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Examining the Impact of Green Supply Chain Management Practices on Sustainable Development Goals

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Abstract

Organizations, in order to remain resilient against turbulent environmental conditions and to adapt to competitive requirements, have no alternative but to create and maintain a sustainable competitive advantage. The purpose of the present study is to examine the impact of green supply chain management practices on sustainable development goals (case study: Foundry Sand Supply Company). The statistical population of the study consisted of all employees of the Foundry Sand Supply Company, totaling 200 individuals, from whom a sample of 100 participants was selected based on the Cochran formula. The sampling method was random. Data were collected using a questionnaire, and the research hypotheses were tested through structural equation modeling. The results indicated that the more effectively the company applies eco-design practices and employs environmentally friendly energy resources in the production process to control environmental risks, the better it can enhance organizational efficiency and productivity.

Keywords: Supply Chain Management, Sustainable Development Goals, Green Procurement

1. Introduction

Sustainable development has become a dominant paradigm in contemporary management and operations research as organizations increasingly confront environmental degradation, resource scarcity, regulatory pressure, and stakeholder expectations. Firms are no longer evaluated solely by economic performance but by their ability to integrate environmental and social objectives into strategic decision-making (Amini, 2016; Stafford-Smith et al., 2021). In this context, supply chain activities represent one of the most influential leverage points for achieving sustainability because procurement, production, logistics, and reverse flows collectively account for the majority of organizational environmental impacts (Alkaha et al., 2022; Sahow et al., 2020). Consequently, Green Supply Chain Management (GSCM) has emerged as a critical managerial philosophy that aligns operational excellence with long-term sustainability performance (El Mokadem & Khalaf, 2025; Yildiz Çankaya & Sezen, 2019).

GSCM extends beyond traditional supply chain efficiency by embedding environmental considerations across upstream and downstream processes, including green purchasing, eco-design, internal environmental management, customer cooperation, and investment recovery (Yazdani & Landran Esfahani, 2023; Yiu et al., 2019; Zhu et al., 2017). These practices transform

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supply chains from cost-oriented systems into sustainability-driven value networks (Delshad, 2022; Tian & Handfield, 2020). Empirical research consistently demonstrates that GSCM practices enhance environmental, economic, and operational outcomes while strengthening corporate legitimacy and competitive advantage (Ali et al., 2024; Hu & Tresirichod, 2024; Lin et al., 2023).

The theoretical foundation of GSCM is rooted in the resource-based view and institutional theory, suggesting that environmental capabilities create inimitable strategic resources and that regulatory and social pressures stimulate sustainable transformation (Niromand et al., 2025; Rashid et al., 2024). Organizations adopting proactive environmental strategies develop superior green innovation capacity and resilience against environmental uncertainty (Motiei, 2021; Muduli et al., 2020). These capabilities enable firms to improve productivity, reduce waste, optimize energy consumption, and enhance stakeholder trust (Fu et al., 2020; Sharma & Horn, 2022).

At the operational level, internal environmental management plays a foundational role by institutionalizing environmental values, policies, and performance monitoring systems within organizations (Aghighi, 2021; Shakiri, 2018). Such internal mechanisms facilitate systematic implementation of green purchasing policies, which influence supplier selection, material sourcing, and lifecycle environmental impacts (Hosseini Doost, 2021; Rajabpour & Afkhami Ardakani, 2019). Strategic supplier collaboration further amplifies these effects by aligning sustainability objectives across organizational boundaries and strengthening long-term partnership stability (Habib & Powers, 2019; Luay Jum'a & Srivastava, 2023).

Eco-design represents another central pillar of GSCM by embedding environmental considerations at the product and process design stage, where the majority of lifecycle costs and impacts are determined (Chaudhuri et al., 2024; Tian & Handfield, 2020). Firms implementing eco-design achieve superior environmental performance while improving product quality, cost efficiency, and market differentiation (Yildiz Çankaya & Sezen, 2019; Zhu et al., 2017). Complementing these forward-flow practices, investment recovery and reverse logistics systems enable organizations to reclaim value from surplus materials, returned products, and waste streams, thereby closing material loops and advancing circular economy objectives (Çankaya et al., 2016; Zubair & Khan, 2016).

The strategic integration of these GSCM dimensions produces measurable sustainability outcomes. Studies across manufacturing, energy, textile, construction, and service sectors confirm that GSCM adoption significantly improves environmental performance, operational efficiency, and sustainable competitiveness (Ali et al., 2024; Seyed Nejad Fahim, 2024; Tajiani, 2020; Tian & Handfield, 2020). Furthermore, digitalization and advanced analytics increasingly strengthen the impact of GSCM by enhancing transparency, coordination, and real-time environmental monitoring (Rashid et al., 2024).

Despite the growing body of international evidence, contextual differences across industries and regions necessitate further empirical investigation. Organizational culture, regulatory environments, technological maturity, and institutional pressures shape the effectiveness of GSCM implementation (Niromand et al., 2025; Stafford-Smith et al., 2021). Developing economies and emerging industrial contexts face unique challenges, including resource constraints, limited environmental awareness, and infrastructural limitations, which influence the adoption and performance outcomes of GSCM practices (Al-Sheyadi, 2022; El Mokadem & Khalaf, 2025).

Additionally, sustainable development goals (SDGs) have become the dominant global framework for evaluating corporate sustainability performance, requiring firms to demonstrate tangible contributions to environmental protection, social welfare, and economic stability (Amini, 2016; Stafford-Smith et al., 2021). GSCM serves as a direct operational mechanism through which organizations can translate SDG commitments into measurable outcomes across production systems, employment structures, and community development (Ali et al., 2024; Hu & Tresirichod, 2024).

Recent empirical studies highlight that firms integrating GSCM within broader strategic management and human resource systems achieve superior sustainability trajectories (Motiei, 2021; Muduli et al., 2020; Tajiani, 2020). Collaborative governance structures, relationship quality, and conflict resolution capabilities further enhance the stability and effectiveness of sustainable supply networks (Ilyas et al., 2016; Tampo & Willcocks, 2019). These findings reinforce the necessity of

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adopting a holistic, system-level perspective on GSCM rather than isolated functional interventions (Alkaha et al., 2022; Delshad, 2022).

Nevertheless, existing research exhibits limitations in simultaneously examining multiple dimensions of GSCM and their integrated effects on sustainable development objectives within a single organizational context. Many studies focus on partial relationships or sector-specific analyses, leaving substantial gaps regarding the comprehensive mechanisms through which GSCM influences sustainability outcomes (Niromand et al., 2025; Tian & Handfield, 2020; Yazdani & Landran Esfahani, 2023). Furthermore, there remains a need for empirical evidence from resource-intensive industrial sectors where environmental externalities are particularly significant.

Accordingly, this study addresses these gaps by empirically investigating the combined impact of green supply chain management practices—internal environmental management, green purchasing, customer cooperation, eco-design, and investment recovery—on sustainable development goals within an industrial production context, contributing both theoretically and practically to the evolving field of sustainable operations management (Aghighi, 2021; Al-Sheyadi, 2022; Ali et al., 2024; El Mokadem & Khalaf, 2025; Niromand et al., 2025).

The aim of this study is to examine the effect of green supply chain management practices on the achievement of sustainable development goals in the case of an industrial manufacturing organization.

2. Methods and Materials

The present study can be classified as applied research in terms of purpose and, based on the method of data collection, as a descriptive–correlational study, because the researcher examines the relationships among the variables of the model. Among the studies in which correlation or covariance matrices are analyzed are factor analysis and structural equation modeling. The statistical population of this study consists of employees of the Foundry Sand Supply Company, totaling 200 individuals. To determine the sample size, the Morgan table or Cochran formula was used. The sampling method was simple random sampling. The target sample in this study consists of employees of the Foundry Sand Supply Company. According to the Morgan table, 127 individuals were randomly selected. The data collection methods in this study include field and library research, and the instrument used is a questionnaire. The variables were measured using questionnaires, with items developed and organized based on the identified variables. A five-point Likert scale was employed in the questionnaire. In this study, research data were obtained through questionnaires. The questionnaires used in this study included: internal environmental management, green purchasing, customer cooperation, eco-design, and investment recovery.

3. Findings and Results

To determine reliability, Cronbach's alpha method was employed. Accordingly, the questionnaire was distributed to and collected from 80 respondents in the statistical sample, and after entering their responses into the SPSS software to calculate Cronbach's alpha, the results shown in Table 1 were obtained. This procedure is conducted to ensure that if the questionnaire demonstrates initial reliability, it can then be distributed among the entire statistical sample; otherwise, the questionnaire must be revised.

Table 1. Cronbach's Alpha Coefficients for Variables and the Overall Questionnaire

Questionnaire Dimensions	Sample Size	Cronbach's Alpha
Internal Environmental Management	30	0.841826
Green Purchasing	30	0.881894
Customer Cooperation	30	0.802097
Eco-Design	30	0.849501
Investment Recovery	30	0.826427
Sustainable Development Goals	30	0.844122
Environmental Goals	30	0.910689
Operational Performance Goals	30	0.821826

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If Cronbach's alpha exceeds 0.70, the questionnaire is considered reliable. Based on the above table, since the Cronbach's alpha values for all variables are greater than 0.70, all variables individually exhibit acceptable reliability. Moreover, the overall Cronbach's alpha coefficient exceeds 0.80, confirming the reliability of the preliminary sample.

Initially, the suitability of the data was examined. Various methods exist for assessing data adequacy, including the Kaiser–Meyer–Olkin (KMO) measure. To ensure that the correlation matrix used as the basis for analysis is not an identity matrix in the population, Bartlett's test of sphericity was applied. The results of the KMO measure and Bartlett's test are presented below.

Table 2. KMO Measure and Bartlett's Test

Test	Statistic	Value
Kaiser–Meyer–Olkin Measure		0.910
Bartlett's Test of Sphericity	Chi-Square	7291.000
	Degrees of Freedom	903
	Significance	0.000

Given that the KMO value exceeds 0.70 and Bartlett's test is significant (Sig < 0.05), the data are considered suitable for factor analysis.

In the standardized estimation model, factor loadings indicate the magnitude of each variable's or item's contribution to explaining the variance of the latent construct; in other words, factor loadings represent the correlation between each observed variable (questionnaire item) and the latent variable (factor). Based on the model output, the factor loadings for all research items were examined. As observed, all factor loadings exceed 0.50, and the calculated AVE values are greater than 0.40, indicating adequate convergent validity. In addition, construct reliability is acceptable as shown in the following table.

Table 3. Construct Reliability and Convergent Validity of the Model

Construct	AVE	R^2	Cronbach's Alpha
Internal Environmental Management	0.502796	0.687270	0.841826
Green Purchasing	0.563557	0.594468	0.881894
Customer Cooperation	0.500485	0.328993	0.802097
Eco-Design	0.502838	0.738447	0.849501
Investment Recovery	0.742642	0.899791	0.826427
Environmental Goals	0.565547	0.729786	0.844122
Operational Performance Goals	0.570941	0.893292	0.910689

Furthermore, as shown in the following table, the square root of the AVE for each construct in PLS is greater than the correlations between constructs, which confirms the discriminant validity of the model.

Table 4. Discriminant Validity Assessment of the Model

	Internal Environmental Management	Green Purchasing	Customer Cooperation	Eco-Design
Internal Environmental Management	1.000000			
Green Purchasing	0.461316	1.000000		
Customer Cooperation	0.266351	0.355938	1.000000	
Eco-Design	0.508995	0.510796	0.526755	1.000000
Investment Recovery	0.317417	0.308045	0.386292	0.305998
Environmental Goals	0.477478	0.367604	0.345942	0.393764
Operational Performance Goals	0.460742	0.587444	0.208858	0.501847
	Investment Recovery	Environmental Goals	Operational Performance Goals	
Investment Recovery	1.000000			
Environmental Goals	0.462486	1.000000		
Operational Performance Goals	0.484447	0.428973	1.000000	

One of the strongest and most appropriate analytical methods in behavioral science research is multivariate analysis, because the nature of such topics is inherently multivariate and cannot be adequately addressed through bivariate methods (in which only one independent variable and one dependent variable are considered at a time). Therefore, in the present study, structural equation modeling and, in particular, path analysis were employed to confirm or reject the research hypotheses. Path analysis (structural modeling) is a technique that simultaneously represents the relationships among the research variables (independent, mediating, and dependent). The purpose of path analysis is to identify causality (effects) among the variables of the study's conceptual model. In the following figure, the structural equation model is presented in the standardized estimation mode.

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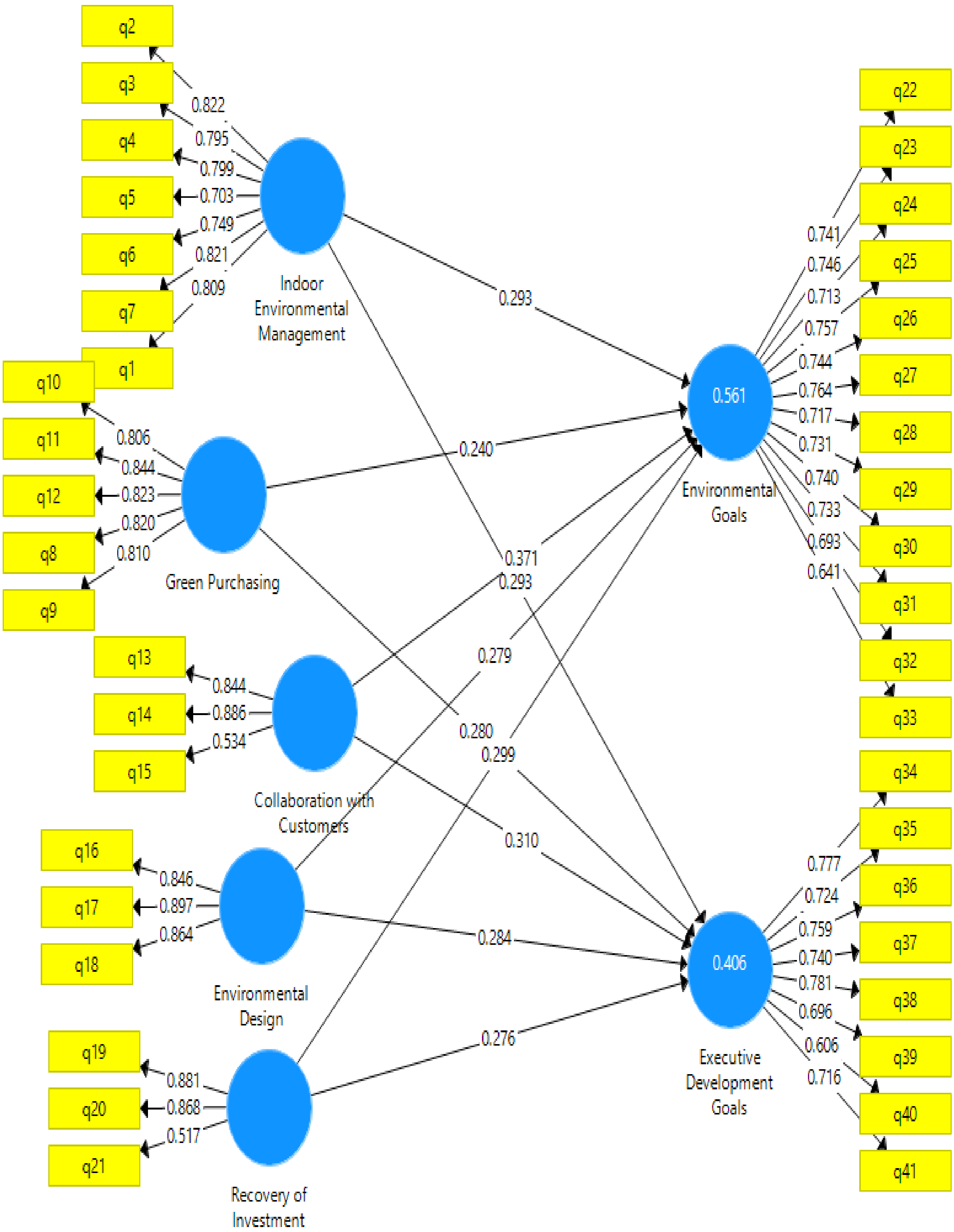

Figure 1. Structural equation model in standardized estimation mode

The subsequent output, shown in the following figure, represents the model in the significance testing mode of the estimated coefficients and parameters, where all estimated coefficients are statistically significant; because test statistics greater than 1.96 or less than −1.96 indicate the significance of the relationships.

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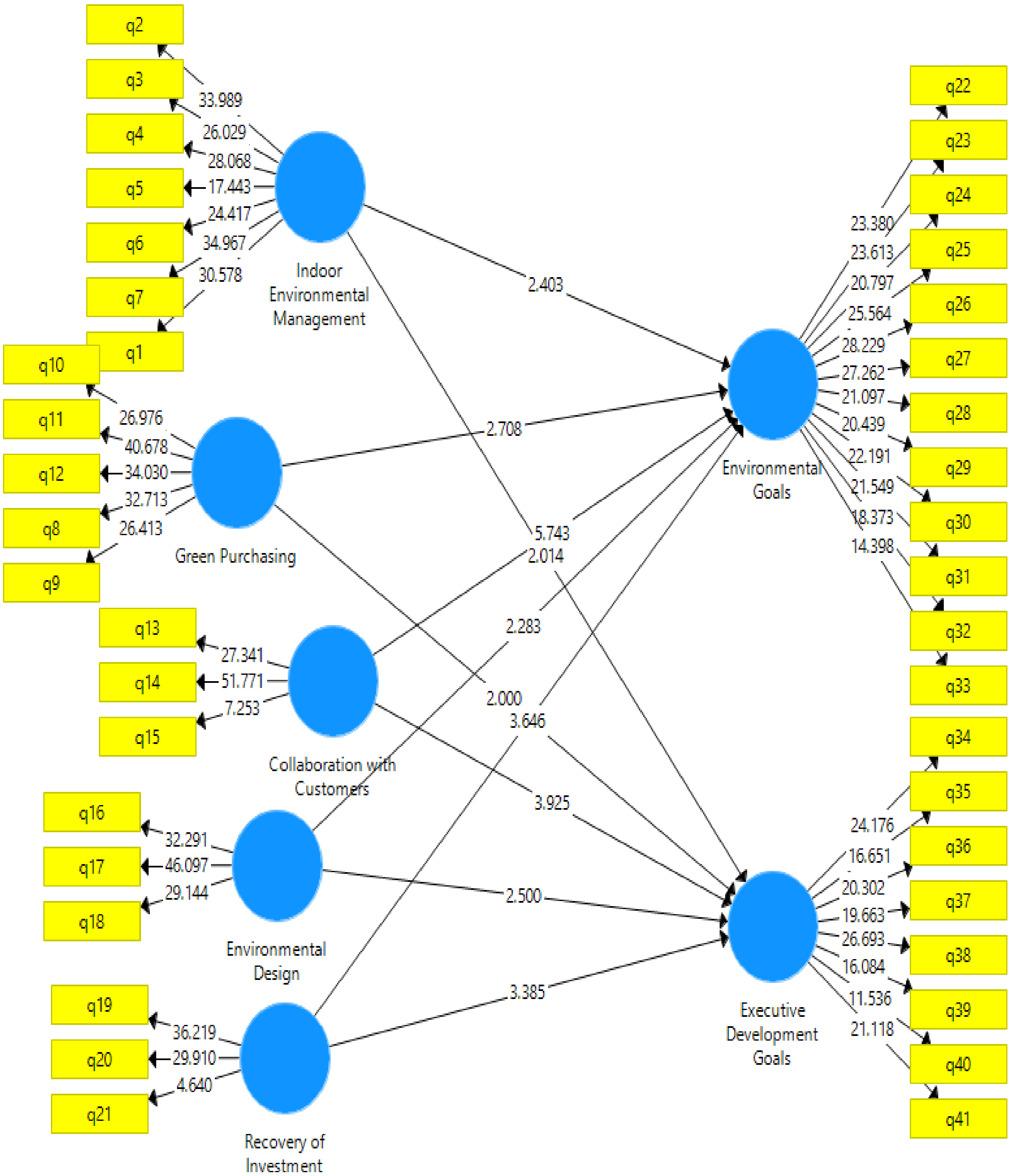

Figure 2. Structural equation model in significance mode

In testing the research hypotheses using structural equation modeling, the model fit indices must be acceptable in order to use the structural model for hypothesis testing.

The Q^2 value must be calculated for all endogenous constructs of the model, and the results should be reported in the model interpretation section. If the Q^2 value for an endogenous construct is zero or less than zero, this indicates that the relationships between that construct and the other constructs in the model are not adequately explained, and therefore the model requires modification. It should be noted that this criterion is calculated only for endogenous constructs whose indicators are reflective.

Henseler et al. (2009) identified three threshold values of 0.02, 0.15, and 0.35 for the predictive relevance of the model regarding endogenous constructs. According to their interpretation, if the Q^2 value for an endogenous construct is close to 0.02, this indicates weak predictive power of the model with respect to the indicators of that construct.

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Table 5. Q² Model Fit Index

Variable	Q^2
Internal Environmental Management	0.351
Green Purchasing	0.359
Customer Cooperation	0.356
Eco-Design	0.362
Investment Recovery	0.351
Environmental Goals	0.349
Operational Performance Goals	0.334

Based on the above explanations and the values presented in the table, which are close to 0.35 for each research component, it can be concluded that the research constructs demonstrate strong predictive power with respect to the presented indicators.

Table 6. Evaluation of Research Hypotheses

Hypothesis	Path Coefficient	t-value	Supported / Rejected
Green supply chain management practices have a significant effect on sustainable development goals.	0.341	8.53	Supported
Internal environmental management has a significant effect on environmental goals.	0.293	2.40	Supported
Green purchasing has a significant effect on environmental goals.	0.240	2.70	Supported
Customer cooperation has a significant effect on environmental goals.	0.371	2.01	Supported
Eco-design has a significant effect on environmental goals.	0.293	2.28	Supported
Investment recovery has a significant effect on environmental goals.	0.276	3.64	Supported
Internal environmental management has a significant effect on operational development goals of society.	0.293	5.74	Supported
Eco-design has a significant effect on operational development goals of society.	0.284	2.50	Supported
Green purchasing has a significant effect on operational development goals of society.	0.279	2.00	Supported
Customer cooperation has a significant effect on operational development goals of society.	0.310	3.92	Supported
Investment recovery has a significant effect on operational development goals of society.	0.299	3.38	Supported

The first hypothesis examined whether green supply chain management practices have a significant effect on sustainable development goals. The results of the structural equation modeling indicate that this relationship is positive and statistically significant, with a standardized path coefficient of 0.341 and a t-value of 8.53. Since the t-value exceeds the critical threshold of ±1.96, the hypothesis is supported, demonstrating that the implementation of green supply chain management practices contributes meaningfully to the achievement of sustainable development goals.

The second hypothesis investigated the effect of internal environmental management on environmental goals. The analysis revealed a positive and statistically significant relationship between these variables, with a path coefficient of 0.293 and a t-value of 2.40. Given that the t-value is greater than the critical value of 1.96, the hypothesis is confirmed, indicating that strengthening internal environmental management practices enhances the organization's environmental performance.

The third hypothesis assessed whether green purchasing influences environmental goals. The findings show that green purchasing has a significant positive impact on environmental goals, as reflected by a path coefficient of 0.240 and a t-value of 2.70. This result supports the hypothesis and suggests that environmentally responsible procurement decisions play a crucial role in improving environmental outcomes.

The fourth hypothesis examined the impact of customer cooperation on environmental goals. The results indicate a statistically significant positive effect, with a standardized path coefficient of 0.371 and a t-value of 2.01. As the t-value exceeds the critical threshold, the hypothesis is supported, highlighting the importance of collaborative relationships with customers in advancing environmental objectives.

The fifth hypothesis evaluated the relationship between eco-design and environmental goals. The analysis demonstrates that eco-design has a positive and significant effect on environmental goals, with a path coefficient of 0.293 and a t-value of 2.28. These results confirm the hypothesis and underscore the role of environmentally conscious product and process design in achieving environmental performance targets.

The sixth hypothesis tested the effect of investment recovery on environmental goals. The findings reveal a statistically significant positive relationship, with a path coefficient of 0.276 and a t-value of 3.64. This supports the hypothesis and indicates

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that recovering value from surplus materials, waste, and obsolete assets contributes substantially to environmental performance improvement.

The seventh hypothesis examined whether internal environmental management affects the operational development goals of society. The results show a significant positive relationship, with a path coefficient of 0.293 and a t-value of 5.74. The hypothesis is therefore supported, suggesting that organizational environmental management practices have broader implications for societal operational development.

The eighth hypothesis investigated the effect of eco-design on the operational development goals of society. The analysis reveals a statistically significant positive effect, with a path coefficient of 0.284 and a t-value of 2.50. This confirms the hypothesis and indicates that eco-design practices extend their influence beyond organizational boundaries to societal operational development.

The ninth hypothesis assessed whether green purchasing impacts the operational development goals of society. The results demonstrate a significant positive relationship, with a path coefficient of 0.279 and a t-value of 2.00. Since the t-value meets the significance criterion, the hypothesis is supported, confirming that sustainable procurement contributes to societal operational development.

The tenth hypothesis evaluated the influence of customer cooperation on the operational development goals of society. The findings indicate a statistically significant positive effect, with a standardized path coefficient of 0.310 and a t-value of 3.92. The hypothesis is therefore supported, highlighting the critical role of customer engagement in achieving broader operational development objectives.

The eleventh hypothesis examined the effect of investment recovery on the operational development goals of society. The analysis shows a positive and statistically significant relationship, with a path coefficient of 0.299 and a t-value of 3.38. This result supports the hypothesis and indicates that effective investment recovery mechanisms contribute meaningfully to the operational development of society.

4. Discussion and Conclusion

The present study investigated the effects of green supply chain management (GSCM) practices on sustainable development goals within an industrial manufacturing context. The findings provide strong empirical evidence that the integrated application of GSCM practices significantly enhances both environmental and operational dimensions of sustainable development. Specifically, the structural model results demonstrated that overall GSCM practices exert a strong positive influence on sustainable development goals, thereby supporting the growing consensus in sustainability management literature that environmental responsibility and competitive performance are not mutually exclusive but rather mutually reinforcing (Ali et al., 2024; El Mokadem & Khalaf, 2025; Niromand et al., 2025). These findings corroborate the resource-based and institutional perspectives, which posit that environmentally oriented capabilities function as strategic resources that enhance organizational legitimacy, adaptability, and long-term competitiveness (Rashid et al., 2024; Stafford-Smith et al., 2021).

The significant effect of internal environmental management on environmental goals confirms that environmental performance begins with internal organizational commitment, leadership support, formalized policies, and performance measurement systems. This result aligns closely with earlier research demonstrating that organizations embedding environmental values within managerial structures achieve superior environmental outcomes (Aghighi, 2021; Motiei, 2021; Muduli et al., 2020). Internal environmental management establishes the cultural and structural foundation necessary for the successful execution of external green initiatives such as green purchasing and eco-design, thereby reinforcing organizational sustainability capacity (Delshad, 2022; Shakiri, 2018).

The positive and significant impact of green purchasing on environmental goals observed in this study supports prior findings that procurement decisions play a pivotal role in reducing environmental footprints across supply networks (Hosseini Doost, 2021; Rajabpour & Afkhami Ardakani, 2019; Yazdani & Landran Esfahani, 2023). By prioritizing environmentally responsible suppliers, recyclable materials, and low-emission inputs, organizations can substantially reduce upstream environmental risks while stimulating sustainability-oriented innovation among suppliers (Yiu et al., 2019; Zhu et

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al., 2017). This reinforces the notion that environmental performance increasingly depends on collaborative supplier governance rather than isolated firm-level actions (Habib & Powers, 2019; Luay Jum'a & Srivastava, 2023).

Customer cooperation also exhibited a strong and significant effect on environmental goals, underscoring the importance of downstream stakeholder engagement in achieving sustainability objectives. This finding is consistent with the argument that sustainability is co-created across supply chain relationships and that customer involvement enhances environmental innovation, demand forecasting, and waste reduction (Chen et al., 2016; Ilyas et al., 2016; Tampo & Willcocks, 2019). Firms that actively collaborate with customers in product design, packaging optimization, and consumption patterns achieve superior environmental performance while strengthening relational trust and market responsiveness (Ali et al., 2024; Lin et al., 2023).

The significant influence of eco-design on environmental goals further validates the critical role of early-stage design decisions in determining lifecycle environmental impacts. As documented by previous research, eco-design interventions offer the highest leverage point for minimizing emissions, material usage, and energy consumption throughout product lifecycles (Chaudhuri et al., 2024; Tian & Handfield, 2020; Yildiz Çankaya & Sezen, 2019). The present findings reaffirm that organizations investing in eco-design capabilities realize both ecological and economic benefits, thereby strengthening long-term sustainability performance (Fu et al., 2020; Zhu et al., 2017).

Investment recovery was also found to significantly enhance environmental goals, indicating the importance of reverse logistics and circular economy mechanisms in sustainable supply chain architecture. Prior studies have emphasized that recovering value from surplus materials, obsolete assets, and waste streams not only reduces environmental harm but also generates economic returns and operational efficiencies (Çankaya et al., 2016; Tian & Handfield, 2020; Zubair & Khan, 2016). This study extends those insights by empirically demonstrating that investment recovery constitutes a core structural pillar of effective GSCM implementation.

Beyond environmental outcomes, the study revealed that internal environmental management, green purchasing, customer cooperation, eco-design, and investment recovery all exert significant positive effects on operational development goals of society. These results provide compelling evidence that GSCM functions as a socio-economic development mechanism rather than merely an environmental compliance tool. This aligns with recent findings that sustainability-oriented supply chain practices improve productivity, employment stability, innovation diffusion, and community well-being (Amini, 2016; Hu & Tresirichod, 2024; Stafford-Smith et al., 2021). By embedding sustainability principles across organizational processes, firms contribute directly to broader development objectives such as responsible consumption, industrial modernization, and environmental stewardship (Ali et al., 2024; Niromand et al., 2025).

The integrated nature of the model underscores that sustainability performance emerges from systemic interactions among multiple GSCM dimensions rather than isolated initiatives. This supports the argument advanced by Alkaha et al. (2022) and Delshad (2022) that effective GSCM requires holistic transformation across supply chain governance, organizational culture, and inter-organizational relationships (Alkaha et al., 2022; Delshad, 2022). The present study's findings reinforce the necessity of coordinated implementation strategies that simultaneously address internal management, supplier relations, product design, customer engagement, and reverse logistics.

Moreover, the strong predictive power of the structural model reflects the increasing strategic relevance of GSCM in contemporary competitive environments characterized by regulatory pressures, stakeholder activism, and market volatility. Firms adopting advanced GSCM frameworks demonstrate enhanced resilience, adaptability, and legitimacy in the face of environmental uncertainty (El Mokadem & Khalaf, 2025; Rashid et al., 2024). The study's results therefore contribute important empirical support to the emerging view that sustainability-oriented operations represent a primary driver of long-term organizational survival and value creation (Ali et al., 2024; Lin et al., 2023; Niromand et al., 2025).

Collectively, these findings advance the theoretical understanding of how GSCM practices influence sustainable development outcomes and provide robust empirical confirmation of the multidimensional benefits of sustainability-oriented supply chain strategies. They also demonstrate that sustainability and profitability are complementary rather than contradictory

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goals, reinforcing the strategic imperative for organizations to integrate environmental responsibility into core business models (Amini, 2016; Stafford-Smith et al., 2021; Yazdani & Landran Esfahani, 2023).

Despite the valuable insights generated by this study, several limitations must be acknowledged. First, the research was conducted within a single industrial organization, which may limit the generalizability of the findings to other sectors or national contexts. Second, the cross-sectional research design restricts the ability to capture dynamic changes in sustainability performance over time. Third, reliance on self-reported questionnaire data may introduce response bias and common method variance.

Future studies should employ longitudinal designs to examine the long-term effects of GSCM practices on sustainable development outcomes. Comparative studies across multiple industries and countries would further enhance the robustness and generalizability of findings. Additionally, incorporating objective environmental and financial performance indicators alongside perceptual measures would provide a more comprehensive assessment of sustainability performance mechanisms.

Managers should adopt an integrated GSCM strategy that simultaneously strengthens internal environmental management, supplier collaboration, eco-design capabilities, customer engagement, and reverse logistics systems. Organizations are encouraged to embed sustainability objectives within corporate governance structures and performance evaluation systems to ensure sustained commitment. Policymakers and industry leaders should also promote cross-sector collaboration and knowledge sharing to accelerate the diffusion of effective GSCM practices across industrial ecosystems.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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