International Journal for Novel Research in Economics , Finance and Management
www.ijnrefm.com
ISSN:3048-7722
Volume 4, Issue 3, May-June-2026, PP: 01-7

Green Supply Chain Management Practices and Their Effect on Operational Performance

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***Abstract* – The need for environmental sustainability has become a strategic necessity for businesses due to increasing regulations, stakeholder pressure, and resource shortages. GSCM incorporates the concept of environmental management into the supply chain process, from design to disposal. This study conducts a quantitative research to examine the association between GSCM activities and operational efficiency in 250 manufacturing companies in India. Based on a mixed methods approach involving surveys (n=250), accounting records analysis, and semi-structured interviews (n=30), the study examines the extent to which the companies implement GSCM practices based on five dimensions, namely, green purchasing, eco-design, reverse logistics, green manufacturing, and green logistics. SEM results show that GSCM practices have a strong positive effect on operational efficiency (β=0.42, p<0.001). In particular, eco-design and green manufacturing have the highest individual effects on operational efficiency. The link is partly mediated by green innovation capabilities.**

***Keywords:* - Green Supply Chain Management (GSCM), Operational Performance, Eco-Design, Green Manufacturing, Reverse Logistics, Sustainability, Environmental Management, India**

I. INTRODUCTION

The increasing environmental crisis worldwide, ranging from climate change, resource depletion, pollution, to the loss of biodiversity, has changed the dynamics of corporate strategy formulation. What was previously seen as a marginal corporate social responsibility issue has become an important strategic element. The government has enacted strict environmental policies; consumers have developed a preference for sustainable products; investors have demanded ESG reporting; and suppliers have been held responsible for their carbon emissions [1], [2].

For manufacturing organizations, the supply chain represents the main avenue through which environmental impacts occur. The upstream process (resource extraction and manufacture of parts) and downstream process (distributive and post-consumption activities) contribute up to 80 percent of the total environmental impact of any product. As such, the dominant trend in managing environmental issues has shifted from "end-of-pipe" pollution control measures to proactive and integrative approaches, such as Green Supply Chain Management (GSCM). GSCM refers to incorporating environmental considerations into supply chain management activities, which include product design, raw material sourcing, production processes, transportation, and product disposition [3], [4].

The issue is still lingering despite increased use of green strategies in businesses: Does going green lead to gains? The earliest studies on the subject adopted the trade-off viewpoint where environmental management activities caused higher costs with little or no return. The newer win-win viewpoint, however, contends that the practice of GSCM will help firms minimize waste, boost efficiency, raise brand value, and foster innovations, leading to improved business performance [5], [6].

Yet the results have been inconclusive. On one hand, some have found positive relationships. On the other hand, there are also studies showing either insignificant or negative impacts in the short run. Such inconsistencies could be due to methodological variations (longitudinal and cross-sectional designs), contextual differences (industries and countries), and overlooking the mediating effect of green innovation capability in the analysis.

The present study fills these gaps by providing a detailed empirical examination of the relationship between GSCM and operational performance within the manufacturing sector of India. As an industrializing country suffering from serious levels of environmental degradation, the setting of India is extremely important. Contributions include the following:

1. Validated Scale of Measurement: In order to assess GSCM and operational performance, a multi-dimensional scale has been devised and validated for measuring green

procurement, green design, reverse logistics, green manufacturing, and green logistics as well as cost, quality, delivery, and flexibility.

2. Empirical Study in an Emerging Market: Based on survey results from 250 firms and financial analysis, we provide strong evidence supporting a positive relationship between GSCM and operational performance.

3. Mediating Effect: Green innovation capabilities have been identified as a partial mediator of the relationship between GSCM and operational performance.

4. Insights from Qualitative Data: Through interviews with 30 supply chain managers, several insights regarding challenges and successful factors have emerged.

II. LITERATURE SURVEY

GSCM literature has expanded dramatically and covers several disciplines such as operations management, logistics, strategy, and environmental economics. Our literature review focuses on three major topics that include: 1) Conceptualization and dimensions of GSCM; 2) Association with operational performance; and 3) Mediators.

GSCM Conceptualization and Dimensions: GSCM is a multi-dimensional construct. The following five practices have been recognized as the essential part of GSCM [3],[7].

1. Green Purchasing (GP): Selection of the suppliers that meet certain environmental criteria (certification according to ISO 14001, usage of recycled material, and carbon footprint); supplier participation in joint activities aimed at improving the environment.

2. Eco-Design (ED): Embedding environmental factors into product/process design that involves designing products that are recyclable, disassemblable, re-manufacturable and made from less material.

3. Reverse Logistics (RL): Collection, reuse, recycling and/or disposal of returned products. RL closes the lifecycle circle.

4. Green Manufacturing (GM): Application of environmentally oriented manufacturing techniques that include reduction of energy consumption, waste generation, water utilization and emissions and usage of non-toxic materials.

5. Green Logistics (GL): Environmental logistics management activities that include environmentally friendly transport operations, packaging and warehousing activities.

Operational Performance and GSCM: The assessment of operational performance usually takes into account a range of dimensions such as cost (savings), quality (improvements), delivery (speed/reliability), and flexibility [6]. The reasoning supporting the positive connection between GSCM and operational performance is as follows:

- Waste Reduction: GSCM activities like lean manufacturing and recycling decrease material and energy wastes, thereby reducing costs.
- Process Efficiency: Green design and green manufacturing practices often bring about process innovations and greater efficiency.
- Risk Management: GSCM decreases regulatory risks, increases reputation, and ensures no disruptions to supply.
- Innovations: Environmental issues can serve as a source of innovations in both environmental and operational spheres.

Nonetheless, there are some counter arguments. The implementation of GSCM entails costs incurred through the adoption of technology, supplier certification, and staff training, which would lead to higher expenses in the short-run [5].

There is empirical evidence that supports the link between the two variables albeit not uniformly. According to a meta-analysis of 65 academic papers, there exists a slight yet statistically significant correlation between GSCM and firm performance ($r = 0.19$), with considerable heterogeneity [8]. Additionally, findings from the literature indicate that the relationship is stronger for studies conducted in developed countries than in developing countries.

Mediating Mechanism: Contemporary research on green SCM goes beyond exploring simple associations to analyzing mediation effects. Green innovation capacity, defined as the ability of a company to innovate new products or processes or adopt a new business model aimed at reducing environmental footprint, serves as a key mechanism [9], [10]. This is because green SCM practices help foster such capabilities, which subsequently affect firm operational performance.

Other potential mediators include organizational learning (acquiring new environmental knowledge) and reputational capital (improved stakeholder perceptions).

Research Gaps and Synthesis: While there have been many studies in this area, gaps exist. Most of the studies that have been conducted are cross-sectional studies and use only the data collected using surveys. Very few studies use both perceptual data along with operational and financial data. The Indian manufacturing environment has been relatively less studied, even though it is economically important and environmentally challenging.

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III. METHODOLOGY

A sequential, mixed-method approach will be used in the current study, involving the following steps: (1) quantitative surveying of GSCM practices and operational performance; (2) gathering of objective data from a sample of firms; and (3) qualitative interviews.

1. Sampling and Data Collection

Sampling Frame: Manufacturing companies in the industries of auto parts, electronics, and pharmaceuticals operating in the National Capital Region (NCR) and state of Maharashtra (Pune-Mumbai industrial belt). The selection of sectors has been made based on their environmental importance and complex nature of logistics. Sampling Size: We randomly selected 500 firms from industry directories. We obtained a 50% response rate (n=250). Respondents: 65% Supply Chain Managers; 20% Plant Managers; 15% Owners/Directors.

Period of Data Collection: April 2025 to January 2026. Objective Data: As part of the validity check of survey responses, we have collected audited annual reports for a sub-sample of 80 respondents (2022-2025) in order to determine operational performance indicators (COGS as a share of sales, inventory turn and ROA).

2. Measures and Instrumentation

We used previously validated scales, adapted for the Indian context. All items were measured on a 5-point Likert scale (1=Strongly Disagree, 5=Strongly Agree).

Construct Dimensions Number of Items Sample Item Source

Green Purchasing Supplier environmental assessment, collaboration 6 "We select suppliers based on environmental criteria (e.g., ISO 14001)." [7]

Eco-Design Design for recyclability, disassembly, reduced materials 5 "We design products that can be recycled or remanufactured." [4]

Reverse Logistics Returns management, recycling, remanufacturing 5 "We have a system for collecting and recycling used products." [3]

Green Manufacturing Pollution prevention, waste reduction, energy efficiency 6 "Our production processes are designed to minimize waste." [7]

Green Logistics Green transportation, warehousing, packaging 4 "We optimize delivery routes to reduce fuel consumption." [6]

Operational PerformanceCost, quality, delivery, flexibility 8 "Our unit production costs have decreased over the past 3 years." [6]

Green Innovation Capability Process, product, and organizational innovation 5 "Our firm develops new products that reduce environmental impact." [10]

Control Variables: Size of firm (employees), industry (dummy variables), firm age, and presence of ISO 14001 certification.

3. Research Design

Validation of Multi-Dimensional Constructs (CFA)

Confirmatory factor analysis was conducted to validate the constructs used for measuring multi-dimensional GSCM and operational performance. Measures of fit include: χ^2/df ratio<3, CFI >0.90, RMSEA <0.08, and SRMR <0.08. Convergent validity: Average variance extracted (AVE)>0.50, composite reliability (CR) >0.70. Discriminant validity: square root of AVE>inter-construct correlation.

Structural Model and Hypotheses Testing

To test the hypotheses, Structural equation modeling using maximum likelihood estimation was employed:

- Direct Effect Hypothesis: H1: GSCM positively influences the operational performance of firms.
- Mediational Hypothesis: H2: Green innovation capability acts as mediator between GSCM and operational performance.

The analysis involved bootstrapping (5,000 resamples).

Robustness Checks

- Common Method Variance: Harman's one-factor test (Variance extracted <50%).
- Endogeneity issue: Instrumental variable regression analysis (distance to environmental training facility as instrument for GSCM adoption).
- Validation of objective data: Correlation between survey-based operational performance measurement and objective data measures (COGS/Revenue, Inventory Turnover Ratio).

4. Qualitative Phase (Interviews)

Semi-structured interviews (45-60 mins) were conducted with 30 supply chain managers (10 from each industry sector). The interview guide covered the following questions: why implement GSCM, obstacles encountered, outcomes achieved, and key success factors.

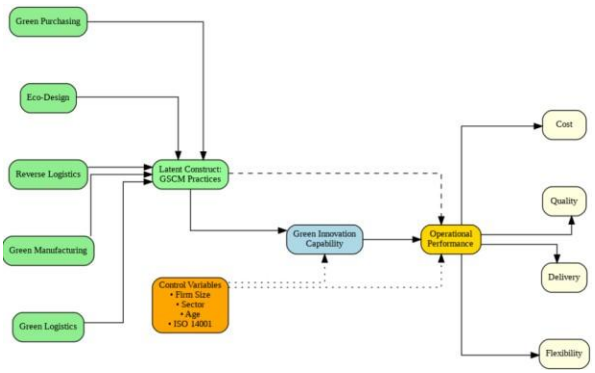

Figure 1: Conceptual Framework of the Study.

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IV. ANALYSIS

This section presents the quantitative results for each competency, followed by a comparative analysis.

1. Descriptive Statistics and Adoption Levels

Table 1: Adoption Levels of GSCM Practices.

GSCM Practice	Mean (1-5)	Std. Dev.	Adoption Level (% Scoring 4 or 5)
Green Purchasing	3.42	0.92	38%
Eco-Design	3.18	1.01	28%
Reverse Logistics	2.85	1.12	18%
Green Manufacturing	3.56	0.88	44%
Green Logistics	3.24	0.96	32%

2. Measurement Model Results

CFA results show that the model fits well: $\chi^2/df = 2.34$, CFI = 0.92, RMSEA = 0.068, SRMR = 0.062. Factor loading values were more than 0.60 and were statistically significant. The value of the Average Variance Extracted (AVE) was between 0.52 and 0.64 (>0.50). The value of Cronbach's Alpha (CR) was between 0.81 and 0.89 (>0.70), confirming convergent validity. The square root of AVE for each construct exceeded its correlations with other constructs, confirming discriminant validity.

3. Structural Model Results (Direct Effects)

Table 2: Structural Model Results.

Path	Coefficient(β)	p-value	Result
GSCM → Operational Performance	0.42	<0.001	Supported
GSCM → Green Innovation Capability	0.58	<0.001	—
Green Innovation Capability → Operational Performance	0.38	<0.001	—
Control: Firm Size → Op. Performance	0.12	0.08(n.s.)	—
Control: ISO 14001 → GSCM	0.31	<0.001	—

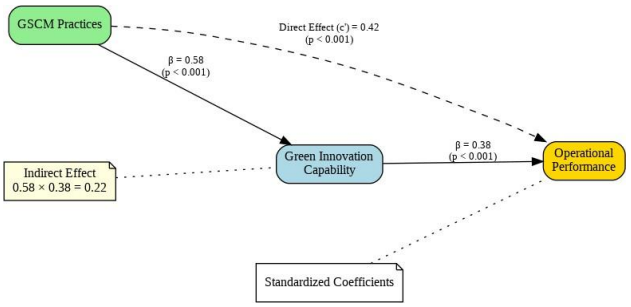

Figure 2: Path Diagram of Structural Model with Standardized Coefficients.

4. Mediation Analysis (Green Innovation Capability)

Table 3: Mediation Analysis Results.

Effect	Estimate	95% CI (Bootstrap)	p-value
Direct Effect (c')	0.20	[0.12, 0.28]	<0.01
Indirect Effect (a×b)	0.22	[0.16, 0.30]	<0.001
Total Effect (c)	0.42	[0.34, 0.50]	<0.001

5. Individual GSCM Practice Effects (Post-hoc Analysis)

Table 4: Individual GSCM Practice Effects.

Practice	Standardized Coefficient (on Op. Perf.)	p-value
Eco-Design	0.31	<0.001
Green Manufacturing	0.28	<0.001
Green Purchasing	0.18	<0.05
Green Logistics	0.14	0.07 (n.s.)
Reverse Logistics	0.09	0.12 (n.s.)

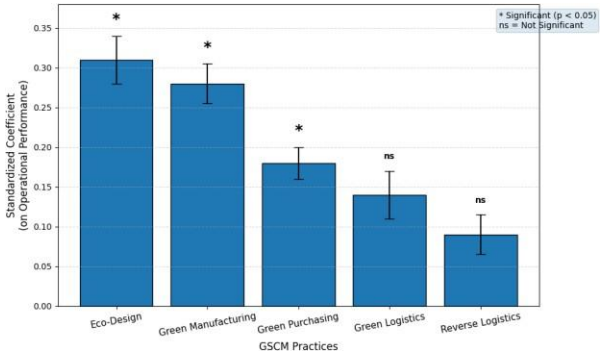

Figure 3: Bar Chart of Standardized Effects of Individual GSCM Practices.

6. Robustness Checks

- Uncommon Methods Bias: The single factor test by Harman yielded 28%, which is less than 50% that implies no bias in the model.
- Endogeneity Problem: The instrumental variable (proximity to environmental training center) was

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statistically significant in the first stage (F=28.4 >10). Second stage IV regression results (β=0.38, p<0.01) were consistent with the regression model.

Concurrent Validity Test for Objective Performance: The correlation between survey-derived operational performance and the objective measure (cost of goods sold/sales) was -0.46 (p<0.001) and with the inventory turnover was +0.39 (p<0.01), providing concurrent validity.

7. Qualitative Findings (Thematic Analysis)

Themes identified from 30 interviews:

1. Regulatory Pressure is the Dominant Force (24/30 managers): "We were forced into environmental sustainability because the Pollution Control Board began penalizing non-compliance among our suppliers. It didn't happen voluntarily; it was survival-driven." This indicates that regulation rather than voluntary corporate social responsibility seems to be driving the process in India.

2. Customer Demand is Increasing but Inconsistent (18/30): "We need to follow the ISO 14001 and report our carbon footprints to our multinational customers, especially automotive OEMs. Our domestic clients don't care about these aspects."

3. Savings through Green Manufacturing Are Achieved (22/30): "We saved 18% in energy costs due to LED lighting and motor efficiency improvements. The investment took only 14 months to repay." This is an example of the win-win theory.

4. Reverse Logistics is the Most Difficult (25/30): "There isn't a proper mechanism for recovering products. The scrap dealers collect what they need, but we can't depend on them for a reliable quality supply." This accounts for the low implementation and insignificant influence of reverse logistics.

5. Innovations Need Outside Support (20/30): "We cooperate with our raw material suppliers and research institutions to create biodegradable packaging materials."

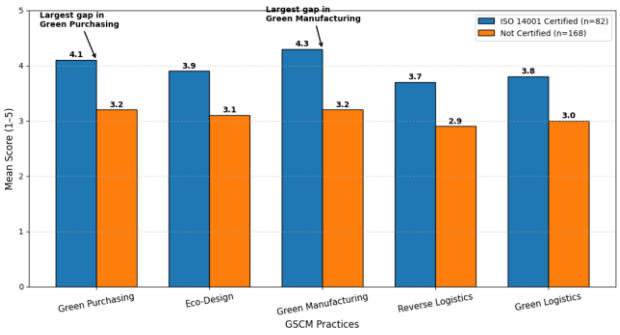

Figure 4: Comparison of GSCM Adoption by ISO 14001 Certification Status.

8. Comparative Analysis with Existing Studies

Table 5: Comparative Analysis with Existing Literature.

Study	Context	Sample	Key Finding	This Study Comparison
[5] (2021)	China (Multiple industries)	200	Positive effect (β=0.35)	Consistent (β=0.42)
[6] (2022)	USA (Electronics)	150	Mixed (positive for cost, n.s. for quality)	Stronger effect in India
[8] (Meta-analysis)	Global (65 studies)	65 studies	Overall r=0.19	Our β=0.42 is higher
[9] (2024)	India (Auto components)	180	Positive, mediated by green innovation	Consistent, extends to multiple sectors
This Study	India (Auto, Electronics, Pharma)	250	β=0.42, partially mediated	—

9. Summary of Key Findings

1. The influence of GSCM on the operational performance (β=0.42, p<0.001) is positive and significant. Companies practicing green policies enjoy reduced costs, enhanced quality, quick delivery, and increased flexibility.

2. The influence is partially mediated through the green innovation capability (indirect effect = 0.22). The GSCM strategy enhances the organization's capacity to innovate environmentally, which in turn enhances operational performance.

3. The most effective practices are eco-design and green manufacturing. They help minimize input costs. Reverse logistics remains conceptual since no significant performance benefits have been realized in the Indian setting due to infrastructural challenges.

4. The ISO 14001 certification status predicts the adoption of GSCM. Certified companies register higher scores in all GSCM dimensions.

V. CONCLUSION

This research paper has attempted a detailed empirical study regarding the impact of Green Supply Chain Management practices on operational performance in Indian manufacturers. Using surveys conducted from 250 companies and interviews from 30 supply chain managers, the paper concludes many valuable points.

The conclusions made are as follows:

1. There is indeed value in Green Supply Chain Management. Companies which follow GSCM practices report much improved operational performance. The magnitude (β=0.42) is quite high. This provides support for the win-win approach as opposed to the trade-off approach. The win-win situation is achieved primarily

through reduction in wastes (lower material and energy expenditure), innovation in processes, and avoidance of risks associated with non-compliance and disruption in supply.

2. Eco-design and green manufacturing are the strongest drivers of performance improvement. Eco-design and green manufacturing involve addressing the issues related to product and process design, in which the largest part of the environmental and economic impacts lie. Reduction in material intensity, recyclable design, and energy efficiency will improve both environmental impact and performance.
3. Innovation capability plays a crucial role in mediation. GSCM does not work directly through performance; it operates via innovation capability.

4. Reverse logistics still poses difficulties within an emerging economy setting. Though significant conceptually from a circular economy perspective, lack of implementation and absence of infrastructure hinder its contribution to organizational performance. Hence, regulatory intervention (such as extended producer responsibility policies) and industry cooperation are necessary for creating reverse logistics networks.

5. Regulatory rather than voluntary compliance is the key determinant within India. Management respondents repeatedly mentioned regulations set by the Pollution Control Board and Ministry of Environment as the chief motivation behind GSCM adoption. Recent strict environmental standards have hastened adoption trends.

Managerial Implications

- For manufacturers, the take-home lesson is simple: GSCM does not have to come at the expense of operational efficiency. Instead, GSCM is an additional business approach that may enhance cost, quality, delivery, and agility. Eco-design and eco-manufacturing are some of the fastest areas for making gains.
- For policymakers, the results indicate that regulation is effective. Still, in order to bridge the gap in reverse logistics, governments need to regulate Extended Producer Responsibility (EPR) and invest in recycling infrastructure.
- For technological suppliers, there is a large market potential to create low-cost green manufacturing technologies (energy-saving motors, waste management facilities, green packaging) suitable for SMEs.

Limitations and Future Research

Limitations of this study exist. The cross-sectional study nature does not allow for causal inferences, even though the use of IV estimation controls for this limitation. This study uses a sample from two regions of India and only includes firms from three different sectors. It does not account for the time delay between the use of GSCM and improvement in operational performance.

Further research should:

- Conduct longitudinal studies observing firm development over several years in order to ensure causality and determine lag effects.
- Use a larger sample consisting of firms from other sectors such as textile, chemical, and plastic as well as from other parts of India, South India, and East India.
- Compare the effects on operational performance based on the use of GSCM in different countries that have different levels of economic development, such as India, Vietnam, and Brazil.
- Conduct a study analyzing the moderating effect of IoT, Blockchain Technology, and Artificial Intelligence in using GSCM and their impact on operational performance.
- Analyze the effects of GSCM on financial performance and operational performance.

In summary, the results from this study show that Green Supply Chain Management is a necessity rather than a mere environmental luxury. Organizations that incorporate green thinking into their supply chain processes perform better than those that do not. It is never an easy process, but it certainly pays to make the effort.

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