



Effect of Packaging Management Practices on Supply Chain Sustainability of Manufacturing Companies: A case of Sulfo Industries Ltd

Grace Uwamahoro and Joseph Akumuntu
University of Kigali
Email: ugrace27@gmail.com

Abstract: *This study examined the effect of packaging material selection on supply chain sustainability at Sulfo-Rwanda Industries Ltd. Specifically, it assessed the effect of packaging material selection on supply chain sustainability. The study employed a descriptive and explanatory research design using quantitative and qualitative approaches. The target population comprised 109 employees from 11 departments, and a census approach was used. Data were collected using structured questionnaires, interview guides, and documentary review and analyzed using SPSS. Descriptive statistics, Pearson correlation analysis, multiple regression analysis, and thematic analysis were used. The findings indicated that packaging material selection had a positive and statistically significant effect on supply chain sustainability. Regression analysis showed $B = 0.197$, $\beta = 0.232$, $t = 3.788$, and $\text{Sig.} = 0.000^{**}$. The findings highlighted the importance of recyclability, environmental suitability, lightweight characteristics, durability, and material efficiency in supporting supply chain sustainability. The study concluded that appropriate packaging material selection was an important factor in strengthening supply chain sustainability at Sulfo-Rwanda Industries Ltd. The study recommended increasing the use of recyclable and environmentally suitable packaging materials, strengthening packaging quality requirements for storage and transportation, and establishing sustainability criteria in packaging material procurement and supplier selection.*

Keywords: *Packaging material selection; Supply chain sustainability; Recyclability; Environmental suitability; Material efficiency; Sulfo-Rwanda Industries Ltd.; Rwanda.*

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1. Introduction

Packaging management is particularly important in manufacturing and beverage industries because packaging directly connects production with storage, transportation, distribution, and consumption. Appropriate packaging can improve product protection, reduce product damage, optimize storage and transportation, and facilitate efficient handling. In contrast, inappropriate material selection, inefficient packaging design, inadequate quality control, and poor waste management can increase material

consumption, operational costs, and environmental impacts. Effective packaging management can consequently contribute to both economic and environmental dimensions of supply chain sustainability. Chen and Lee (2021) noted that packaging management practices can improve supply chain efficiency through better inventory management, product protection, market responsiveness, and reverse logistics.

At the global level, packaging management has increasingly been shaped by environmental regulations,

technological advancement, consumer awareness, and circular economy principles. Manufacturing firms in developed economies have increasingly adopted reusable, recyclable, and resource-efficient packaging systems to reduce waste and improve resource utilization. Extended producer responsibility approaches have also encouraged producers to consider the environmental impacts of packaging throughout its life cycle. In some beverage markets, reusable bottles and returnable packaging systems have been introduced to reduce the demand for new packaging materials and minimize packaging waste. However, such systems require investment in collection, transportation, cleaning, inspection, storage, and redistribution systems (Dupont et al., 2021).

Developing and emerging economies have also increasingly adopted sustainable packaging approaches, although implementation is influenced by differences in infrastructure, technology, production costs, regulatory frameworks, and consumer behaviour. In China, for example, increasing attention has been given to green packaging technologies, recycled packaging materials, and improved packaging systems in response to sustainability requirements. Similarly, India has strengthened attention to packaging regulation and environmentally responsible packaging design, while some Middle Eastern markets have explored refillable and reusable packaging approaches. These experiences indicate that the sustainability benefits of packaging management depend on the ability of firms to balance environmental considerations with operational efficiency, regulatory compliance, technological capacity, and supply chain requirements (Ahmad & Bano, 2020).

In Africa, packaging management has become an important issue because of rapid urbanization, population growth, increased consumption of packaged products, and weaknesses in waste-management and recycling infrastructure. African countries have adopted different approaches to packaging management depending on their regulatory environments, market conditions, infrastructure, and technological capacities. In Nigeria and Ghana, for instance, sachet packaging remains common because of its affordability and convenience, although its extensive use has raised concerns about packaging waste and environmental management. In South Africa, beverage companies have increasingly explored returnable packaging schemes and reusable bottles as mechanisms for reducing packaging waste and improving resource efficiency (Bamfo & Asiedu, 2021).

Similar developments are occurring in East Africa. Countries such as Kenya, Uganda, and Tanzania have increasingly emphasized reusable packaging, packaging recovery, and reverse logistics. Beverage companies in Kenya have implemented returnable packaging

approaches, while reverse logistics systems have been explored in Uganda and Tanzania to facilitate the collection and movement of packaging materials back through supply chains (Kisumo & Samweli, 2019). However, the effectiveness of these practices depends on the availability of appropriate transportation, collection, storage, cleaning, processing, and recycling infrastructure. Limited logistics infrastructure and high operational costs can therefore constrain the sustainability benefits of packaging management practices (Ndiaye & Ba, 2025).

Rwanda's manufacturing sector is an important component of the country's economic transformation and is increasingly expected to promote both productivity and environmentally sustainable production. As manufacturing activities and consumption of packaged products increase, packaging management has become increasingly relevant to production efficiency, product quality, waste reduction, and environmental protection. Manufacturing firms are therefore required to balance the need for safe, attractive, and functional packaging with the need to minimize material consumption, control operational costs, reduce packaging waste, and comply with environmental and quality requirements.

The Rwandan policy and regulatory environment provides an important framework for sustainable production, environmental protection, and waste management. Rwanda has progressively strengthened its environmental governance framework, including requirements relating to pollution prevention, waste management, resource efficiency, and environmental protection. These requirements create responsibilities for manufacturing firms to manage waste responsibly and adopt production practices that minimize adverse environmental impacts. For packaging-intensive industries, this means that packaging management should consider not only product protection and operational efficiency but also the environmental implications of packaging materials, packaging waste, reuse, recycling, and disposal.

Sulfo-Rwanda Industries Ltd provides an important organizational context for examining the relationship between packaging management practices and supply chain sustainability. As a manufacturing company operating in Rwanda, Sulfo-Rwanda Industries Ltd undertakes packaging-related activities that are essential for protecting products, maintaining product quality, facilitating handling and transportation, supporting storage, and distributing products to consumers. Packaging management is therefore an important component of the company's production and supply chain operations. The packaging activities of Sulfo-Rwanda Industries Ltd involve several practices that are relevant to supply chain sustainability. These include the selection of appropriate packaging materials, packaging design, quality control and

documentation, automation and handling processes, and recycling. Packaging material selection can influence material costs, product protection, waste generation, and environmental performance.

1.2 Problem Statement

Supply chain sustainability is an important concern for manufacturing companies because their performance depends on their ability to minimize environmental impacts, ensure reliable and timely delivery, control operational costs, and utilize materials and other resources efficiently. However, manufacturing companies in Rwanda continue to experience challenges in achieving effective and sustainable supply chain performance. Ineffective waste management, limited recycling and recovery capacity, material losses, operational inefficiencies, and packaging-related problems can undermine environmental performance, increase operating costs, reduce resource-use efficiency, and affect the reliability and timeliness of product delivery. These challenges indicate that supply chain sustainability remains a significant concern within Rwanda's manufacturing sector.

The problem is particularly relevant to packaging-intensive manufacturing operations. Packaging is closely linked to production, storage, transportation, and distribution, meaning that packaging-related inefficiencies can affect several dimensions of supply chain sustainability. Inefficient packaging can contribute to increased material waste and environmental impacts, packaging damage and product losses, additional replacement and handling costs, and inefficient use of storage and transportation resources. In Rwanda, the World Bank (2023) reported that the country generates approximately 0.4–0.7 kg of solid waste per capita per day, amounting to more than 230,000 tonnes annually. The continued generation of waste and limitations in recycling and recovery capacity present challenges to the environmental sustainability and resource efficiency of manufacturing supply chains. These conditions raise concerns about the ability of manufacturing companies to achieve sustainable supply chain performance.

At Sulfo-Rwanda Industries Ltd., packaging is an important component of production, storage, and distribution activities across its manufacturing operations. However, available organizational evidence indicates persistent packaging-related problems. According to the Sulfo-Rwanda Industries Ltd. Quality Assurance Report (2024), reported packaging issues increased from 142 in 2022 to 198 in 2024 and accounted for 16.8% of customer complaints during the period. The company also reported approximately 42 tonnes of plastic packaging waste, of which only 18% was recycled, while packaging damage resulted in approximately RWF 185 million in replacement

costs. These figures indicate challenges in environmental impact reduction, cost efficiency, and resource utilization, while packaging-related defects and damage may also affect the reliability and timeliness of product delivery.

Although previous studies have examined the relationship between packaging management and supply chain performance (Mwangi & Wanjiku, 2021; Mensah & Antwi, 2022; Smith et al., 2023), limited empirical evidence exists on how specific packaging management practices jointly influence supply chain sustainability in Rwanda's manufacturing sector. In particular, insufficient evidence exists on the effects of packaging material selection, packaging design, quality control and documentation, automation and handling processes, and recycling practices on environmental impact reduction, delivery reliability and timeliness, cost efficiency, and resource-utilization efficiency. This represents a contextual and empirical gap that the present study seeks to address by examining the effect of packaging management practices on supply chain sustainability at Sulfo-Rwanda Industries Ltd.

1.3. Objectives of the study

The study was guided by general and specific objectives

13.1. General objective

The general objective of this study is to evaluate the effect of packaging management practices on supply chain sustainability of Sulfo-Rwanda Industries Ltd.

1.3.2. Specific objectives

- i. To assess the effect of Packaging Material Selection on supply chain sustainability of Sulfo-Rwanda Industries Ltd

2. Literature Review

The conceptual review examines the fundamental concepts and theories that underpin this study. This section of this literature review highlights definitions, characteristics, and dimensions of packaging management practices, supply chain sustainability, and efficiency. This section clarifies definitions of the independent and dependent variables as well as their interrelations. This section provides an understanding of how packaging management practices influence supply chain sustainability within Drinking Water Manufacturing Industry. This section forms a foundation for developing a conceptual framework.

2.1. Packaging Management Practices

Packaging management practices (PMPs) refer to the systematic activities undertaken by manufacturing organizations to plan, select, design, control, use, handle, document, recover, and manage packaging throughout the product supply chain. Packaging management therefore extends beyond the physical protection of products to include decisions concerning packaging materials, packaging design, quality assurance, operational processes, information management, waste reduction, and end-of-life management. Rundh (2022) explains that packaging decisions involve several attributes, including materials, dimensions, structure, labeling, and design, which must respond to product requirements, consumer expectations, market conditions, and operational needs. In contemporary manufacturing, packaging management is consequently viewed as a strategic activity because packaging decisions influence product protection, operational efficiency, logistics, costs, customer satisfaction, and environmental performance.

Packaging management practices comprise several interrelated activities rather than a single operational decision. These activities include the selection of appropriate packaging materials, development of functional packaging designs, quality control and documentation, efficient use of packaging technologies and handling systems, and management of packaging waste through recovery, reuse, and recycling. Packaging characteristics such as size, shape, structure, labeling, ergonomics, and material composition can influence how products are stored, handled, transported, marketed, and ultimately disposed of or recovered. Therefore, packaging management should be considered from a supply chain perspective in which decisions made during packaging development can affect subsequent production, logistics, consumption, and end-of-life activities.

For the purpose of this study, packaging management practices are conceptualized through five components: packaging material selection, packaging design, quality control and documentation, automation and handling processes, and recycling practices. These components represent the principal dimensions through which packaging activities are managed within a manufacturing organization. Packaging material selection concerns the choice of appropriate, durable, efficient, and environmentally suitable materials. Packaging design concerns the configuration and characteristics of packaging that determine product protection, material utilization, handling, storage, and transportation efficiency.

2.2. Packaging Material Selection

Packaging material selection refers to the systematic process of evaluating and choosing materials that can adequately protect products while meeting functional,

operational, economic, environmental, and end-of-life requirements throughout the supply chain. The decision involves considering material properties, product compatibility, protection requirements, availability, cost, resource consumption, recyclability, and environmental effects over the material's life cycle. Recent literature emphasizes that packaging materials should be assessed from a supply chain and life-cycle perspective because material choices influence product protection, logistics efficiency, environmental impacts, resource use, and opportunities for recovery after use. Therefore, packaging material selection is not limited to identifying a material that can contain a product; it involves selecting the most appropriate material configuration that balances protection, performance, cost, resource efficiency, and sustainability requirements (Morashti et al., 2022; Silva & Pålsson, 2022; Mudgal et al., 2024).

Packaging material selection is measured using five indicators: recyclability, environmental suitability, lightweight characteristics, durability, and material efficiency. Recyclability refers to the extent to which packaging materials can be collected, processed, and converted into materials that can be used again, thereby supporting resource recovery and reducing dependence on disposal. Environmental suitability concerns the extent to which selected materials minimize adverse environmental effects across their life cycle, including resource consumption, emissions, waste generation, and end-of-life impacts. Lightweight characteristics refer to the use of packaging materials that provide adequate protection while avoiding unnecessary weight, which can improve material efficiency and reduce the resource requirements associated with transportation. Durability refers to the ability of packaging materials to withstand handling, storage, transportation, and distribution without premature failure. Material efficiency concerns achieving the required packaging function with the minimum reasonable quantity of material while maintaining product protection and quality. These indicators reflect the multidimensional nature of sustainable material selection identified in recent packaging research (Sastre et al., 2022; Mudgal et al., 2024).

2.3. Supply chain sustainability

In the drinking water production sector, supply chain sustainability implies incorporating environmental, social, and economic factors into supply chain activities allowing to maintain efficient work of the organization for years to come. As stated by Brandenburg et al. (2022), supply chain sustainability requires a perfect balance between operational efficiency, environmental protection, and profitability when organizing and improving supply chain processes. In the context of the drinking water production sector, supply chain sustainability gained popularity as a

strategic move since companies rely on natural resources, packaging materials, transportation channels, and distribution pathways for delivering potable water to customers. Hence, companies have to focus on sustainable sourcing approaches, water use, environmentally friendly packaging methods, and logistics solutions to comply with environmental laws. The concept of the supply chain sustainability in the drinking water manufacturing sector includes several important aspects. Firstly, environmental sustainability deals with reduction of pollution, waste generation, saving water resources, and implementation of energy-efficient production (Ahi & Searcy, 2021). Secondly, operational efficiency appears in the form of production, inventory, and transportation processes improvements to minimize operational costs and enhance productivity (Dubey et al., 2021). Thirdly, social sustainability ensures employees' safety, ethical sourcing of raw materials, customer health safeguard, and community well-being (Seuring & Gold, 2022). Finally, economic sustainability can be defined as profitability maximization, costs elimination, and long-term stability of business operations achieved by implementing sustainable practices in supply chains. (Brandenburg et al., 2022).

2.4. Theoretical Review

The theoretical review examines theories that provide explanations for the relationship between packaging management practices and supply chain sustainability. In accordance with the study objectives, the review focuses on Circular Economy Theory. This theory is relevant because it explains the management and circulation of packaging materials, while Lean Supply Chain Theory explains waste reduction and operational efficiency (Marques et al., 2022).

Circular Economy Theory explains how economic and production systems can reduce resource losses by maintaining materials and products in productive use for as long as possible through reduction, reuse, recovery, reprocessing, and recycling. Unlike the conventional linear model of resource extraction, production, use, and disposal, the circular economy emphasizes closed-loop material flows and the preservation of resource value. Recent research on circular supply chains demonstrates that circular economy principles are increasingly integrated into supply chain management to reduce waste, increase material recovery, and improve resource efficiency (Montag, 2022). This theory is particularly relevant to packaging management because packaging materials can generate substantial waste when they are disposed of after use, whereas appropriate material selection, design, collection, reuse, and recycling can support more circular material flows (Silva & Pålsson, 2022).

Circular Economy Theory is particularly useful for explaining packaging material selection, packaging design, and recycling practices. Recyclability, environmental suitability, and material efficiency influence the possibility of recovering packaging materials. Packaging design can incorporate considerations of material reduction, recyclability, reuse, and end-of-life management. Packaging waste collection systems, material reuse systems, returnable packaging systems, reprocessing and material recovery, and recycling partnerships provide mechanisms through which packaging materials can be recovered and returned to productive use. These practices are therefore directly connected to environmental impact reduction and resource-utilization efficiency, which are two important indicators of supply chain sustainability in this study (Montag, 2022; Morashti et al., 2022).

2.5. Empirical Literature

Li and Zhang (2023) investigated how packaging material selection at Tetra Pak operations in China influenced supply chain sustainability in aseptic dairy and beverage production. The study examined whether replacing traditional plastic and glass cartons with FSC-certified paperboard and renewable polyethylene reduced environmental impacts and improved logistics performance. Grounded in Triple Bottom Line Theory, the researchers used a cross-sectional design involving 150 supply chain executives from Tetra Pak's Shanghai and Guangzhou facilities and analyzed the data using multiple regression and environmental impact assessment tools. The findings demonstrated that sustainable packaging material selection significantly reduced carbon emissions and material waste ($\beta = -0.44$, $p < 0.01$), while improving transport space utilization and reducing logistics costs ($\beta = 0.38$, $p < 0.05$). The study concluded that eco-optimized materials improved sustainability and operational throughput by enabling lighter loads and reducing transport frequency. However, the study primarily emphasized environmental impacts and logistics costs associated with material substitution and did not sufficiently examine other dimensions of supply chain sustainability, particularly delivery reliability and broader resource-utilization efficiency. It also examined a specialized packaging environment in China, limiting the generalizability of its findings to other manufacturing contexts. The present study addresses this gap by examining packaging material selection through recyclability, environmental suitability, lightweight characteristics, durability, and material efficiency and relating these practices to multiple dimensions of supply chain sustainability at Sulfo-Rwanda Industries Ltd.

Gebremariam and Debebe (2025) assessed the impact of packaging material choice on sustainability and operational efficiency among Abyssinia Water Bottling and Shebelle

Bottlers PLC in Ethiopia's FMCG sector. The study investigated whether shifting from standard PET plastic bottles to lighter and partially recycled plastics affected supply chain performance. A survey of 190 operations and logistics managers was combined with secondary operational performance data, and regression analysis was employed. The findings showed that lighter and partially recycled packaging materials significantly reduced transportation fuel consumption ($\beta = -0.41$, $p < 0.01$) and storage costs ($\beta = -0.33$, $p < 0.05$), while waste output and CO₂ emissions also improved. However, the study concentrated heavily on lightweight and recycled plastic materials and therefore did not adequately investigate other criteria that may influence packaging material selection, such as durability, environmental suitability, recyclability across the full packaging life cycle, and material efficiency. Furthermore, the study focused mainly on transportation and storage outcomes rather than examining delivery reliability and the broader set of sustainability indicators adopted in the present study. The present research addresses this gap by using a more comprehensive operationalization of packaging material selection and linking it to environmental impact reduction, delivery reliability, cost efficiency, and resource-utilization efficiency.

Namutebi and Okello (2024) investigated how packaging material selection influenced supply chain sustainability at Lato Milk Ltd. and Jesa Farm Dairy in Uganda. The study examined whether switching from conventional opaque plastics to recyclable and insulated composite packaging affected delivery reliability and waste management outcomes. Using a cross-sectional design, 175 operations managers were surveyed and the data were analyzed through Structural Equation Modeling (SEM). The findings indicated that recyclable and insulated packaging materials improved operational efficiency by reducing spoilage during transport ($\beta = 0.47$, $p < 0.01$) and improved sustainability indicators through reduced landfill waste and better recycling rates ($\beta = 0.39$, $p < 0.05$). Although the study provides evidence linking material selection to both operational and environmental outcomes, its focus was primarily on dairy products and transport-related spoilage. It did not sufficiently examine cost efficiency, resource-utilization efficiency, and the broader organizational processes through which packaging materials are selected and managed. In addition, the dairy-specific context may not fully reflect packaging requirements in diversified manufacturing operations. The present study addresses these limitations by assessing material selection using multiple indicators and examining its effect on a broader measure of supply chain sustainability at Sulfo-Rwanda Industries Ltd.

Mwansasu and Mwangike (2025) examined the influence of packaging material selection on supply chain sustainability

and operational performance at Tanzania Breweries Limited (TBL). The objective was to assess how circular packaging materials, including returnable glass bottles and lightweight recyclable cans, affected production efficiency and environmental outcomes. A mixed-methods case study involving 155 survey respondents from procurement, logistics, and sustainability functions and 13 in-depth interviews with senior operations leaders was conducted. Inferential analysis indicated that circular packaging significantly improved competitive advantage, waste management, and per-unit logistics costs ($\beta = -0.36$, $p < 0.01$). The study concluded that strategic material selection improved sustainability through reduced disposal costs and improved reverse logistics. Nevertheless, its emphasis on circular packaging in the beverage industry means that it provides limited evidence regarding material selection in other manufacturing environments. It also emphasized competitive advantage, waste management, and logistics cost rather than simultaneously assessing environmental impact reduction, delivery reliability, cost efficiency, and resource-utilization efficiency. The present study therefore extends the literature by examining material selection using a broader set of sustainability outcomes in the context of Sulfo-Rwanda Industries Ltd.

3. Methodology

The study assessed the effect of packaging material selection on supply chain sustainability at Sulfo-Rwanda Industries Ltd. The research used a descriptive and explanatory research design to describe packaging management practices and determine the relationships between packaging management practices and supply chain sustainability. Packaging material selection was treated as one of the five dimensions of packaging management practices and was examined as an independent variable. The study focused on how the selection of packaging materials was associated with supply chain sustainability at Sulfo-Rwanda Industries Ltd. The explanatory research design enabled the researcher to determine the statistical effect of packaging material selection on supply chain sustainability while considering the other packaging management practices included in the study.

The study population consisted of 109 employees from 11 key departments of Sulfo-Rwanda Industries Ltd. These departments included Logistics, Production, Quality Assurance and Control, Procurement, Environmental, Health and Safety, Operations, Finance and Accounting, Warehouse Management, Sales and Marketing, Research and Development, and Customer Service. The census sampling technique was used, whereby all 109 employees were included in the study. This approach allowed the researcher to obtain information from the entire identified

population rather than selecting a smaller sample. The inclusion of employees from different departments provided information on packaging management practices and supply chain sustainability from different organizational functions.

Data on packaging material selection were collected using a structured questionnaire administered to all 109 employees. Packaging material selection was measured as part of Section B of the questionnaire, which measured packaging management practices. The questionnaire used closed-ended statements measured on a five-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree. The packaging material selection items focused on recyclability, environmental suitability, lightweight characteristics, durability, and material efficiency. These indicators enabled the researcher to obtain standardized responses concerning the extent to which appropriate packaging material selection practices were implemented at Sulfo-Rwanda Industries Ltd. The use of standardized responses also allowed the collected information to be coded and subjected to statistical analysis.

Supply chain sustainability was measured as the dependent variable in the study. It was assessed using four indicators, namely environmental impact reduction, delivery reliability and timeliness, cost efficiency, and resource-utilization efficiency. Environmental impact reduction focused on the reduction of packaging waste and environmental impacts, while delivery reliability and timeliness concerned the dependable and timely movement of products. Cost efficiency focused on packaging, handling, storage, transportation, and related operational costs. Resource-utilization efficiency assessed the efficient use of packaging materials, equipment, storage, and other supply chain resources. These indicators provided the basis for assessing the extent to which packaging material selection was associated with supply chain sustainability.

The study also used a semi-structured interview guide and a documentary review checklist to complement the questionnaire data. Interviews were conducted with two key informants, namely the Production Manager and Supply Chain Manager. The interviews focused on the implementation of packaging material selection and its perceived implications for environmental performance, delivery reliability, cost efficiency, and resource utilization. Documentary review covered production reports, supply chain and logistics records, quality assurance and quality control reports, packaging-related records, sustainability and environmental compliance reports, and other relevant organizational documents. The information obtained through interviews and documentary review provided additional contextual information and was compared with questionnaire findings where relevant.

The validity and reliability of the research instruments were assessed before the main data collection. A pilot study was conducted at Bralirwa Plc using 11 respondents, representing approximately 10% of the main study population. The pilot study assessed the clarity, relevance, logical sequencing, response options, and understanding of questions relating to packaging management practices and supply chain sustainability. Three unclear items were removed, and minor wording and formatting adjustments were made, resulting in a final questionnaire containing 44 substantive items. The Content Validity Index was reported as 0.936, which was above the threshold of 0.80 stated in the study. Reliability was assessed using Cronbach's Alpha, and the 44 retained items produced a coefficient of 0.844, which was above the acceptable threshold of 0.70. The pilot responses were not included in the final dataset used for the main study.

The quantitative data were coded, entered, cleaned, and analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the collected data. For packaging material selection, the mean scores of items relating to recyclability, environmental suitability, lightweight characteristics, durability, and material efficiency were aggregated to obtain a composite measure. Supply chain sustainability was similarly measured using composite scores for environmental impact reduction, delivery reliability and timeliness, cost efficiency, and resource-utilization efficiency. The mean scores were interpreted using the five-point Likert scale, where 4.21–5.00 represented very high agreement, 3.41–4.20 represented high agreement, 2.61–3.40 represented moderate agreement, 1.81–2.60 represented low agreement, and 1.00–1.80 represented very low agreement.

Multiple linear regression analysis was used to determine the effect of packaging material selection on supply chain sustainability while controlling for the other packaging management practices. In the regression model, packaging material selection was represented by X_1 , while supply chain sustainability was represented by Y . The coefficient β_1 represented the regression coefficient for packaging material selection. The regression coefficient, standardized beta coefficient, t-value, and p-value were used to determine the direction, magnitude, relative contribution, and statistical significance of packaging material selection. For Specific Objective I, the main test was the multiple regression coefficient β_1 , t-value, and p-value. The hypothesis was tested at a 5% significance level. A p-value below 0.05 led to rejection of the null hypothesis and indicated a statistically significant effect of packaging material selection on supply chain sustainability, while a p-value equal to or greater than 0.05 led to failure to reject

the null hypothesis. Before regression analysis, linearity, independence of observations, normality of residuals, homoscedasticity, and absence of problematic multicollinearity were assessed.

4. Results and Discussion

This section presents the findings of the study through systematic data presentation, analysis, interpretation, and discussion in line with the research objectives. It begins with the presentation of the response rate obtained from the 109 employees of Sulfo-Rwanda Industries Ltd who participated in the study. It then presents the descriptive analysis of packaging material selection. Finally, inferential statistical analyses comprising correlation analysis, multiple regression analysis, and hypothesis testing are performed in accordance with the study

objectives to assess the effect of packaging material selection evaluate the effect of automation and handling processes, and determine the effect of recycling practices on the supply chain sustainability of Sulfo-Rwanda Industries Ltd.

4.1.1. Descriptive statistics Packaging material selection practices used by Sulfo-Rwanda Industries Ltd

Below is a description of the analysis of the practices for the selection of packaging material used by Sulfo-Rwanda Industries Ltd. The analysis was based on the answers of 109 workers, and its objective is to analyze the degree of appropriateness of the packaging material selection practices that the company uses in order to promote sustainable supply chains. The information provided will be represented in terms of frequencies, percentages, mean score values, and standard deviations to determine the degree of agreement with each statement.

Table 1: Packaging material selection practices used by Sulfo-Rwanda Industries Ltd

	Mean	St. Dev
Sulfo-Rwanda Industries Ltd ensures that packaging materials are eco-friendly and sustainable.	4.06	0.98
Sulfo-Rwanda Industries Ltd selects packaging materials that protect product quality during storage and transportation.	2.11	0.31
Sulfo-Rwanda Industries Ltd evaluates the cost-effectiveness of packaging materials before procurement.	4.72	0.73
Sulfo-Rwanda Industries Ltd prioritizes durable materials that reduce product damage and waste.	4.64	0.89
Sulfo-Rwanda Industries Ltd regularly reviews and updates packaging materials based on market trends.	3.94	0.57
Sulfo-Rwanda Industries Ltd sources packaging materials from reliable and certified suppliers.	4.37	0.82
Sulfo-Rwanda Industries Ltd selects packaging materials based on customer requirements for product safety, convenience, and usability.	4.59	0.85
Overall average	4.06	0.74

Source: Primary data, 2026

The findings indicate an overall high level of agreement that Sulfo-Rwanda Industries Ltd applies packaging material selection practices, with an overall mean of 4.06 and standard deviation of 0.74. The highest-rated practice was evaluating the cost-effectiveness of packaging materials before procurement (Mean = 4.72, SD = 0.73), followed by prioritizing durable materials that reduce product damage and waste (Mean = 4.64, SD = 0.89) and selecting materials based on customer requirements for product safety, convenience, and usability (Mean = 4.59, SD = 0.85). Sourcing materials from reliable and certified suppliers also recorded a very high level of agreement (Mean = 4.37, SD = 0.82). Similarly, ensuring that packaging materials are eco-friendly and sustainable (Mean = 4.06, SD = 0.98) and regularly reviewing materials based on market trends (Mean = 3.94, SD = 0.57) recorded high levels of agreement. However, selecting

packaging materials that protect product quality during storage and transportation recorded the lowest mean of 2.11 (SD = 0.31), indicating a low level of agreement with relatively consistent responses. These findings suggest that the company places considerable emphasis on cost, durability, supplier reliability, and customer requirements when selecting packaging materials, while greater attention may be required to ensure that material selection adequately protects product quality throughout storage and transportation.

The findings are broadly consistent with Li and Zhang (2023), who found that sustainable packaging materials can contribute to improved environmental and logistics performance, and with Gebremariam and Debebe (2025), who reported that lighter and partially recycled packaging materials were associated with reductions in fuel and

storage costs. Similarly, Namutebi and Okello (2024) found that appropriate packaging material selection contributed to reduced product spoilage and improved supply chain sustainability. The current findings particularly support these studies because cost-effectiveness (Mean = 4.72), durability and waste reduction (Mean = 4.64), and environmental suitability (Mean = 4.06) were highly rated. However, the low rating for protecting product quality during storage and transportation (Mean = 2.11) differs from the emphasis in previous studies on packaging materials as a means of reducing product losses and improving logistics performance. This suggests that although material selection at Sulfo-Rwanda Industries Ltd is generally strong, the protective function of packaging across storage and transportation requires further improvement. Strengthening this aspect could reduce product damage and losses and thereby enhance cost efficiency, resource utilization, delivery reliability, and overall supply chain sustainability.

According to the explanation of the Operational Manager of Sulfo-Rwanda Industries Ltd, there are several aspects that the company considers when selecting packaging materials, including product protection requirements, durability, availability, cost-efficiency, and environmental considerations. The company aims to select packaging materials that ensure maintenance of the product quality during storage and transportation but at the same time reduces unnecessary wastes. This includes the selection of materials depending on their suitability for the products

and contribution to efficient supply chain operations. According to the explanation of the Supply Chain Manager of Sulfo-Rwanda Industries Ltd, supplier reliability and consistency are the important aspects of packaging material procurement. The company works with approved suppliers that can deliver materials which would meet the required quality and production needs. According to the manager, supplier evaluation helps to ensure continuous availability of packaging materials and avoid disruptions in their supplies that would negatively influence the production and distribution activities. However, both managers admitted that there was a need for improvement regarding incorporation of sustainability criteria into packaging material selection decisions. They stated that although the company considered the durability and cost-efficiency, more attention needed to be paid to the selection of materials with higher environmental benefits, such as recyclable and eco-friendly options.

4.1.2. Level of supply chain sustainability at Sulfo-Rwanda Industries Ltd

This section provides descriptive findings on the level of supply chain sustainability at Sulfo-Rwanda Industries Ltd based on the responses of 109 employees. Mean and standard deviation were used to measure the perceptions of the employees regarding the sustainable supply chain practices maintained by the firm. The higher mean scores indicated better sustainability initiatives while low scores indicated areas requiring improvement.

Table 2: Level of supply chain sustainability at Sulfo-Rwanda Industries Ltd

	Mean	St. Dev
Sulfo-Rwanda Industries Ltd ensures timely delivery of products to meet customer demand.	4.77	.62
Sulfo-Rwanda Industries Ltd optimizes inventory levels to reduce stockouts and excess.	3.72	.69
Sulfo-Rwanda Industries Ltd minimizes operational costs through efficient supply chain practices.	4.68	.78
Sulfo-Rwanda Industries Ltd reduces waste and environmental impact in its supply chain operations.	4.79	.47
Sulfo-Rwanda Industries Ltd maintains accurate tracking of materials and finished products.	4.56	.81
Sulfo-Rwanda Industries Ltd implements sustainable practices in packaging, transportation, and warehousing.	3.16	.43
Sulfo-Rwanda Industries Ltd integrates modern technology to support supply chain management.	4.30	.86
Sulfo-Rwanda Industries Ltd monitors supplier performance to ensure quality and sustainability.	4.49	.60
Sulfo-Rwanda Industries Ltd fosters collaboration across departments to enhance operational efficiency.	4.39	.91
Overall average	4.32	0.69

Source: Primary data, 2026

The findings indicate an overall very high level of supply chain sustainability at Sulfo-Rwanda Industries Ltd, as reflected by the overall mean of 4.32 and standard deviation of 0.69. The highest-rated practice was the reduction of waste and environmental impact in supply chain operations (Mean = 4.79, SD = 0.47), followed by ensuring timely delivery of products to meet customer demand (Mean = 4.77, SD = 0.62) and minimizing operational costs through efficient supply chain practices (Mean = 4.68, SD = 0.78). Maintaining accurate tracking of materials and finished products (Mean = 4.56, SD = 0.81), monitoring supplier performance (Mean = 4.49, SD = 0.60), and fostering collaboration across departments (Mean = 4.39, SD = 0.91) also recorded very high levels of agreement. Integration of modern technology to support supply chain management recorded a very high level of agreement (Mean = 4.30, SD = 0.86), while optimizing inventory levels received a high level of agreement (Mean = 3.72, SD = 0.69). However, implementing sustainable practices in packaging, transportation, and warehousing recorded the lowest mean of 3.16, indicating a moderate level of agreement, although the low standard deviation of 0.43 suggests relatively consistent responses. The results suggest that Sulfo-Rwanda Industries Ltd demonstrates strong supply chain sustainability, particularly in environmental impact reduction, delivery reliability, cost efficiency, material tracking, and supplier performance, while further strengthening sustainability practices across packaging, transportation, and warehousing could improve overall supply chain sustainability.

The results show that the level of supply chain sustainability of Sulfo-Rwanda Industries Ltd recorded an overall mean of 4.32, which falls within the range of 4.21–5.00, indicating a very high level of agreement among respondents. This means that respondents strongly agree

that the organization has high supply chain sustainability due to timely delivery, cost efficiency, waste reduction, inventory optimization, supplier monitoring, technological integration and collaboration across departments. The standard deviation of 0.69 indicates low variability, suggesting high consistency among respondents in terms of sustainability performance of the company. However, the weakest area identified was the implementation of sustainable practices in packaging, transportation and warehousing, which recorded a mean of 3.16, indicating a need for further improvement of sustainable logistics practices. These findings are supported by Fahimnia et al. (2022), who found out that sustainable supply chain management improves organizational performance via integration of environmental, economic and operational practices. Similarly, Uwizeyimana and Habimana (2023) found out that sustainable packaging management practices significantly improve supply chain performance of manufacturing companies in Rwanda.

4.1.3 Inferential Statistics

This section presents the findings and discussion of the study on the effect of packaging material selection on supply chain sustainability at Sulfo-Rwanda Industries Ltd. It focuses on recyclability, environmental suitability, lightweight characteristics, durability, and material efficiency and examines their relationship with supply chain sustainability. The findings are presented and discussed in relation to the study objective and the indicators of supply chain sustainability, namely environmental impact reduction, delivery reliability and timeliness, cost efficiency, and resource-utilization efficiency.

Table 3: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.901a	.812	.803	.14449	1.924

a. Predictors: (Constant), X1 = Packaging material selection

b. Dependent Variable: Y = supply chain sustainability at Sulfo-Rwanda Industries Ltd.

Table 3 shows that the multiple correlation coefficient (R = 0.901) indicates a very strong positive association between the combined packaging management practices and supply chain sustainability. The coefficient of determination ($R^2 = 0.812$) indicates that the five packaging management practices jointly explain 81.2% of the observed variation in supply chain sustainability at Sulfo-Rwanda Industries Ltd., while the remaining 18.8% is attributable to other factors not included in the model.

The adjusted R^2 of 0.803 indicates that the model retains a high explanatory capacity after adjustment for the number of predictors included. This finding suggests that packaging material selection, packaging design, quality control and documentation, automation and handling processes, and recycling practices collectively provide substantial explanatory power for supply chain sustainability. The standard error of the estimate of 0.14449 indicates the extent of variation between the

observed and predicted values of supply chain sustainability, with the relatively small value suggesting a reasonably good fit of the model to the observed data. The Durbin-Watson statistic of 1.924 is close to the recommended value of 2, suggesting that the residuals are

sufficiently independent and that there is no serious autocorrelation problem. Therefore, the regression model provides an appropriate basis for assessing the statistical contribution of the packaging management practices to supply chain sustainability.

Table 4: ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	9.279	1	1.856	88.38	.000 ^b
	Residual	2.150	107	.021		
	Total	11.430	108			

a. Dependent Variable: Y = supply chain sustainability at Sulfo-Rwanda Industries Ltd.

b. Predictors: (Constant), X1 = Packaging material selection, design

The ANOVA results in Table 4 indicate that the overall regression model is statistically significant ($F = 88.380$, $p < .001$). Since the significance level is below the predetermined 0.05 level, the null hypothesis that the five packaging management practices jointly have no statistically significant effect on supply chain sustainability is rejected. This result indicates that the set of packaging management practices, considered jointly, significantly

explains variations in supply chain sustainability at Sulfo-Rwanda Industries Ltd. The significance of the overall regression model is consistent with the findings of studies that have demonstrated the importance of integrating sustainable packaging, operational efficiency, quality management, and waste-management practices within supply chain systems.

Table 5: Regression coefficients

Model		Unstandardized Coefficients	Standardized Coefficients	95.0% Confidence Interval for B			
		B	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	-1.307		-3.924	.000	-1.969	-.646
	X1 = Packaging material selection,	.197	.232	3.788	.000	.094	.299

a. Dependent Variable: Y = supply chain sustainability at Sulfo-Rwanda Industries Ltd.

The results in Table 5 showed that packaging material selection had a positive and statistically significant effect on supply chain sustainability at Sulfo-Rwanda Industries Ltd. The unstandardized regression coefficient for packaging material selection was $B = 0.197$, indicating that a one-unit increase in packaging material selection was associated with a 0.197-unit increase in supply chain sustainability, while holding the other variables in the regression model constant. The standardized beta coefficient of $\beta = 0.232$ indicated a positive contribution of packaging material selection to supply chain sustainability. The results further showed that the effect was statistically significant because the t-value was 3.788 and the significance value was 0.000, which was less than the 0.05 significance level. Therefore, the null hypothesis that packaging material selection had no statistically significant effect on supply chain sustainability was rejected. The 95%

confidence interval for the coefficient ranged from 0.094 to 0.299, and because the interval did not include zero, the positive effect was further supported.

4.2. Discussion of Findings

The findings indicated that packaging material selection played an important role in improving supply chain sustainability at Sulfo-Rwanda Industries Ltd. The findings showed that the company placed considerable attention on the selection of packaging materials, particularly in relation to cost-effectiveness, durability, supplier reliability, customer requirements, and environmental considerations. Appropriate packaging material selection was important because the materials used could influence product protection, waste generation, resource utilization,

transportation activities, and the overall sustainability of supply chain operations. However, the findings also indicated that greater attention was required to ensure that selected packaging materials adequately protected product quality during storage and transportation. These findings suggested that packaging material selection needed to balance cost, durability, environmental suitability, product protection, and resource efficiency.

The findings were consistent with Circular Economy Theory, which explained the management and circulation of packaging materials through reduction, reuse, recovery, reprocessing, and recycling. In the context of Sulfo-Rwanda Industries Ltd., the selection of recyclable, environmentally suitable, and material-efficient packaging materials could support the recovery of materials and reduce unnecessary waste. The theory therefore helped explain how appropriate packaging material selection could contribute to environmental impact reduction and resource-utilization efficiency. The findings supported the view that packaging materials should not only be selected according to their immediate functional requirements but also according to their environmental and resource implications throughout the supply chain.

The findings were consistent with previous studies conducted by Li and Zhang (2023), Gebremariam and Debebe (2025), and Namutebi and Okello (2024). Li and Zhang (2023) found that sustainable packaging material selection reduced environmental impacts and improved transport space utilization and logistics costs. Similarly, Gebremariam and Debebe (2025) found that lighter and partially recycled packaging materials reduced transportation fuel consumption, storage costs, waste output, and carbon dioxide emissions. Namutebi and Okello (2024) also found that appropriate packaging material selection contributed to reduced product spoilage and improved supply chain sustainability. These findings were generally consistent with the present study because they demonstrated that appropriate packaging material choices could improve environmental performance, operational efficiency, product protection, and supply chain sustainability. However, the present study considered a wider range of material-selection characteristics, including recyclability, environmental suitability, lightweight characteristics, durability, and material efficiency, thereby providing a broader assessment of packaging material selection at Sulfo-Rwanda Industries Ltd.

The interview findings provided further explanation of the quantitative results. The Operational Manager explained that the company considered product protection requirements, durability, availability, cost-efficiency, and environmental considerations when selecting packaging

materials. The Supply Chain Manager also emphasized supplier reliability and consistency, explaining that the company worked with approved suppliers capable of providing packaging materials that met required quality and production needs. These practices indicated that packaging material selection was linked to both operational continuity and supply chain efficiency. However, the managers also indicated that more attention was needed to incorporate sustainability criteria into packaging material selection decisions, particularly through greater use of recyclable and environmentally friendly materials.

The findings therefore suggested that packaging material selection at Sulfo-Rwanda Industries Ltd. involved both strengths and areas requiring improvement. The company demonstrated consideration of cost-effectiveness, durability, customer requirements, and supplier reliability, which could support operational efficiency and continuity of supply. However, the need for greater emphasis on product protection during storage and transportation and stronger incorporation of environmental criteria indicated opportunities for improving sustainability. These findings were consistent with Circular Economy Theory and the previous studies, which emphasized the importance of recyclability, environmental suitability, efficient material use, and appropriate packaging choices in supporting sustainable supply chain practices.

5. Conclusion and Recommendations

5.1. Conclusion

The study concluded that packaging material selection had a significant contribution to supply chain sustainability at Sulfo-Rwanda Industries Ltd. Appropriate consideration of recyclability, environmental suitability, lightweight characteristics, durability, and material efficiency supported environmental impact reduction, delivery reliability and timeliness, cost efficiency, and resource-utilization efficiency. The findings further showed that although the company considered cost-effectiveness, durability, supplier reliability, customer requirements, and environmental factors when selecting packaging materials, greater attention was needed to strengthen product protection during storage and transportation and to incorporate more sustainable packaging materials. Therefore, strengthening packaging material selection practices while maintaining product quality, cost-effectiveness, and resource efficiency could help Sulfo-Rwanda Industries Ltd. improve the overall sustainability of its supply chain

5.2. Recommendations

Based on the findings concerning packaging material selection and supply chain sustainability at Sulfo-Rwanda Industries Ltd., the following three specific recommendations were made:

- 1) Sulfo-Rwanda Industries Ltd. should increase the use of recyclable and environmentally suitable packaging materials. The company should review its current packaging materials and give greater preference to materials that can be recycled, recovered, or reused while maintaining the required product quality.
- 2) Sulfo-Rwanda Industries Ltd. should strengthen packaging material quality requirements for storage and transportation. The company should ensure that selected packaging materials meet clear durability and product-protection requirements before they are approved for use. Packaging materials should be tested for their ability to protect products during handling, storage, and transportation.
- 3) Sulfo-Rwanda Industries Ltd. should establish clear sustainability criteria in its packaging material procurement and supplier-selection process. Procurement and supply chain staff should assess packaging materials based on recyclability, environmental suitability, weight, durability, and material efficiency, in addition to price and supplier reliability. Suppliers that consistently provide packaging materials meeting these sustainability and quality requirements should be prioritized.

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