A Study on Optimization of Reverse Logistics Component Routes in Supply Chain Management Towards VJ Logistics Salem

Mr. Dhanush S[1], Mrs.Dr C.Meera[2]

Student[1] School of Management Studies, Karpagam College of Engineering Coimbatore, Tamilnadu, India

Director[2] School of Management Studies, Karpagam College of Engineering-Coimbatore, Tamilnadu, India

ABSTRACT

This study investigates the impact of reverse logistics on supply chain resilience and sustainability at V.J. Logistics India Private Limited, Salem. Reverse logistics — encompassing product returns, recycling, remanufacturing, and responsible disposal — has emerged as a strategic imperative amid growing environmental scrutiny and regulatory demands. A descriptive research design was adopted, with data collected from 123 respondents using a structured questionnaire. The study employs Simple Percentage Analysis, Chi-Square Test, Correlation Analysis, and ANOVA to examine relationships among key variables. Findings reveal that 87.8% of respondents affirm that reverse logistics has enhanced their company's overall sustainability, and 35.0% indicate efficient carbon-emission reduction through reverse logistics activities. The study identifies labour costs and unpredictable return volumes as primary challenges. The chi-square test confirms a significant relationship between educational qualification and recycling/disposal methods ($p < 0.05$). ANOVA results establish a significant association between employee designation and sustainability-planning coordination. The research recommends integrating reverse logistics into core supply chain strategy, adopting advanced technologies such as AI and blockchain, and designing products for circular-economy principles. These measures can strengthen supply chain resilience while advancing environmental sustainability goals.

Keywords: *Reverse Logistics, Supply Chain Resilience, Sustainability, Green Logistics, Circular Economy, Carbon Emissions, V.J. Logistics*

I. INTRODUCTION

In today's environmentally conscious business landscape, increasing scrutiny over corporate environmental impact has catalysed a paradigm shift in supply chain management. Integral to this transformation is the ascendancy of reverse logistics, which diverges from traditional linear production models by focusing on the upstream movement of goods within the supply chain. This 'backward flow' encompasses diverse activities such as returns processing, product repair and remanufacturing, recycling, and responsible disposal. Once viewed primarily as a cost centre, reverse logistics has become a strategic imperative driven by escalating sustainability demands, stricter environmental regulations, and growing consumer awareness.'Greening' the supply chain is a critical subject matter for competitive manufacturing and service supply chains. Due to increasing environmental issues and associated resource depletion problems, environmental regulatory bodies continue to impose stricter regulations. The customer's environmental consciousness has also evidently increased. Manufacturing processes are often blamed for harming the environment through waste, resource depletion, and ecosystem disruption (Gupta, 1995; Beamon, 1999). Green Supply Chain Management (GSCM), which integrates green concerns into supply chain management, has emerged as a strategy for major companies — especially in the electronics industry — to achieve profit and market-share objectives while reducing environmental risk and impact (Zhu and Sarkis, 2006).

1.1 Benefits of Reverse Logistics

Environmental Benefits: Reverse logistics facilitates the recovery and recycling of products and materials, significantly reducing waste in landfills and the pollution generated by manufacturing processes. By reusing and recycling materials, the need to produce new materials is reduced.

Economic Benefits: Returned products or recycled materials can be reconditioned or reused, allowing companies to recover part of their value. Reverse logistics also reduces costs associated with waste management and the purchase of new raw materials.

Improved Customer Relations: An efficient reverse logistics system, especially in returns management, can improve the customer experience, increasing satisfaction and loyalty. Companies that adopt reverse logistics practices also reinforce their brand image as responsible entities.

Operational Efficiency: Reverse logistics forces companies to review and optimize their supply chains, which can lead to greater efficiency in all operations and drive innovation in processes and technologies.

1.2 Types of Reverse Logistics

Reverse logistics encompasses several key activities: (1) Customer returns management — reintegrating products into the supply chain through repair, reconditioning, recycling, or disposal; (2) Material recycling — reducing resource consumption and waste to support the circular economy; (3) Reconditioning and remanufacturing — restoring used or defective products to 'as-new' condition; (4) Hazardous waste management — ensuring proper treatment of industrial waste; and (5) Return of excess inventory — managing unsold or excess stock to reduce overstock.

1.3 Industry Profile

The logistics industry in India is growing rapidly, expected to expand at a CAGR of 15.5% between FY2019 and FY2024. Valued at USD 150 billion, it contributes 14.4% of the country's GDP. India's logistics performance ranking improved from 54th in 2014 to 35th in 2016 in the World Bank's Logistics Performance Index. The industry's growth is driven by the expansion of e-commerce, government initiatives such as 'Sagarmala' and 'Make in India,' and increasing globalization.

1.4 Company Profile

V.J. Logistics India Private Limited (CIN: U63030TZ2020PTC033686) is a private limited company incorporated on 07 April 2020, registered at the Registrar of Companies, Coimbatore. Classified as a non-government company, it is engaged in supporting and auxiliary transport activities. The company is headquartered at 830/486 Rohini Garden, Alagapuram Periya Pudur Fairlands, Salem – 636 016, Tamil Nadu, India, with authorised capital of Rs. 1,500,000.

1.5 Statement of the Problem

The growing complexity of global supply chains, increased consumer demand for sustainable practices, and stricter environmental regulations have intensified the need for companies to adopt reverse logistics. However, there is a significant challenge in integrating reverse logistics effectively into traditional supply chains without compromising cost-efficiency, operational stability, and environmental goals. Companies often struggle to measure the direct impact of reverse logistics on supply chain resilience and sustainability.

1.6 Objectives of the Study

Primary Objective: To optimise the reverse logistics component routes towards improving efficiency and reducing transportation costs.

Secondary Objectives:

- To analyse the impact of optimised reverse logistics on overall supply chain performance.
- To explore the role of technology and software solutions in improving reverse logistics processes.
- To assess the environmental benefits of optimised reverse logistics routes, including reduced emissions.
- To identify the main challenges faced in reverse logistics route optimisation and suggest solutions.

II. REVIEW OF LITERATURE

Govindan et al. (2015) demonstrated that reverse logistics improves supply chain resilience by creating systems that handle product returns, repairs, recycling, or refurbishing. This adds flexibility, enabling supply chains to respond quickly to disruptions while encouraging decentralised systems that reduce dependence on central hubs.

Agrawal et al. (2016) highlighted that reverse logistics reduces environmental impact by promoting resource recovery and minimising waste. It facilitates the reuse, refurbishment, and recycling of products, significantly lowering raw material consumption and aligning with circular-economy principles.

Hazen et al. (2016) found that reverse logistics significantly contributes to reducing carbon emissions by decreasing the need for raw material extraction and production. By focusing on product returns and remanufacturing, companies can reduce energy consumption and transportation emissions.

Waqas et al. (2018) identified that the most critical barriers to reverse logistics adoption include high financial costs, lack of qualified professionals, absence of government support policies, and poor organisational culture. They noted that implementation is particularly difficult in developing countries.

Prajapati et al. (2019) identified strategic barriers as the most crucial to implementing reverse logistics, followed by environmental and regulatory, operational, economic, technological, and sociocultural barriers. Good management guidance is required to address these barriers.

Carter & Rogers (2018) argued that integrating reverse logistics promotes a closed-loop supply chain, enhances corporate social responsibility (CSR) initiatives, and helps companies achieve sustainability certifications that improve competitive edge.

2.1 Research Gap

Despite considerable research on reverse logistics, significant gaps remain in understanding its full impact on supply chain resilience and sustainability. There is a notable lack of quantitative studies empirically measuring the direct effects of reverse logistics on key performance indicators such as cost efficiency, carbon emissions reduction, and resource optimisation. The integration of emerging technologies such as artificial intelligence and blockchain in enhancing reverse logistics processes remains underexplored.

III. RESEARCH METHODOLOGY

Research Design: A descriptive research design was adopted for this study to describe the characteristics and relationships of the variables under investigation.

Sampling Design: A simple random sampling strategy was employed to ensure unbiased representation of the target population.

Sample Size: The study included 123 respondents, comprising employees and managers at V.J. Logistics India Private Limited and related supply chain stakeholders.

Period of Study: The study was conducted over a three-month period.

Data Collection: Primary data were collected through a structured questionnaire distributed via Google Forms and printed hardcopies. Secondary data were sourced from company publications, websites, books, and journal articles.

3.1 Statistical Tools Used

The following analytical tools were employed:

- Simple Percentage Analysis — to describe and interpret frequency distributions.
- Chi-Square Test — to assess the significance of associations between categorical variables.
- Correlation Analysis (Pearson, Kendall's tau-b, Spearman's rho) — to measure the strength and direction of relationships between variables.
- One-Way ANOVA — to test differences in means across multiple groups.

IV. DATA ANALYSIS AND INTERPRETATION

4.1 Demographic Profile of Respondents

TABLE 4.1: Gender of Respondents

Gender	Respondents	Percentage
Male	107	87.0%
Female	16	13.0%
TOTAL	**123**	**100.0%**

Source: Primary Data

Majority (87.0%) of the respondents are male, indicating a male-dominated workforce in the logistics sector.

TABLE 4.2: Age Group of Respondents

Age	Respondents	Percentage
Below 25 years	33	26.8%
26-30 years	30	24.4%
31-35 years	20	16.3%
36-40 years	23	18.7%
Above 41 years	17	13.8%
TOTAL	**123**	**100.0%**

Source: Primary Data

Majority (26.8%) of the respondents belong to the below-25-years age group, indicating a relatively young workforce.

TABLE 4.3: Educational Qualification

Qualification	Respondents	Percentage
HSC	11	8.9%
Diploma	31	25.2%
Under Graduation	40	32.5%
Post Graduation	26	21.1%
Others	15	12.2%
TOTAL	**123**	**100.0%**

Source: Primary Data

Majority (32.5%) of the respondents hold an undergraduate degree, reflecting an educated workforce capable of engaging with sustainability initiatives.

4.2 Reverse Logistics and Carbon Emission Reduction

TABLE 4.4: How Effectively Has Reverse Logistics Helped Reduce Carbon Emissions?

Response	Respondents	Percentage
Very Efficiently	31	25.2%
Efficiently	43	35.0%
Neutral	30	24.4%
Inefficiently	12	9.8%
Very Inefficiently	7	5.7%

TOTAL	**123**	**100.0%**

Source: Primary Data

A combined 60.2% of respondents rated reverse logistics as efficient or very efficient in reducing carbon emissions. The majority (35.0%) indicated it works efficiently, confirming reverse logistics as an effective tool for emission reduction at V.J. Logistics.

TABLE 4.5: Reverse Logistics Activities Contributing Most to Carbon Reduction

Activity	Respondents	Percentage
Optimised Transportation Routes	24	19.5%
Consolidation of Return Shipments	32	26.0%
Reuse of Packaging Materials	25	20.3%
Energy-Efficient Transportation	26	21.1%
Efficient Warehouse Management	16	13.0%
TOTAL	**123**	**100.0%**

Source: Primary Data

Consolidation of return shipments (26.0%) is identified as the most impactful activity in reducing carbon emissions, followed by energy-efficient transportation methods (21.1%).

4.3 Recycling and Reuse Efforts

TABLE 4.6: Reverse Logistics Influence on Recycling and Reuse Efforts

Response	Respondents	Percentage
Very Efficiently	44	35.8%
Efficiently	25	20.3%
Neutral	38	30.9%
Inefficiently	10	8.1%
Very Inefficiently	6	4.9%
TOTAL	**123**	**100.0%**

Source: Primary Data

A significant 35.8% of respondents feel that reverse logistics has very efficiently influenced the industry's recycling and reuse efforts. Only 13.0% report inefficiency, indicating a predominantly positive impact.

TABLE 4.7: Overall Company Sustainability

Response	Respondents	Percentage
Yes	108	87.8%
No	15	12.2%
TOTAL	**123**	**100.0%**

Source: Primary Data

An overwhelming 87.8% of respondents confirmed that reverse logistics has increased their company's overall focus on sustainability, validating its strategic importance.

4.4 Cost Analysis of Reverse Logistics

TABLE 4.8: How Costly Are Reverse Logistics Operations?

Cost Level	Respondents	Percentage
Very High	36	29.3%
High	32	26.0%
Medium	37	30.1%
Low	11	8.9%
Very Low	7	5.7%
TOTAL	**123**	**100.0%**

Source: Primary Data

The cost distribution is mixed: 55.3% consider operations very high or high cost, while 30.1% rate them as medium cost. This underscores the need for cost optimisation strategies in reverse logistics.

TABLE 4.9: Major Cost Drivers in Reverse Logistics

Cost Driver	Respondents	Percentage
Transportation & Shipping	28	22.8%
Labour Costs for Handling Returns	38	30.9%
Warehousing & Storage	21	17.1%
Warehouse Space & Equipment	19	15.4%
Product Refurbishment/Recycling	17	13.8%
TOTAL	**123**	**100.0%**

Source: Primary Data

Labour costs for handling returns emerge as the primary cost driver (30.9%), followed by transportation and shipping costs (22.8%). These insights highlight areas requiring targeted cost-reduction measures.

4.5 Energy Efficiency

TABLE 4.10: Reverse Logistics Impact on Industry Energy Efficiency

Response	Respondents	Percentage
Very Efficiently	37	30.1%
Efficiently	35	28.5%
Neutral	34	27.6%
Inefficiently	10	8.1%
Very Inefficiently	7	5.7%
TOTAL	**123**	**100.0%**

Source: Primary Data

A combined 58.6% of respondents rate reverse logistics as very efficient or efficient in improving energy efficiency. The use of energy-efficient vehicles (29.3%) is the most adopted measure for improving energy efficiency in logistics operations.

V. STATISTICAL ANALYSIS

5.1 Chi-Square Test

H_0: There is no significant relationship between educational qualification and methods used for recycling or disposing of returned products.

H_1: There is a significant relationship between educational qualification and methods used for recycling or disposing of returned products.

Test	Value	df	Sig.
Pearson Chi-Square	286.8	16	.000
Likelihood Ratio	262.437	16	.000
N of Valid Cases	123		

Result: The asymptotic significance value is 0.000 ($p < 0.05$). Therefore, H_1 is accepted — there is a significant relationship between educational qualification and methods used for recycling or disposing of returned products.

5.2 Correlation Analysis

The Pearson correlation coefficient between Age and Coordination in Reverse Logistics Processes is 0.942 ($p < 0.01$), indicating a strong positive correlation. Kendall's tau-b = 0.924 and Spearman's rho = 0.962, further confirming a highly significant positive relationship. Older and more experienced employees demonstrate higher coordination efficiency in reverse logistics operations.

5.3 ANOVA

H_0: There is no significant relationship between designation and planning and coordination in reverse logistics improving sustainability efforts.

H_1: There is a significant relationship between designation and planning and coordination in reverse logistics improving sustainability efforts.

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	111.240	4	27.810	129.389	.000
Within Groups	25.362	118	0.215		
Total	**136.602**	**122**			

Result: The F-value is 129.389 and $p = 0.000$ (< 0.05). Therefore, H_1 is accepted — there is a significant relationship between employee designation and planning and coordination in reverse logistics improving sustainability efforts. Higher-designation employees show greater influence on sustainability planning outcomes.

VI. FINDINGS

Key findings from the study are as follows:

- 87.0% of the respondents are male, indicating the male-dominated nature of the logistics industry.
- The majority (26.8%) of respondents are below 25 years of age, reflecting a young workforce.
- 35.0% of respondents feel that reverse logistics efficiently helps their company reduce carbon emissions.
- Consolidation of return shipments (26.0%) is the most impactful reverse logistics activity for carbon emission reduction.
- 35.8% of respondents state that reverse logistics has very efficiently influenced their industry's recycling and reuse efforts.
- 87.8% of respondents confirm that reverse logistics has increased their company's overall sustainability.
- Labour costs for handling returns (30.9%) are the primary cost driver in reverse logistics systems.

- Unpredictable return volumes (23.6%) are identified as the primary complexity factor in reverse logistics operations.
- 30.1% of respondents consider reverse logistics very efficient in improving energy efficiency.
- Advanced software for route optimisation (26.0%) is the most frequently used planning tool.
- Chi-Square analysis confirms a significant association between educational qualification and recycling/disposal methods ($p < 0.05$).
- Correlation analysis reveals a strong positive relationship ($r = 0.942$) between age and coordination effectiveness in reverse logistics.
- ANOVA confirms a significant relationship between employee designation and sustainability planning coordination ($F = 129.389$, $p < 0.05$).

VII. SUGGESTIONS

Integrate Reverse Logistics into Supply Chain Strategy: Companies should view reverse logistics as an integral part of their overall supply chain strategy rather than a secondary function, aligning its goals with cost reduction, customer satisfaction, and environmental sustainability objectives.

Adopt Advanced Technologies: Utilising digital tools like AI, IoT, and blockchain can help optimise reverse logistics processes by improving real-time tracking, enhancing transparency, and predicting return patterns — thus enhancing both resilience and sustainability.

Collaborate with Supply Chain Partners: Building partnerships with suppliers, retailers, and logistics providers helps share the responsibility of reverse logistics and leads to innovative ways to reduce waste, reuse products, and handle returns more efficiently.

Incentivise Product Returns: Offering consumers incentives such as discounts or credits for returning used or damaged products can increase the efficiency of reverse logistics, promoting sustainability and securing a steady flow of returned goods for refurbishment.

Design for the Circular Economy: Products should be designed with their end-of-life in mind, incorporating ease of disassembly, recycling, or repurposing to reduce the burden of reverse logistics and enhance overall supply chain sustainability.

Continuous Monitoring and Reporting: Implement metrics to regularly track the performance of reverse logistics operations, such as return rates, recovery rates, and environmental impacts, to ensure continuous improvement and alignment with sustainability and resilience goals.

VIII. CONCLUSION

Reverse logistics plays a critical role in enhancing both supply chain resilience and sustainability. By efficiently managing the return, repair, recycling, and disposal of products, companies such as V.J. Logistics can minimise environmental impacts and create more adaptable supply chains capable of withstanding disruptions. The statistical analyses in this study — chi-square, correlation, and ANOVA — all confirm significant relationships between workforce characteristics, reverse logistics practices, and sustainability outcomes. Sustainable reverse logistics also provides a competitive advantage by improving brand reputation and customer loyalty. For companies to fully realise the potential of reverse logistics, it must be integrated into broader supply chain strategies, supported by advanced technology, and driven by a commitment to the principles of the circular economy.

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