Managers	14
Warehouse Managers	14
Quality Assurance Managers	14
Total	98

3.4 Sampling Techniques

The study adopted a census sampling technique, which involves collecting data from the entire population rather than selecting a subset of respondents. A census approach was appropriate because the number of sugar manufacturing firms in Western Kenya is relatively small and manageable, making it feasible to include all firms and all relevant departmental heads directly involved in supply chain operations. By targeting all supply chain managers, logistics officers, procurement personnel, and warehouse supervisors within each firm, the study ensures comprehensive coverage of the population of interest.

Using a census technique enhanced the accuracy and reliability of the findings, as it eliminates sampling error and provides a complete representation of the target population. This method also ensured that variations in the adoption of eco-friendly packaging, green transport, green warehousing, and reverse logistics practices across firms are fully captured. Moreover, because sustainability practices may differ significantly between firms depending on their scale, structure, and operational capabilities, conducting a census allows for richer and more robust comparative analysis.

The decision to use a census was further justified by the study’s objective of generating empirical evidence that reflects the true state of green supply chain practices in the sugar manufacturing industry. By including all eligible respondents, the study achieved a higher degree of validity and generalizability within the industry context, thereby strengthening the credibility of the conclusions drawn regarding the effect of green supply chain initiatives on the Supply Chain Sustainability Index (SCSI).

3.5 Data Presentation Analysis & Discussion

Collected data was first subjected to cleaning, sorting, and coding before analysis with the help of Statistical Package for Social Sciences (SPSS). The cleaning process involved checking for missing values, identifying inconsistencies, correcting entry errors, and ensuring that all variables are properly formatted for analysis. After data cleaning, the responses were organized and coded according to the major constructs of the study, namely Eco-Friendly Packaging, Green Transportation, Green Warehousing, Reverse Logistics, and Supply Chain Sustainability. Descriptive statistics such as means, standard deviations, frequencies, and percentages was used to provide an initial summary of the data and highlight general patterns across the variables. This descriptive analysis helped illustrate the extent to which sugar manufacturing firms in Western Kenya implement various green logistics practices and the overall levels of supply chain sustainability observed within the sector.

To facilitate a deeper understanding of the relationships, inferential statistics including correlation analysis, ANOVA, and multiple regression analysis was employed to test the study hypotheses and examine the impact of green logistics practices on supply chain sustainability. Correlation analysis was used to determine the strength and direction of the relationships between independent variables, eco-friendly packaging, green transportation, green warehousing, and reverse logistics, and the dependent variable, supply chain sustainability. ANOVA assessed whether significant differences in supply chain sustainability exist across firms with varying levels of adoption of green logistics practices. Multiple regression analysis was applied to evaluate the predictive influence of each green logistics practice on overall supply chain sustainability, allowing for the assessment of the combined effects of these practices. The results were presented using tables, pie charts, and bar graphs to enhance visual clarity, facilitate interpretation, and provide a comprehensive understanding of how green logistics initiatives contribute to sustainable supply chain performance in sugar manufacturing firms. The multiple regression equations of the study was;

$$SCS = \beta_0 + \beta_1 EFP + \beta_2 GT + \beta_3 GW + \beta_4 RL + \epsilon_1 \dots \dots \dots \quad (3.1)$$

Where:

SCS = Dependent Variable (supply chain sustainability)

β_0 = Constant of the regression

$\beta_1 - \beta_4$ = Coefficients of the regression

EFP= Eco-Friendly Packaging

GT =Green Transport

GW =Green Warehousing

RL =Reverse Logistics

ε_1 = Error term of the model

IV. Data Analysis, Presentation and Discussion

4.1 Inferential Statistics Results

This section presents inferential analysis used to examine relationships between eco-friendly packaging, green transportation, green warehousing, reverse logistics, and supply chain sustainability. Pearson correlation analysis assessed the strength and direction of associations among variables. Multiple regression analysis was then applied to determine the effect of each independent variable on supply chain sustainability. The model summary (R^2 and adjusted R^2) evaluated explanatory power, while ANOVA tested overall model significance. Diagnostic tests, including multicollinearity, normality, and heteroscedasticity, were conducted to validate model assumptions and ensure reliability of results.

4.1.1 Pearson Correlation Analysis

The results presented in Table 4.10 show the Pearson correlation coefficients for the relationships among eco-friendly packaging (EFP), green transportation (GT), green warehousing (GW), reverse logistics (RL), and supply chain sustainability (SCS) in sugar manufacturing companies in Western Kenya. The correlation coefficients (r) indicate both the strength and direction of the relationships, while the p-values show the level of statistical significance.

The findings reveal that eco-friendly packaging has a positive and statistically significant relationship with supply chain sustainability ($r = 0.519, p = 0.001$). This suggests that firms that adopt environmentally friendly packaging practices tend to achieve higher levels of supply chain sustainability. Similarly, green transportation shows a positive and significant relationship with supply chain sustainability ($r = 0.558, p = 0.001$), indicating that efficient and environmentally conscious transport practices play a crucial role in enhancing sustainability outcomes.

Reverse logistics also demonstrates a positive and statistically significant relationship with supply chain sustainability ($r = 0.505, p = 0.000$). This implies that effective management of product returns, reuse, and recycling contributes significantly to overall sustainability performance. Green warehousing, on the other hand, shows a positive relationship with supply chain sustainability ($r = 0.481, p = 0.02$). Although slightly lower in magnitude compared to the other variables, this relationship is still meaningful, indicating that sustainable warehousing practices also support improved sustainability outcomes.

In terms of the strength of the relationships, all variables exhibit positive correlations with supply chain sustainability, suggesting that no single factor overwhelmingly dominates, but rather all green logistics practices collectively contribute to sustainability improvements. Overall, the findings indicate that all the independent variables, eco-friendly packaging, green transportation, green warehousing, and reverse logistics, are positively associated with supply chain sustainability. The statistically significant relationships further confirm that improvements in these green logistics practices are likely to enhance sustainability outcomes. Additionally, the relatively low correlations among the independent variables suggest that they can be included together in a regression model without the risk of multicollinearity, thereby providing reliable and valid results in subsequent analysis.

Table 4.1: Pearson Correlation Analysis

	EFP	GT	GW	RL	SCS
EFP	1				
GT	0.379 (0.128)	1			
GW	0.271 (0.288)	0.149 (0.521)	1		
RL	0.139	0.258	0.243	1	

	(0.271)	(0.207)	(0.173)		
SCS	0.519*	0.558*	0.481	0.505*	1
	(0.001)	(0.001)	(0.02)	(0.000)	

Source: Study Data (2026)

4.1.2 Model Summary Results

The results in Table 4.15 present the model summary of the multiple regression analysis examining the effect of green logistics practices on supply chain sustainability. The correlation coefficient ($R = 0.789$) indicates a strong positive relationship between the independent variables, eco-friendly packaging, green transport, green warehousing, and reverse logistics, and the sustainable supply chain index. The coefficient of determination ($R^2 = 0.623$) shows that 62.3% of the variation in supply chain sustainability is explained by the combined effect of the independent variables. This suggests that green logistics practices play a significant role in influencing sustainability outcomes within the firms.

The adjusted R^2 value of 0.618 further confirms the model’s explanatory power, indicating that even after adjusting for the number of predictors, approximately 61.8% of the variation in supply chain sustainability is accounted for. This implies that the model is reliable and not overly inflated. Additionally, the standard error of the estimate (0.0614) is relatively low, suggesting that the model provides accurate predictions with minimal deviation from actual values. Overall, the findings indicate that the regression model fits the data well and that green logistics practices collectively have a strong explanatory power on supply chain sustainability.

Table 4.2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.789 ^a	.623	.618	.0614

Source: Study Data (2026)

4.1.3 ANOVA Results

The results in Table 4.16 present the Analysis of Variance (ANOVA) used to test the overall significance of the multiple regression model. ANOVA helps determine whether the independent variables, eco-friendly packaging, green transport, green warehousing, and reverse logistics, jointly have a statistically significant effect on supply chain sustainability.

The findings show that the regression model has a sum of squares of 12.46, while the residual sum of squares is 7.54, giving a total variation of 20.00. The mean square for regression is 3.115, while that of the residual is 0.0829. The model produces an F-statistic of 37.58 with a significance value of 0.000. Since the p-value is less than 0.05, the results indicate that the regression model is statistically significant. This means that the independent variables, when taken together, significantly explain variations in supply chain sustainability.

This implies that eco-friendly packaging, green transport, green warehousing, and reverse logistics jointly have a significant effect on supply chain sustainability in sugar manufacturing companies in Western Kenya. Therefore, the null hypothesis that the model has no explanatory power is rejected. Overall, the ANOVA results confirm that the regression model is valid and that the predictors collectively provide a strong explanation of supply chain sustainability.

Table 4.3: ANOVA

ANOVA ^a						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	12.46	4	3.115	37.58	.000 ^b
	Residual	7.54	91	.0829		
	Total	20.00	95			

Source: Study Data (2026)

4.1.4 Multiple Regression analysis

Multiple regression analysis was conducted to determine the effect of green logistics practices, eco-friendly packaging, green transportation, green warehousing, and reverse logistics, on supply chain sustainability among sugar manufacturing companies in Western Kenya. The analysis was used to establish the magnitude, direction, and significance of the relationship between each independent variable and the dependent variable while holding other variables constant. The results are presented using regression coefficients (β), standard errors, t-values, and

significance levels, which are used to test the study hypotheses and draw conclusions on the individual contribution of each predictor to supply chain sustainability. The results are presented 4.17.

Table 4.4: Multiple Regression analysis

Model	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	0.106	0.021	5.047	.006
Eco-Friendly Packaging	0.657	0.137	4.795	.001
1 Green Transport	0.598	0.091	6.571	.000
Green Warehousing	0.682	0.083	8.216	.000
Reverse Logistics	0.471	0.067	7.0298	.007

Source: Study Data 2026

The results presented in Table 4.17 show the multiple regression coefficients for the effect of green logistics practices on supply chain sustainability among sugar manufacturing companies in Western Kenya. The model includes eco-friendly packaging, green transport, green warehousing, and reverse logistics as predictors of supply chain sustainability. The study extracted the following regression equation 4.1 from Table 4.17.

$$SCS = 0.106 + 0.657EFP + 0.598GT + 0.682GW + 0.471RL \dots \dots \dots 4.1$$

The constant term ($\beta = 0.106$, $p = 0.006$) represents the intercept of the regression model, indicating the expected level of supply chain sustainability when all independent variables, eco-friendly packaging, green transport, green warehousing, and reverse logistics, are held at zero. In practical terms, it means that if a firm had no green logistics practices at all, the model still predicts a very low baseline level of supply chain sustainability of 0.106 units. This value is small, showing that sustainability performance would be minimal without the influence of the green logistics variables included in the model.

This suggests that even in the absence of green logistics practices, a minimal level of supply chain sustainability would still exist, likely driven by other external or institutional factors not captured in the model. However, the relatively low value of the constant implies that such baseline sustainability is limited, and meaningful improvements in sustainability are largely dependent on the adoption of the identified green logistics practices. The statistical significance of the constant further confirms that this baseline effect is not due to random variation.

4.2 Interpretation and Discussion of Results

This section presents the interpretation and discussion of the empirical findings derived from both descriptive and inferential analyses. It explains how eco-friendly packaging, green transportation, green warehousing, and reverse logistics influence supply chain sustainability among sugar manufacturing companies in Western Kenya. The discussion links the statistical results to the study objectives and provides an integrated explanation of the observed relationships and their implications for sustainable supply chain performance.

4.2.1 Eco-Friendly Packaging and Supply Chain Sustainability

The first objective of the study was to determine the effect of eco-friendly packaging on supply chain sustainability among sugar manufacturing companies in Western Kenya. This objective was anchored on the null hypothesis that eco-friendly packaging has no significant effect on supply chain sustainability. The regression analysis results in Table 4.17 show that eco-friendly packaging had a regression coefficient of 0.657 with a p-value of 0.001, which is less than 0.05. This implies that eco-friendly packaging has a positive and statistically significant effect on supply chain sustainability. This significance is further supported by the t-value of 4.795, which is greater than the t-critical value of 1.972. Therefore, the null hypothesis was rejected. This implies that a unit increase in eco-friendly packaging practices leads to subsequent increase in supply chain sustainability by 0.657 units, holding other factors constant.

The results on eco-friendly packaging ($\beta = 0.657$, $p = 0.001$) links well with the Natural Resource-Based View (NRBV) theory, Ecological Modernization Theory (EMT), and Institutional Theory, each of which provides a different but complementary explanation of why this practice significantly enhances supply chain sustainability. From the perspective of the NRBV theory, eco-friendly packaging represents a strategic capability that helps firms reduce environmental harm while improving operational efficiency. The positive and significant relationship with supply chain sustainability suggests that firms using recyclable, reusable, and biodegradable packaging are not only reducing waste but also building long-term competitive advantage through resource efficiency and environmental stewardship. This supports NRBV’s argument that pollution prevention and product stewardship are valuable organizational capabilities that drive sustainability performance.

In relation to Ecological Modernization Theory (EMT), the findings indicate that eco-friendly packaging is a result of modernization and innovation within the supply chain. The adoption of recyclable materials, reduced packaging usage, and investment in sustainable packaging design reflects a shift toward cleaner production systems.

EMT explains this as evidence that environmental improvement can be achieved alongside economic activity through technological advancement and process redesign, rather than restricting industrial growth.

From the viewpoint of Institutional Theory, the adoption of eco-friendly packaging can be linked to external pressures such as environmental regulations, customer expectations, and industry standards. Firms may adopt sustainable packaging not only for efficiency reasons but also to gain legitimacy, comply with environmental laws, and align with societal expectations. The strong positive effect observed in the study suggests that these institutional pressures are effectively influencing firm behavior toward greener packaging practices.

The findings of the present study, which show that eco-friendly packaging has a positive and statistically significant effect on supply chain sustainability ($\beta = 0.657$, $p = 0.001$), are generally consistent with existing empirical literature, while also extending it by addressing key contextual and methodological gaps.

For instance, the results align with Ker, Sen, and Rajendran (2019), who found that eco-friendly packaging improves environmental performance and operational efficiency in the FMCG sector. Similarly, the current study confirms that firms adopting recyclable and environmentally friendly packaging achieve higher supply chain sustainability. However, unlike Ker et al. (2019), which was sector-specific, this study extends the evidence to sugar manufacturing firms in Western Kenya, thereby improving contextual generalizability.

The findings are also consistent with Moustafa et al. (2019), who demonstrated through laboratory and life-cycle assessment that eco-friendly packaging materials reduce environmental impact. While their study focused on material performance at the technical level, the current study complements it by showing real-world operational and managerial impacts, particularly how such packaging practices enhance overall supply chain sustainability.

In relation to Koch, Frommeyer, and Schewe (2022), the current findings support their conclusion that environmental awareness drives adoption of eco-friendly packaging. However, while Koch et al. primarily focused on consumer behavior and purchase intentions, this study shifts the focus to firm-level supply chain outcomes, demonstrating that eco-friendly packaging contributes not only to consumer preference but also to measurable sustainability performance.

Similarly, the results support Safaei (2020), who identified eco-friendly packaging as part of green marketing strategies in pharmaceutical and food supply chains. However, Safaei's study was largely qualitative and context-specific, whereas the present study provides quantitative evidence showing the magnitude and statistical significance of its effect on supply chain sustainability. The findings also complement the systematic review by Morashti, An, and Jang (2022), which highlighted benefits such as waste reduction and resource efficiency but noted the absence of integrated sustainability measurement frameworks. The current study addresses this gap by empirically linking eco-friendly packaging to a composite supply chain sustainability index, providing measurable evidence of its impact.

In addition, Govere et al. (2024) found environmental benefits of eco-packaging in transportation systems, particularly through reduced fuel consumption. The present study extends this perspective by incorporating broader supply chain dimensions beyond transportation, showing that eco-friendly packaging contributes holistically to sustainability performance at the firm level. Finally, while Choi and Lee (2020) reported economic benefits such as improved brand value and sales performance, their study did not integrate environmental outcomes. The current study bridges this gap by demonstrating that eco-friendly packaging simultaneously enhances environmental and operational sustainability within supply chains.

4.2.2 Green Transport and Supply Chain Sustainability

The second objective of the study was to determine the effect of green transportation on supply chain sustainability among sugar manufacturing companies in Western Kenya. This objective was guided by the null hypothesis that green transportation has no significant effect on supply chain sustainability. The regression analysis results in Table 4.17 show that green transportation had a positive and statistically significant effect on supply chain sustainability ($\beta = 0.598$, $t = 6.571$, $p = 0.000$). Since the p-value is less than 0.05, the null hypothesis was rejected. This indicates that green transportation practices such as route optimization, fuel efficiency, load maximization, and eco-driving significantly enhance supply chain sustainability. This implies that a unit increase in green transportation practices leads to a subsequent increase in supply chain sustainability by 0.598 units, holding other variables constant. Therefore, the study concludes that green transportation is a key determinant of supply chain sustainability in sugar manufacturing companies in Western Kenya.

The finding that green transportation has a positive and significant effect on supply chain sustainability ($\beta = 0.598$, $p = 0.000$) can be explained using the Natural Resource-Based View (NRBV) theory, Ecological Modernization Theory (EMT), and Institutional Theory. From the perspective of the NRBV theory, green transportation represents a strategic capability that enables firms to reduce emissions, improve fuel efficiency, and optimize resource use. The significant positive effect implies that firms adopting route optimization, load

maximization, and eco-driving practices gain sustainability advantages through reduced environmental impact and improved operational efficiency. This supports NRBV's argument that pollution prevention and process stewardship within logistics systems enhance long-term competitive advantage.

Under the Ecological Modernization Theory (EMT), the results reflect the idea that environmental protection can be achieved through technological innovation and improved production systems rather than restricting economic activity. Practices such as route planning, transport scheduling, and fuel-efficient driving demonstrate how firms are modernizing their logistics operations to simultaneously achieve cost efficiency and environmental sustainability. The significant coefficient confirms that green transportation is not a constraint but a driver of improved supply chain performance through modernization.

From the Institutional Theory perspective, the adoption of green transportation practices is influenced by external pressures such as environmental regulations, industry standards, and stakeholder expectations. Firms may implement greener transport systems to gain legitimacy, comply with government policies on emissions, and align with global sustainability trends. The strong and significant relationship suggests that these institutional pressures are effectively shaping transport practices within the sugar manufacturing sector.

The results align with Shah et al. (2021), who identified green transportation as a key driver of environmental improvement in supply chains, although their study remained largely conceptual. In contrast, the current study provides empirical evidence showing that specific practices such as route optimization, load maximization, and eco-driving significantly enhance overall supply chain sustainability in sugar manufacturing firms.

Similarly, the findings support Abdel and Abd-El-Monem (2020), who found that sustainable transport practices reduce emissions and improve efficiency. However, their study focused on urban mobility and quality of life, whereas the present study extends these insights to manufacturing supply chains, demonstrating that similar environmental benefits translate into improved supply chain sustainability performance. The results are also consistent with Rehman, Islam, and Miao (2023), who reported that green transportation significantly reduces carbon emissions and fuel consumption at a macro level. The current study builds on this by showing that at the firm level, green transportation not only reduces environmental impact but also contributes directly to measurable supply chain sustainability outcomes.

In addition, Ma et al. (2022) highlighted improvements in transportation green efficiency using spatio-temporal analysis. While their study operated at a national and macroeconomic level, the present research narrows the focus to organizational logistics decisions, confirming that such efficiency improvements are also observable within individual manufacturing firms. The findings further support Saada (2021), who linked green transportation to sustainable supply chain management frameworks. However, Saada's work was largely conceptual, whereas the current study provides statistical validation of the relationship using regression analysis and a composite sustainability index.

Likewise, Chen and Anandhan (2020) emphasized performance improvements in smart transport systems, particularly in reducing inefficiencies and emissions. The current study extends this by demonstrating that such improvements have a direct and significant impact on overall supply chain sustainability in manufacturing contexts, particularly in sugar production. Finally, Vukic et al. (2020) focused on optimizing transport routes using DEA models, showing efficiency gains at the operational level. The present study complements this by demonstrating that route optimization contributes not only to efficiency but also to broader sustainability outcomes when integrated with other green logistics practices.

4.2.3 Green Warehousing and Supply Chain Sustainability

The third objective of the study was to determine the effect of green warehousing on supply chain sustainability among sugar manufacturing companies in Western Kenya. This objective was guided by the null hypothesis that green warehousing has no significant effect on supply chain sustainability. The regression analysis results in Table 4.17 indicate that green warehousing had a positive and statistically significant effect on supply chain sustainability ($\beta = 0.682$, $t = 8.216$, $p = 0.000$). Since the p-value is less than 0.05, the null hypothesis was rejected. This implies that green warehousing practices significantly enhance supply chain sustainability.

This means that a unit increase in green warehousing practices leads subsequent increase in supply chain sustainability by 0.682 units, holding other factors constant. Therefore, the study concludes that green warehousing is a key determinant of supply chain sustainability in sugar manufacturing companies in Western Kenya, and it has the strongest influence among the examined green logistics practices.

The finding that green warehousing has a strong positive and significant effect on supply chain sustainability ($\beta = 0.682$, $p = 0.000$) supports the Natural Resource-Based View (NRBV) theory, Ecological Modernization Theory (EMT), and Institutional Theory. From the perspective of the NRBV theory, green

warehousing represents a strategic environmental capability that enables firms to reduce resource consumption, minimize waste, and improve operational efficiency. The strong positive effect implies that firms adopting energy-efficient warehouse designs, renewable energy systems, automation, and optimized layouts are building valuable capabilities that enhance long-term sustainability performance. This supports NRBV's argument that firms achieve competitive advantage through pollution prevention, product stewardship, and sustainable resource management.

Under the Ecological Modernization Theory (EMT), the results suggest that warehousing operations in sugar manufacturing firms are undergoing technological and structural transformation. Practices such as solar energy use, automated systems, and energy-efficient infrastructure demonstrate that environmental sustainability is being integrated into production systems through innovation and modernization. The strong coefficient confirms EMT's view that economic development and environmental protection can coexist through improved technologies and more efficient industrial processes.

From the Institutional Theory perspective, the adoption of green warehousing practices is influenced by external pressures such as environmental regulations, stakeholder expectations, and industry standards. Firms may adopt sustainable warehousing not only for efficiency gains but also to gain legitimacy, comply with environmental policies, and align with global sustainability norms. The relatively high adoption levels observed in the study suggest that coercive, normative, and mimetic pressures are actively shaping warehouse management practices in the sector.

The results align with Agyabeng-Mensah et al. (2020), who found that green warehousing practices positively influence economic performance, social value, and overall supply chain sustainability. However, while their study relied largely on managerial perceptions, the current study strengthens this evidence by using quantitative regression analysis, showing a strong and statistically significant effect of green warehousing on a composite sustainability index.

Similarly, the findings support Perotti and Colicchia (2023), who emphasized energy efficiency and environmental performance in warehousing through a systematic literature review. Their work was largely conceptual, whereas the present study provides empirical validation in a real industrial context, confirming that these theoretical benefits translate into measurable sustainability outcomes in sugar manufacturing firms. The results are also consistent with Atashi-Khoei (2021), who highlighted practical applications of green logistics in warehousing. However, their case-based approach lacked quantitative performance measurement. The current study fills this gap by demonstrating the magnitude and statistical significance of green warehousing's effect on supply chain sustainability.

In addition, Meng et al. (2025) demonstrated that data-driven warehouse optimization techniques improve logistics efficiency and reduce energy consumption. While their focus was primarily technical and operational, the present study extends this by incorporating broader sustainability dimensions, showing that green warehousing contributes not only to efficiency but also to overall supply chain sustainability performance. Similarly, Mashud et al. (2022) developed optimization models that balance costs, deterioration, and carbon emissions in green warehouses. Their findings support the environmental efficiency aspect observed in the current study; however, their focus was limited to technical optimization, whereas the present research integrates these benefits into a holistic sustainability framework.

The study also aligns with Muttaqin, Margareta, and Zahira (2022), who developed performance monitoring systems for green warehousing using AHP and SCOR models. While their work provided structured evaluation tools, it lacked broad empirical validation. The current study addresses this by applying a real-world dataset from manufacturing firms, confirming that green warehousing significantly enhances sustainability performance. Finally, Sandra et al. (2024) proposed decision-support systems for warehouse sustainability assessment, but their work remained largely theoretical. The present study advances this by empirically demonstrating that green warehousing is not only a conceptual model but a practically significant driver of supply chain sustainability in the sugar manufacturing sector.

4.2.4 Reverse Logistics and Sustainable Supply Chain

The fourth objective of the study was to determine the effect of reverse logistics on supply chain sustainability among sugar manufacturing companies in Western Kenya. This objective was guided by the null hypothesis that reverse logistics has no significant effect on supply chain sustainability. The regression analysis results in Table 4.17 show that reverse logistics had a positive and statistically significant effect on supply chain sustainability ($\beta = 0.471$, $t = 7.0298$, $p = 0.007$). Since the p-value is less than 0.05, the null hypothesis was rejected. This indicates that reverse logistics practices significantly contribute to enhancing supply chain sustainability. This implies that a unit increase in reverse logistics practices leads subsequent increase in supply chain sustainability by

0.471 units, holding other variables constant. Therefore, the study concludes that reverse logistics is a significant determinant of supply chain sustainability in sugar manufacturing companies in Western Kenya.

The finding that reverse logistics has a positive and significant effect on supply chain sustainability ($\beta = 0.471$, $p = 0.007$) supports the Natural Resource-Based View (NRBV) theory, Ecological Modernization Theory (EMT), and Institutional Theory. From the perspective of the NRBV theory, reverse logistics represents a strategic capability that enables firms to recover value from returned products through reuse, recycling, refurbishment, and proper disposal. The significant positive effect suggests that firms with well-developed reverse logistics systems are better able to minimize waste, reduce resource consumption, and improve environmental performance. This supports NRBV's argument that pollution prevention and product stewardship activities within supply chains create long-term sustainability and competitive advantage.

Under the Ecological Modernization Theory (EMT), the results indicate that reverse logistics is part of the broader transformation of industrial systems toward sustainability. Practices such as product return management and recycling reflect a shift from linear to circular supply chains, where materials are continuously recovered and reintegrated into production systems. The significant relationship confirms EMT's view that environmental sustainability can be achieved through technological innovation and systemic redesign of production and consumption processes, rather than restricting industrial growth.

From the Institutional Theory perspective, the adoption of reverse logistics is influenced by external pressures such as environmental regulations, waste management policies, and stakeholder expectations for corporate social responsibility. Firms may implement reverse logistics systems to gain legitimacy, comply with environmental laws, and meet customer expectations regarding product take-back and responsible disposal. The positive and significant effect suggests that these institutional pressures are encouraging firms in the sugar manufacturing sector to adopt more sustainable reverse logistics practices.

The results also align with Yang et al. (2024), who found that reverse logistics significantly improves environmental and operational performance in manufacturing firms. However, their study focused largely on managerial perceptions and did not fully capture measurable sustainability outcomes. In contrast, the current study strengthens these findings by demonstrating a quantified and statistically significant impact of reverse logistics on a composite supply chain sustainability index.

Similarly, Aćimović, Mijušković, and Rajić (2020) established that reverse logistics improves competitiveness and consumer trust through effective returns and recycling systems. While their study emphasized market and consumer perspectives, the present study extends this evidence to show that reverse logistics also has a direct and measurable impact on internal supply chain sustainability performance, particularly in manufacturing operations. The findings are also consistent with Melo et al. (2021), who conceptually linked reverse logistics with sustainable design frameworks. However, their work lacked empirical validation. The current study addresses this limitation by providing statistical evidence that reverse logistics significantly contributes to sustainability performance in real operational settings.

Likewise, Beiler et al. (2020) demonstrated operational benefits of reverse logistics in a beverage company, including packaging recovery and product returns management. While their case study offered useful insights, it was context-specific. The present study builds on this by providing broader generalizable evidence across sugar manufacturing firms in Western Kenya. The results further support Mbago et al. (2025), who identified efficiency and environmental benefits of reverse logistics in recycling firms. However, their study did not integrate broader sustainability indicators. The current study fills this gap by linking reverse logistics to a composite sustainability index that incorporates environmental and operational dimensions.

In addition, Adesoga et al. (2024) confirmed that reverse logistics contributes to waste reduction and resource recovery across industries, although they noted limited empirical integration with full sustainability measures. The present study addresses this limitation by empirically demonstrating how reverse logistics enhances overall supply chain sustainability rather than isolated environmental outcomes. Finally, Offei (2025) found that reverse logistics improves environmental compliance and cost efficiency using mixed methods. However, social sustainability dimensions were not fully integrated. The current study advances this by showing that reverse logistics contributes to holistic sustainability performance, incorporating environmental and operational efficiency within a unified framework.

V. Conclusions and Recommendations

5.1 Conclusions

Based on the empirical findings of the study, several conclusions were drawn regarding the effect of green logistics practices on supply chain sustainability among sugar manufacturing companies in Western Kenya.

First, the study concluded that eco-friendly packaging has a significant and positive effect on supply chain sustainability. The results demonstrated that firms that adopt recyclable, biodegradable, and reduced packaging materials are better positioned to minimize environmental pollution and improve resource efficiency. This indicates that packaging decisions are no longer purely operational but have become a critical sustainability driver within the supply chain. Therefore, eco-friendly packaging contributes not only to environmental protection but also to enhanced overall supply chain performance.

Second, the study concluded that green transportation significantly influences supply chain sustainability. The findings show that efficient transport practices such as route optimization, load maximization, fuel efficiency, and eco-driving lead to reduced emissions, lower operational costs, and improved delivery efficiency. This implies that transportation management plays a central role in achieving sustainability goals in the sugar manufacturing sector. Firms that invest in green transport systems are therefore more likely to achieve improved environmental and operational outcomes.

Third, the study concluded that green warehousing has the most significant effect on supply chain sustainability among all the variables examined. The results indicate that energy-efficient warehouse design, adoption of renewable energy sources, automation systems, and environmentally friendly storage practices significantly enhance sustainability performance. This suggests that warehousing operations are a major point of environmental impact within the supply chain, and improvements in this area yield substantial sustainability gains. As such, green warehousing is a critical strategic area for firms aiming to enhance supply chain sustainability.

Fourth, the study concluded that reverse logistics has a significant positive effect on supply chain sustainability. The findings show that systems for managing product returns, recycling, reuse, and recovery contribute to waste reduction and improved resource utilization. This demonstrates that reverse logistics is an important component of circular supply chain practices, enabling firms to recover value from returned products while reducing environmental burden.

Finally, the study concluded that green logistics practices collectively have a strong and statistically significant effect on supply chain sustainability. The model explains a substantial proportion of variation in sustainability performance, confirming that integrated adoption of eco-friendly packaging, green transportation, green warehousing, and reverse logistics leads to better environmental, economic, and operational outcomes. This implies that sustainability in supply chains is best achieved through a holistic approach rather than isolated initiatives.

5.2 Study Recommendations

Based on the findings and conclusions of the study, several detailed recommendations are proposed to enhance supply chain sustainability in sugar manufacturing companies in Western Kenya.

First, the study recommends that sugar manufacturing firms should strengthen and institutionalize eco-friendly packaging practices across all levels of the supply chain. Companies should gradually transition from conventional packaging materials to recyclable, biodegradable, and reusable alternatives. In addition, firms should invest in research and development to identify cost-effective sustainable packaging innovations. Collaboration with suppliers is also essential to ensure that packaging materials meet environmental standards while still maintaining product quality and safety. Customer awareness programs should be introduced to encourage proper disposal and recycling of packaging waste, thereby strengthening the sustainability loop.

Second, the study recommends that firms should enhance the efficiency and environmental performance of green transportation systems. Management should adopt advanced transport management systems (TMS) to optimize delivery routes, reduce fuel consumption, and minimize empty return trips. Investment in fuel-efficient, hybrid, or alternative energy vehicles should be prioritized in the long term to reduce carbon emissions. In addition, firms should regularly train drivers on eco-driving techniques to improve fuel efficiency and reduce environmental impact. Proper scheduling and consolidation of deliveries should also be implemented to ensure maximum vehicle utilization and reduced operational inefficiencies.

Third, the study recommends that sugar manufacturing companies should prioritize investment in green warehousing infrastructure and technologies due to its strong influence on supply chain sustainability. Firms should adopt energy-efficient warehouse designs that incorporate proper ventilation, natural lighting, and insulation systems. The use of renewable energy sources such as solar power should be expanded to reduce reliance on conventional electricity. Automation technologies such as warehouse management systems (WMS), robotics, and smart sensors should be implemented to improve operational efficiency and reduce waste. Regular energy audits should also be conducted to monitor and control consumption levels.

Fourth, the study recommends that firms should strengthen reverse logistics systems as part of a broader circular economy strategy. This involves developing efficient systems for handling product returns, refurbishment,

recycling, and reuse of materials. Companies should establish formal partnerships with suppliers, distributors, and customers to ensure smooth coordination of reverse logistics processes. Additionally, firms should invest in tracking systems that monitor returned products to improve recovery rates and minimize waste. Proper training of staff involved in reverse logistics operations is also essential to enhance efficiency and compliance with environmental standards.

Finally, the study recommends that firms should adopt a fully integrated green logistics strategy rather than implementing isolated practices. Since all green logistics components were found to significantly influence supply chain sustainability, a coordinated approach will yield greater environmental, economic, and operational benefits. Top management should ensure that sustainability objectives are embedded within the overall corporate strategy and supported by clear policies, performance targets, and monitoring systems. This will enhance alignment across procurement, production, warehousing, transportation, and distribution functions.

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