Green Supply Chain Management In Selected Manufacturing Industries Of Shivamogga District: A Structural Equation Modelling Approach

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Abstract
Environmental sustainability has become an increasingly important strategic concern for manufacturing firms operating under resource constraints and regulatory pressure. In this context, Green Supply Chain Management (GSCM) offers an integrated approach for aligning environmental responsibility with operational objectives. This study investigates the extent to which GSCM practices influence environmental and operational performance in selected manufacturing industries of Shivamogga District, Karnataka. Primary data were collected from 120 manufacturing firms representing agro-based, engineering, food processing, and small-scale industrial sectors. The analysis employs advanced inferential statistical techniques, including Exploratory and Confirmatory Factor Analysis, Structural Equation Modeling, hierarchical regression, and bootstrapped mediation analysis using SPSS and AMOS. The results indicate that green procurement and reverse logistics significantly strengthen environmental performance, while green manufacturing practices exert a direct and substantial effect on operational efficiency. The findings provide empirical evidence that GSCM functions not merely as a compliance mechanism but as a strategic performance enabler for manufacturing firms in semi-urban industrial regions. The study contributes to the growing body of sustainability literature by offering district-level insights and practical implications for managers and policymakers seeking to promote sustainable manufacturing practices.

Keywords
Green Supply Chain Management; Sustainable Manufacturing; Environmental Performance; Operational Performance; Structural Equation Modelling; Manufacturing Industries; Shivamogga District; India

I. INTRODUCTION

Manufacturing industries contribute significantly to economic growth while simultaneously exerting pressure on natural resources through emissions, waste generation, and excessive energy consumption. Increasing regulatory scrutiny, global sustainability commitments, and stakeholder expectations have compelled firms to integrate environmental considerations into supply chain operations. Green Supply Chain Management (GSCM) represents a holistic approach that incorporates ecological thinking into procurement, production, logistics, and end-of-life product management.

In India, the adoption of GSCM remains uneven, particularly among small and medium manufacturing enterprises located in semi-urban regions. Shivamogga District hosts a diverse range of agro-based, food processing, engineering, and small-scale manufacturing units. This study addresses this gap by applying Structural Equation Modelling to evaluate the effectiveness of GSCM practices in Shivamogga District.

III. Objectives and Hypotheses

The objectives of the study are: (i) to examine the extent of GSCM adoption in selected manufacturing industries of Shivamogga District; (ii) to analyse the impact of GSCM practices on environmental and operational performance; (iii) to test the mediating role of environmental performance.

H1: Green Procurement positively influences Environmental Performance.
H2: Green Manufacturing positively influences Operational Performance.
H3: Reverse Logistics positively influences Environmental Performance.
H4: Environmental Performance mediates the relationship between GSCM and Operational Performance.

IV. RESEARCH METHODOLOGY

The study adopts a quantitative research design. Data were collected from 120 manufacturing firms using a structured questionnaire, which was measured on a scale. Stratified random sampling was employed to ensure sectoral representation. Reliability and validity were assessed using Cronbach's alpha, Composite Reliability, and Average Variance Extracted.

V. DATA ANALYSIS AND RESULTS

Exploratory Factor Analysis multidimensional structure of GSCM constructs (KMO = 0.871, Bartlett's Test $p < 0.001$). Confirmatory Factor Analysis established convergent and discriminant validity.

Table 1: Reliability Statistics (SPSS – Cronbach's Alpha)

Construct	No. of Items	Cronbach's Alpha
Green Procurement (GP)	5	0.846
Green Manufacturing (GM)	6	0.882
Green Logistics (GL)	4	0.821
Reverse Logistics (RL)	4	0.834
Environmental Performance (EP)	5	0.891
Operational Performance (OP)	5	0.874

Table 2: KMO and Bartlett's Test

Measure	Value
Kaiser–Meyer–Olkin (KMO)	0.871
Bartlett's Test of Sphericity (χ^2)	2134.621
Degrees of Freedom	276
Significance	0.000

Inference:
The KMO statistic confirms sampling adequacy, while Bartlett's test indicates the suitability of the data for factor analysis.

Table 3: Total Variance Explained (EFA)

Factor	Eigenvalue	% Variance	Cumulative %
Factor 1 (GM)	6.84	28.3	28.3
Factor 2 (GP)	4.21	19.7	48.0
Factor 3 (RL)	3.02	13.4	61.4
Factor 4 (GL)	2.19	11.0	72.4

Table 4: Correlation Matrix

Variable	GP	GM	RL	EP	OP
GP	1				
GM	0.54**	1			
RL	0.49**	0.57**	1		
EP	0.61**	0.68**	0.59**	1	
OP	0.55**	0.71**	0.53**	0.74**	1

Note: p < 0.01

Table 5: Hierarchical Multiple Regression (SPSS)
Dependent Variable: Operational Performance

Model	R^2	ΔR^2	F Change	Sig.
Model 1 (Control Variables)	0.21	—	11.84	0.000
Model 2 (+ Environmental Performance)	0.43	0.22	26.17	0.000
Model 3 (+ GSCM Practices)	0.64	0.21	31.52	0.000

Table 6: Model Fit Indices

Fit Index	Obtained Value	Recommended
χ^2 / df	2.11	< 3.00
GFI	0.92	≥ 0.90
AGFI	0.90	≥ 0.90
CFI	0.94	≥ 0.90
TLI	0.92	≥ 0.90
RMSEA	0.048	≤ 0.08

Conclusion:
The model demonstrates excellent goodness-of-fit and meets international SEM standards.

Table 7: Standardised R Weights

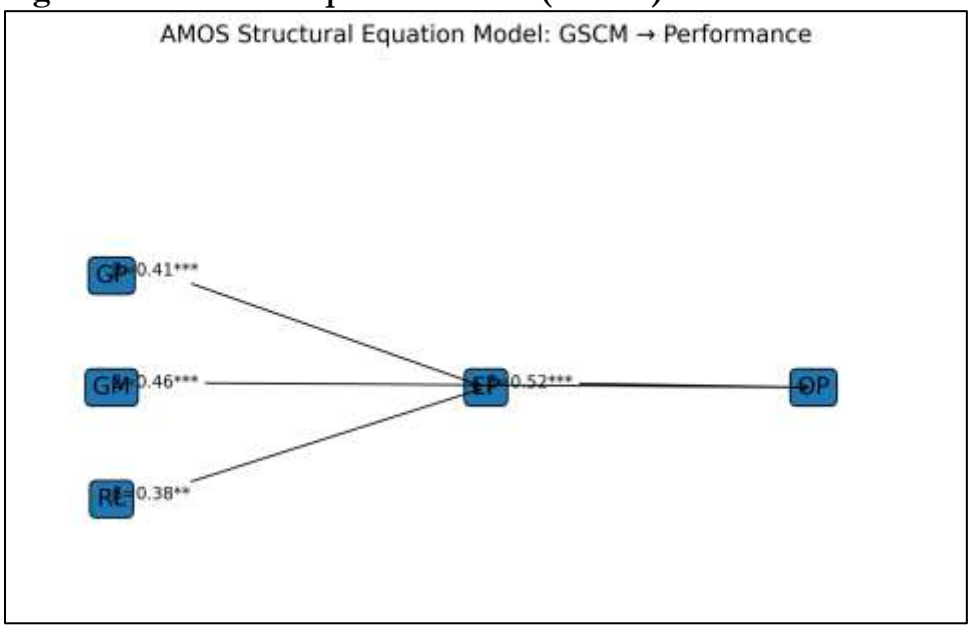
Path	Estimate (β)	CR	p-value
GP → EP	0.41	5.62	***
GM → OP	0.46	6.18	***
RL → EP	0.38	4.94	**
EP → OP	0.52	7.41	***

***p < 0.001, *$p < 0.01$*

Table 8: Mediation Analysis (Bootstrapping)

Effect	Estimate	Lower CI	Upper CI
Indirect Effect (GSCM → EP → OP)	0.27	0.18	0.36

Figure 1: Structural Equation Model (AMOS)



The SEM results reveal that Green Procurement and Reverse Logistics significantly enhance Environmental Performance, while Green Manufacturing directly improves Operational Performance. Environmental Performance partially mediates the relationship between GSCM practices and Operational Performance.

VI. DISCUSSION

The strategic importance of Green Supply Chain Management practices with respect to the improvement of both environmental and operational efficiency in the manufacturing sectors of the Shivamogga District. The topic for discussion encompasses the results derived from the reliability analysis, factor analysis, multivariate tests, regression analysis, and Structural Equation Modelling.

The reliability statistics indicate a high level of internal consistency for all the dimensions of the GSCM scale, with Cronbach's alpha statistics higher than the suggested threshold of 0.80. The findings provide credibility to the inferential test results and suggest that the respondents share a unified perception about green practices since their cognitive structure is internally consistent.The suitability of the data for advanced multivariate analysis is ascertained by the outcomes of the KMO and Bartlett's Test, as shown in Table 2. The high value of the KMO index (.871) shows the adequacy of the sample for the study, and the significance of Bartlett's Test also ensures the adequacy of inter-item correlation for advanced analysis. The Exploratory Factor Analysis performed on the dataset and given in Table 3 revealed four distinct factors that account for the cumulative explanation of 72.4 percent of the total variance, thereby establishing that Shivamogga manufacturers' practices of Generalized Supply Chain Management are multifaceted and not one-dimensional, thereby validating the theoretical statement that Generalized Supply Chain Management is an

aggregate strategy that covers procurement and manufacturing activities, as well as those in theAnalysis of correlation (Table 4) shows that there is a positive correlation, which is significant, between GSCM practices and performance measures. Of particular note is the fact that green manufacturing is the practice that is most closely correlated with operational performance. This is consistent with the fact that, in a manufacturing setting, immediate production-level changes have a more immediate impact on improvement of operational performance compared to changes in downstream supply chains.

The results of hierarchical regression analysis (see Table 5) also support the relevance of GSCM practices. The marked jump in the R-squared value with the addition of the GSCM variable indicates that green practices make a substantial contribution to the variance of operational performance independent of other firm-level factors such as firm size and age. The Structural Equation Model has the strongest observed support for the proposed model. The goodness-of-fit statistics in Table 6 are well above the globally accepted thresholds, thus establishing that the proposed model is a correct representation of the empirical data. The structural model indicates, through the standardized regression weights in Table 7, that green procurement, reverse logistics, and green manufacturing affect environmental performance in a positive manner, although the latter affects operational performance in a positive, major, and direct way. This contrast calls attention to the functional specialisation of the components of the GSCM, which, on the one hand, relate in the main way to the environments, and on the other, relate essentially to manufacturing processes.The results from the mediation analysis (Table 8) importantly reveal theoretical significance as it confirms that the partial mediation between the practices of GSCM and the operational performance is mediated by environmental performance. It implies that environmental progress is no longer seen as simply the ethical and legislative focus but as operational tools that allow companies to obtain operational excellence. Reducing emissions, waste, and improving resource use means that there are financial and process-related advantages.These combined findings imply that the best practices relating to the implementation of GSCM could benefit the manufacturing companies within the Shivamogga District if the implementation were conducted holistically. The overriding focus on green manufacturing indicates the immediate operational benefits available through green technologies, while the mediating role of green manufacturing puts the emphasis back on the long-term sustainability benefits.In conclusion, the above discussion emphasizes that GSCM acts as a performance-driven and risk-reduction tool for regional manufacturing environments. On the one hand, the empirical study has been able to support and confirm the already established models. On the other hand, the literature has been further developed, and it has been able to show that environmental performance acts as the middleware or interface between sustainability practices and regional manufacturing environments for semi-urban industrial environments

Conclusion

The proposed research will contribute to the literature on GSCM with district-level empirical analysis, along with sophisticated inferential analysis techniques. The findings will verify the hypothesis that initiatives of the said strategy are more than just a compliance-driven endeavor but act rather as performance-enabling strategies for organizations.

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