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Green Supply Chain Management and Environmental Performance: The Influence of Eco-Design, Reverse Logistics, and Green Purchasing.

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ABSTRACT

Chemical manufacturing firms in Pakistan play a significant role in the industrial and economic development; however, their operations also contribute to various environmental challenges. These firms are often associated with high energy consumption, greenhouse gas emissions, industrial waste generation, water pollution, and the release of hazardous chemicals into the environment. Consequently, improving environmental performance (ENP) has become a critical priority for chemical manufacturing firms in Pakistan, particularly through the adoption of green practices, eco-innovation, sustainable production technologies, and effective environmental management systems. Therefore, this study investigates the effects of eco-design, reverse logistics, and green purchasing on ENP, while examining the mediating role of sustainable process management (SPM). A quantitative research design is adopted, and data was collected through a structured questionnaire distributed among employees working in chemical manufacturing firms in Pakistan. The collected data were analyzed using Structural Equation Modeling. The findings reveal that reverse logistics significantly improves ENP, whereas eco-design and green purchasing do not show significant direct effects. However, all green supply chain management (GSCM) practices significantly influence SPM, which subsequently enhances ENP. The study concludes that SPM plays a critical role in transforming green supply chain initiatives into improved environmental sustainability outcomes within the chemical manufacturing industry.

INTRODUCTION

The chemical manufacturing industry plays a central role in the financial growth in Pakistan (Nizam et al., 2023), particularly through its contribution to petrochemicals, fertilizers, industrial gases, and other value-added manufacturing activities (Qambrani et al., 2024). Pakistani chemical manufacturing

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industry significantly contributes to exports and employment opportunities (Ahmad & Shabir, 2007). However environmental issues due to hazardous waste generation, air pollution, excessive use of energy and industrial effluents have been escalated as a result of the fast pace of industrial activities. The environmental problems have put pressure on the manufacturing firms to implement environmentally friendly business practices (Mady et al., 2026) that increase the environmental performance (ENP) of the companies without reducing their competitiveness and efficiency. As a result, ENP has become a key strategic issue for chemical production companies (Gkika & Kyzas, 2026), which represents the capacity of the company to impact its environmental footprint, reduce waste, control emissions and meet environmental regulations. Because of global environmental concerns and the national environmental policy, companies are more interested in carrying out green supply chain management (GSCM) practices (Rahman et al., 2026) which include eco-design, reverse logistics, and green purchasing. These practices help organizations to embed environmental considerations in production and procurement processes, product design and waste management. In addition, sustainable process management (SPM) adds support to the implementation of environmentally responsible operational systems and allows continuous improvement of the environment in the industries' overall process. Therefore, the knowledge of how to enhance ENP by implementing GSCM practices became increasingly significant for not only researchers but also industrial practitioners in the chemical manufacturing industry in Pakistan.

Despite growing focus on sustainability and environmental management, there are still common practical environmental issues that many chemical manufacturing companies in Pakistan are managing. These issues include industrial waste management, use of toxic substances, inadequacy in recycling systems and pollution control. The chemical manufacturing industry is known for its resource-heavy production processes (Abu-Siam et al., 2026), leading to environmental concerns. Many companies still face challenges in incorporating eco-design in product development in establishing efficient reverse logistics and in executing environmentally friendly purchasing practices throughout the supply chain (Letunovska et al., 2023). Lack of integrated SPM systems also diminishes the effectiveness of environmental efforts and long-term environmental benefits of green practices. There is some existing evidence from industry that environmental accidents, waste emissions and usage of hazardous materials are still pervasive problems in industrial sectors, particularly those in the developing and emerging economies. Thus, the real challenge is for many chemical companies to realize the potential of green supply chain efforts to deliver tangible environmental benefits (Eltayeb & Zailani, 2014). This situation demands needs of research on the effects of eco-design, reverse logistics, and green purchasing on the ENP directly and indirectly via SPM in the perspective of Pakistani chemical manufacturing industry.

This study contributed to the body of literature by developing an integrated model that illustrates how GSCM practices relate to ENP in the chemical manufacturing sector in Pakistan. Although previous studies have focused on the GSCM in various industrial and geographical settings (Attar et al., 2016; Green et al., 2012; Kurian, 2018; Yang & Wang, 2020), there has been little empirical investigation on the interaction between the three factors: eco-design, reverse logistics and green purchasing and their impact on ENP of manufacturing industries. This study has made a significant contribution because it introduced the concept of integrating several dimensions of the GSCM into a single model which explains the improvements in organizational environmental outcomes because of the environmentally responsible practices. Furthermore, the study is contextually critical as it is the first empirical study in chemical industry of Pakistan highlighted the role of eco-design, reverse logistics and green purchasing on environmental sustainability.

The main goal of this study is to investigate the impact of eco-design, reverse logistics and green

purchasing on the ENP in the chemical manufacturing sector in Pakistan. The study also seeks to explore the impact of these GSCM practices on SPM. Furthermore, it seeks to investigate role of SPM as a mediator between these GSCM practices and ENP. It is mainly directed towards the ENP aspect such as lowering the emissions, minimizing waste, controlling hazardous materials and improving the overall environmental sustainability of various products manufacturing processes. The results are expected to assist policy makers, industrial managers and environmental regulators to create more effective environmental management strategies to ensure industrial development. Therefore, the study offers insights to industrial managers on the potential of environmentally responsible practices in the supply chain to improve environmental outcomes and enhance sustainability performance.

LITERATURE REVIEW

Theoretical Foundation of the Study Based on Natural Resource-Based View (NRBV)

This study is grounded in the Natural Resource-Based View (NRBV) theory (Hart, 1995), which provides a strong theoretical explanation for the relationship between GSCM practices and ENP in the chemical manufacturing industry. The NRBV theory is an extension of Resource Based View (RBV) which postulates that companies can sustain competitive advantage by building the environment-friendly capability and resources that enable them to increase long-term sustainability and operational efficiency (Bals & Rosca, 2022). The theory focuses on the idea that businesses can enhance their performance and decrease their environmental impact by taking a proactive approach to environmental issues.

Within this research, eco-design, reverse logistics and green purchasing are considered as strategic environmental competencies which help companies to minimize waste, reduce pollution, conserve resources, and enhance environmental results. They promote SPM through improving sustainable production systems, responsible purchasing and waste recovery systems. Improved environmental control and operational sustainability then enhances the ENP, supporting SPM. SPM then boosts ENP through improved environmental control and operational sustainability (Famiyeh et al., 2018). The NRBV theory can offer an appropriate context to understand how environmentally oriented organizational practices can lead to improved ENP within the chemical manufacturing industry in Pakistan. The theory also confirms the argument that environmental sustainability is not just a regulatory requirement (Grillo et al., 2021), but also a strategic organizational capacity that enhances the sustainability of industries in the long term and their environmental responsibility. Based on these arguments, conceptual framework (Figure 1) has been proposed. Conceptual framework of the study is presented in Figure 1 highlighting the relationship between eco-design, reverse logistics, green purchasing, sustainable process management and environmental performance.

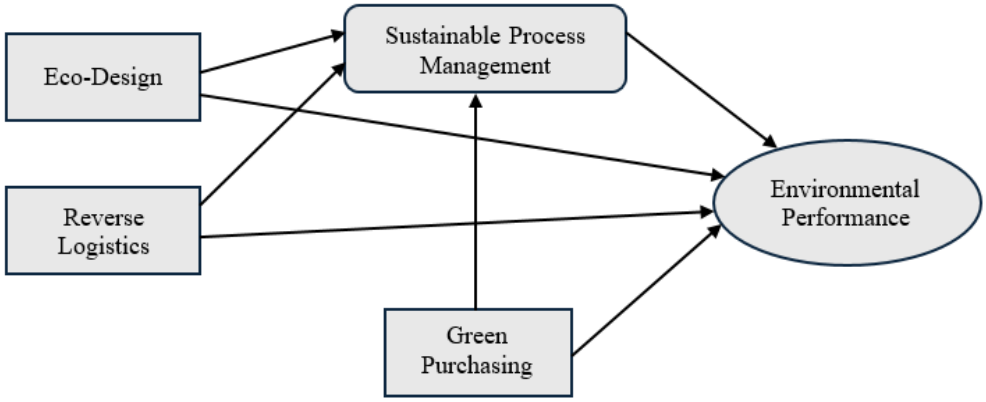

Figure 1: Conceptual Framework of the Study

HYPOTHESES DEVELOPMENT

Eco-Design and Environmental Performance

Eco-design is the incorporation of an environmental dimension in product and process design, to decrease the adverse environmental effects throughout the product life cycle. Earlier research shows that eco-design can make a substantial contribution to ENP by the reduction of the use of various resources (Cappelletti et al., 2023). The organizations that implement eco-design practices tend to redesign the products to make them easier to recyclable, recover and more energy-efficient, thereby increasing the environmental sustainability of the product. Eco-design can help industries in the manufacturing division to improve the pollution prevention and cleaner production aspects by promoting environmental-friendly production processes, and sustainable use of materials (Cappelletti et al., 2023; Othman et al., 2026). The NRBV also indicates that companies engaged in eco-design development can obtain improved ENP by engaging in proactive environmental management strategies. Eco-design is more relevant in the chemical manufacturing industry where it can be used to manage risks to the environment regarding toxic products and industrial waste. Eco-design is thus expected to benefit the environment. Hence, it is hypothesized that:

H1: Eco-design has a positive effect on ENP.

Reverse Logistics and Environmental Performance

Reverse logistics deals with the process of collecting, recycling, reusing, repairing and disposing of products and materials after use by customers (Kinobe et al., 2012). Based on existing literature, it can be confirmed that reverse logistics is already an important factor that can make ENP better (Singh et al., 2025), because it can reduce the accumulation of waste, minimize environmental pollution and use resources efficiently. Product recovery and recycling activities can help to decrease landfill waste, reduce raw material use and raw material related environmental degradation of manufacturing activities. Furthermore, reverse logistics plays a central role in sustainable environmental management by confirming the safe disposal and management of hazardous materials (Kinobe et al., 2012). For chemical industries, which are sensitive to the environment, reverse logistics systems can effectively manage industrial waste and minimize industrial accidents to the environment. Empirical research has been conducted for reverse logistics practices regularly, and the reported results indicate positive results in relation to environmental outcomes. Thus, reverse logistics is likely to have a positive effect on the ENP in the chemical manufacturing industry in Pakistan. Therefore, it is proposed that:

H2: Reverse logistics has a positive effect on ENP.

Green Purchasing and Environmental Performance

Green purchasing is defined as the purchase of environmentally friendly goods, products, services and materials that have a minimum negative environmental impact (Chen & Chang, 2013; Meijers et al., 2019). Earlier research indicates that green purchasing has a positive effect on ENP as it helps firms to work with green suppliers and to implement green procurement (Walton et al., 1998). Businesses that have adopted green purchasing policies tend to focus on suppliers which have environmental certifications, eco-labelling initiatives and environmentally friendly production systems. These practices are effective in minimizing pollution, hazardous material consumption, waste production and encouraging environmentally responsible manufacturing processes. Incorporating environmental criteria into purchasing decisions also contributes to environmental compliance and sustainable supply chain through green purchasing. Choosing environmentally responsible suppliers in the chemical manufacturing sector can lead to safer production methods, better environmental outcomes, and a

greener industry. The ability to carry out procurement in an environmentally responsible manner contributes to the sustainability and environmental competitiveness of an organization (Jaiswal & Kant, 2018; Walton et al., 1998). Thus, green purchasing is anticipated to have a positive impact on ENP in the Chemical Sector of Pakistan. Therefore, it is proposed that:

H3: Green purchasing has a positive effect on ENP.

Eco-Design and Sustainable Process Management

Eco-design is an important aspect of process management for the improvement of sustainable processes (Chung & Wee, 2008; Othman et al., 2026), by involving environmental issues in the design of products and in the design of production systems. The literature suggests that companies that have embraced eco-design are more likely to have operational processes that reduce waste and are more competent in the use of resources leading to environmental sustainability. Eco-design makes companies rethink their production processes for environmental safety over the whole life cycle (Kouser et al., 2025). This is beneficial for SPM by cleaner production technologies, reduction of material use, and better environmental monitoring systems. Eco-design also helps the industries to meet environmental standards and to integrate them in business (Othman et al., 2026). Companies with environmental design skills have the potential to both enhance internal sustainability processes and boost operational sustainability. The execution of eco-design in the chemical manufacturing sector contributes to the creation of environmentally safe production system for the companies, which enables SPM. Hence, it is expected that the eco-design will positively impact SPM leading to following hypothesis:

H4: Eco-design has a positive effect on SPM.

Reverse Logistics and Sustainable Process Management

Reverse logistics plays an key role in SPM by optimizing waste recovery and recycling processes (Kinobe et al., 2012; Singh et al., 2025). Previous research has shown that businesses that use good reverse logistics systems to manage their reverse flows become better at creating sustainable practices that increase process efficiency and environmental responsibility (García-Sánchez et al., 2019; Singh et al., 2025). Reverse logistics contributes to SPM by maximizing material recycling and environmentally friendly handling of products along the supply chain (Mbago et al., 2025). These practices allow companies to manage the resources they have more efficiently, as well as minimize the environmental footprint of industrial processes. Additionally, in manufacturing sectors reverse logistics also supports environmental management systems by embedding recycling and remanufacturing operations in the systems of the organizations. Therefore, companies with an environmentally friendly operating capacity will enhance their long-term sustainability performance. In the chemical manufacturing sector, reverse logistics practices help companies effectively control hazardous materials and minimize environmental risks. Thus, following hypothesis is proposed:

H5: Reverse logistics has a positive effect on SPM.

Green Purchasing and Sustainable Process Management

Green purchasing is seen as an integral part of SPM because it includes environmental aspects within the selection of suppliers and in their procurement processes (Björklund, 2011). It is evident from literature that companies employing green purchasing are more likely to develop sustainable operational processes for protecting the environment and conserving resources (Björklund, 2011; Meijers et al., 2019). Green purchasing promotes companies to work with environmentally friendly suppliers, green materials, and establish green standards for their supply chain (Jazairy & von

Haartman, 2021). Such environmental purchasing choices have the potential to increase the sustainability of the purchasing process by lowering pollution, using less hazardous materials, and promoting cleaner production systems. Moreover, green purchasing also helps to implement environmental management systems and operational policies based on sustainability in enterprises. Therefore, the ability to conduct environmentally responsible procurement contributes to a firm's sustainability and operational efficiency. Green purchasing can help companies optimize SPM by providing them with environmentally safe and sustainable material procurement. Hence, green purchasing will be expected to positively affect SPM, leading to following hypothesis:

H6: Green purchasing has a positive effect on SPM.

Sustainable Process Management and Environmental Performance

SPM is the adoption of environmental-friendly process methods and practices that are designed to ensure sustainable outcomes and protect the environment over time (Yang & Wang, 2020). It has been proven in past studies that SPM can have a substantial positive effect on ENP (Van et al., 2025; Wang et al., 2021) as an outcome of lowering emissions and upgrading the use of resources and managing environmental risks. Firms with good SPM systems can do more to put environmental standards into practice on a day-to-day basis and to measure environmental results on an ongoing basis. SPM also contributes to cleaner production, safety at the workplace and raw material efficiency. In manufacturing industries, these practices help to ensure environmental sustainability and adherence to environmental regulations (Feng & Chen, 2018; Muniapan, 2015). Organization that has better sustainability-oriented capabilities in the operation will realize better environmental results and long-term environmental competitiveness. SPM is crucial in chemical manufacturing where environmentally sustainable operational controls can minimize pollution and dangerous environmental effects. Hence, sustainability in process management is expected to positively impact the ENP.

H7: SPM has a positive effect on ENP.

SPM acts as a key mediating variable between the two relationships, namely GSCM practices and ENP. Some previous studies indicate that the operational systems and management processes that are environmentally responsible are more effective in improving environmental sustainability through eco-design, reverse logistics and green purchasing. Eco-design encourages development of products and processes which consider the environment (Chung & Wee, 2008; Gavrilescu et al., 2017), reverse logistics encourages recycling and waste recovery activities and green purchasing encourages people to make decisions which are environmentally sustainable. Successful implementation of these practices to enhance ENP, however, relies heavily on the ability of the organization to embed sustainability in their operational processes. The implementation of SPM allows more sustainable production and environmental monitoring (Attaran & Attaran, 2007; Mendoza-Fong et al., 2019)which improve the environmental impact of green supply chain projects. SPM is especially significant in the chemical manufacturing sector, as it enables companies to effectively manage and limit pollution, control hazardous materials, and enhance environmental sustainability. Thus, the mediation of SPM between GSCM and ENP is expected.

H8: SPM mediates the relationship between eco-design and ENP.
H9: SPM mediates the relationship between reverse logistics and ENP.
H10: SPM mediates the relationship between green purchasing and ENP.

METHODOLOGY

Research Design

This study carried out a survey to inspect the influence of GSCM practices on ENP in the chemical manufacturing industry of Pakistan. The study uses a quantitative approach as it aims to test the hypothesized relationships among the variables of eco-design, reverse logistics, green purchasing, SPM, and ENP by applying statistical analysis techniques. The data collection for this study employs a survey method as it is an effective and systematic way of acquiring standardized responses from many respondents. The study employs a structured questionnaire that contains previously validated measurement scales which have been adapted from previous studies to ensure reliability and validity.

Population and Sample Size

This study aims to examine the population of employees involved in chemical manufacturing companies in Pakistan. The chemical manufacturing industry is chosen because it has a high level of environmental impact and the industry is increasingly focused on sustainability in industry and environmental management (Hall & Howe, 2010; Parthasarathy et al., 2005). The target respondents are managers, supervisors, environmental officers, procurement staff, supply chain staff, and operational staff that have knowledge about environmental practice and environmental sustainability initiatives within the organization. These respondents are suitable as they are directly engaged in activities within the supply chain, environmental management activities and decision-making processes within organizations related to sustainability. A total number of 700 questionnaires are distributed to the employees of chemical manufacturing companies in Pakistan. After data screening, 303 valid questionnaires were received for final analysis.

Sampling Design

This study employs a purposive sampling technique to select respondents from chemical manufacturing companies in Pakistan. Purposive sampling is appropriate since the study preferred the respondents who have relevant knowledge and experience in the subject of the study, GSCM practices, sustainable operational processes and environmental management activities. These include employees engaged in procurement, supply chain management, production operations, environmental management and sustainability related activities who are more familiar with implementation of eco-design, reverse logistics, green purchasing and SPM within their organizations. Structured questionnaires are sent to selected respondents in chemical manufacturing firms, and the data collection process is carried out. The questionnaires are distributed through both physical and electronic methods to facilitate greater access and response. The purposive sampling method, therefore, helps in collecting relevant and reliable information from the knowledgeable participants who can provide accurate information about the environmental sustainability practices and ENP of the chemical manufacturing industry.

Questionnaire Development

Questioniares for data collected was developed by adapting the measures from earlier studies. Eco-designed and reverse logistics was considered by using ten scale items which was adapted from Epoh and Mafini (2018). Similarly, green purchase and ENP was measured by adapting eleven scale items from Zhu et al. (2008). Finally, this study adapted three scale items from Li et al. (2025) to measure SPM. All the measures are reported in Table 1.

Table 1: Variable Measures

Variables	Scale Items	Source
Eco-design	1. "We prefer design of products for reduced consumption of material/energy 2. We prefer design of products for reuse, recycle, recovery of material and component parts. 3. We prefer design of products to avoid or reduce the use of hazardous products. 4. We prefer designing processes for minimization of waste. 5. We prefer design of products considering life cycle assessment.	Epoh and Mafini (2018)
Reverse logistics	1. We prefer to collect used products from customers for recycling. 2. We prefer to repair and provide maintenance services after sales. 3. We prefer recapture value through remanufacturing and proper disposal of returned products. 4. We prefer returning products to suppliers for recycling. 5. We prefer interacting with operations and reverse logistics staff for designing reverse logistics programs.	Epoh and Mafini (2018)
Green Purchase	1. We prefer eco-labeling products. 2. We prefer cooperation with suppliers for environmental objectives. 3. We prefer environmental audit for suppliers' internal management. 4. We prefer suppliers' ISO14000 certification. 5. We prefer second-tier supplier environmentally friendly practice evaluation.	Zhu et al. (2008)
Sustainable Process Management	1. Our firm has established an environmental management system, such as ISO 14001. 2. Workplace safety has been enhanced, ensuring occupational health 3. Active participation in societal activities, adhering to relevant codes of conduct and engaging in social welfare activities, undertaken by our firm.	Li et al. (2025)
Environmental Performance	1. We prefer reduction in air emissions. 2. We prefer reduction of solid waste. 3. We prefer reduction of effluent waste. 4. We prefer to decrease the frequency of environmental accidents. 5. We prefer to decrease consumption of hazardous and toxic materials. 6. We prefer improvement in an enterprise's environmental situation."	Zhu et al. (2008)

DATA ANALYSIS

Respondents Profile

As shown in Table 2, the majority (83%) of respondents are male (n = 251) compared to 17% of respondents being female (n = 52). The chemical manufacturing industry in Pakistan is male dominated. While considering marital status, 63% (n = 191) of respondents were married while 37% (n = 112) were single. Therefore, it can also be inferred from the data that married individuals receive more significant levels of support, as they comprise a larger proportion of the workforce involved in this study. Regarding educational qualifications, the largest group of respondents (41%, n=124) hold a master's degree followed closely by 35% (n=106) who have obtained a bachelor's degree and 15% (n=46) who hold professional training qualifications, while only 9% (n=27) have a doctorate. The collective responses suggest that respondents are well educated with sufficient knowledge to offer credible data regarding GSCM and environmental sustainability practices within their organizations.

Table 2: Respondents Profile

Demographic Variable	Category	Frequency	Percentage
Gender	Male	251	83%
	Female	52	17%
Marital Status	Married	191	63%
	Single	112	37%
Education	Bachelor's degree	106	35%
	Master's degree	124	41%
	PhD Degree	27	9%
	Professional Education	46	15%

Descriptive Statistics

Descriptive statistics and data diagnostics for all measurement items in the study are shown in Table 3. The outcomes show there are no missing values, therefore, the data set is complete and suitable for further statistical analysis. The mean scores fall within the range 2.779 – 3.403, which suggests that the participants were moderately responsive to the dimensions of GSCM practices, SPM, and ENP. The standard deviations for the responses indicate acceptable response variability. Furthermore, skewness and kurtosis values show that data is normally distributed. The minimum and maximum values also help to show that answers span the entire Likert scale of 5 points. The results showed that the data obtained are reliable and suitable for analysis using SEM.

Table 3: Data Satisfices

	No.	Missing	Mean	Median	Min	Max	SD	Kurtosis	Skewness
ECD1	1	0	2.779	3	1	5	1.108	-0.733	0.198
ECD2	2	0	3.132	3	1	5	1.27	-0.958	-0.221
ECD3	3	0	3.132	3	1	5	1.311	-1.045	-0.21
ECD4	4	0	2.98	3	1	5	1.29	-0.978	0.009
ECD5	5	0	2.99	3	1	5	1.241	-0.898	-0.054
REL1	6	0	2.97	3	1	5	1.265	-0.975	-0.091
REL2	7	0	3.343	3	1	5	1.264	-0.983	-0.264
REL3	8	0	3.389	3	1	5	1.282	-1.018	-0.267
REL4	9	0	3.366	3	1	5	1.333	-1.126	-0.282
REL5	10	0	3.403	3	1	5	1.301	-1.08	-0.282
GRP1	11	0	3.29	3	1	5	1.313	-1.067	-0.188
GRP2	12	0	3.03	3	1	5	1.178	-0.806	-0.119
GRP3	13	0	3.102	3	1	5	1.183	-0.833	-0.199
GRP4	14	0	3.092	3	1	5	1.25	-0.905	-0.176
GRP5	15	0	3.046	3	1	5	1.229	-0.946	-0.142
SPM1	16	0	3.089	3	1	5	1.29	-1.007	-0.213
SPM2	17	0	3.383	3	1	5	1.226	-0.831	-0.321
SPM3	18	0	3.287	3	1	5	1.259	-0.906	-0.266
ENP1	19	0	3.343	3	1	5	1.303	-1.05	-0.243
ENP2	20	0	3.264	3	1	5	1.268	-0.904	-0.223
ENP3	21	0	3.376	4	1	5	1.255	-0.948	-0.337
ENP4	22	0	3.066	3	1	5	1.167	-0.695	-0.091
ENP5	23	0	3.063	3	1	5	1.243	-0.917	-0.078
ENP6	24	0	3.102	3	1	5	1.183	-0.834	-0.079

Measurement Model Assessment

The convergent validity results of study constructs are stated in Table 4, and the measurement model assessment is shown in Figure 2. The results denote that all the factor loadings are greater than the recommended value of 0.70, which signifies the strong item reliability (Hair et al., 2017; Khan et al., 2022). The alpha for all constructs is satisfactory and has values also above 0.7. The same applies to the Composite Reliability (CR) values which vary from 0.913 to 0.943 and are all above the recommended value of 0.70, representing good construct reliability (Hair et al., 2022). All the Average Variance Extracted (AVE) values are above 0.5, which is greater than the acceptable criterion, thus showing a satisfactory convergent validity (Tanveer & Latif, 2025). The measurement model quality is also supported by the strong relationships between values and their corresponding constructs as shown in Figure 2. Hence, it can be concluded that the measurement model has good reliability and convergent validity for further analysis of the structural model.

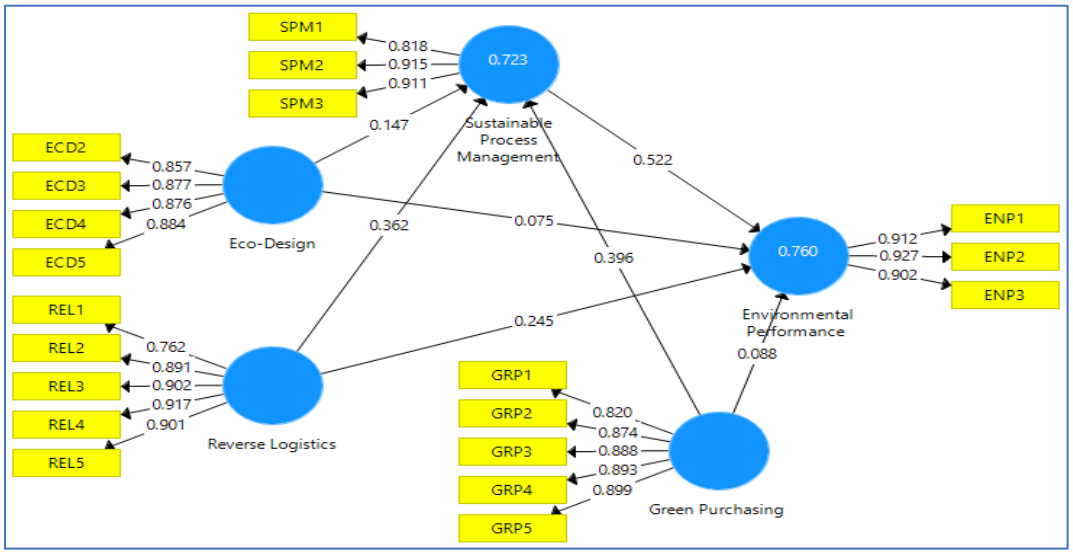

Figure 2: Measurement Model Assessment

Table 4: Convergent Validity

Variables	Items	Loading	Alpha	CR	AVE
Eco-Design	ECD2	0.857	0.896	0.928	0.763
	ECD3	0.877			
	ECD4	0.876			
	ECD5	0.884			
Environmental Performance	ENP1	0.912	0.901	0.938	0.835
	ENP2	0.927			
	ENP3	0.902			
Green Purchasing	GRP1	0.82	0.924	0.943	0.767
	GRP2	0.874			
	GRP3	0.888			
	GRP4	0.893			
	GRP5	0.899			
Reverse Logistics	REL1	0.762	0.923	0.943	0.768
	REL2	0.891			
	REL3	0.902			
	REL4	0.917			
	REL5	0.901			
Sustainable Process Management	SPM1	0.818	0.856	0.913	0.778
	SPM2	0.915			
	SPM3	0.911			

The results of Heterotrait-Monotrait Ratio (HTMT) was used to evaluate discriminant validity among the study constructs (Hafkesbrink, 2021). All HTMT values are found to be less than the recommended value of 0.90. The results show that each construct is empirically different from the others and measures a different concept in the research context. Accordingly, the discriminant validity of measurement model is established that means constructs of the study are sufficiently differentiated and appropriate for further assessment of the structural model. The values of HTMT are presented in Table 5.

Table 5: Heterotrait-Monotrait Ratio (HTMT)

	Eco-Design	Environmental Performance	Green Purchasing	Reverse Logistics	Sustainable Process Management
Eco-Design					
Environmental Performance	0.818				
Green Purchasing	0.808	0.84			
Reverse Logistics	0.703	0.775	0.806		
Sustainable Process Management	0.809	0.763	0.608	0.708	

STRUCTURAL MODEL ASSESSMENT

Direct Effect Results

The result of the direct effect test of the structural model is presented in Table 6 and the relationship between the study constructs and the assessment of the structural model is given in Figure 3 below. The result indicates that there is insignificant effect of eco-design on ENP ($\beta = 0.075$, $p > 0.05$) which suggests that hypothesis 1 was rejected. Likewise, green purchasing has positive but insignificant influence on ENP ($\beta = 0.088$, $p > 0.05$), which rejected hypothesis 3. Regarding the reverse logistics, the outcome shows that it has a positive effect on the ENP ($\beta = 0.245$, $p<0.05$), which supports Hypothesis 2. In addition, eco-design, reverse logistics and green purchasing all show positive impacts on SPM and thus support hypotheses 4, 5 and 6. ENP is also significantly influenced by SPM ($\beta = 0.522$, $p < 0.05$) which supported hypothesis 7.

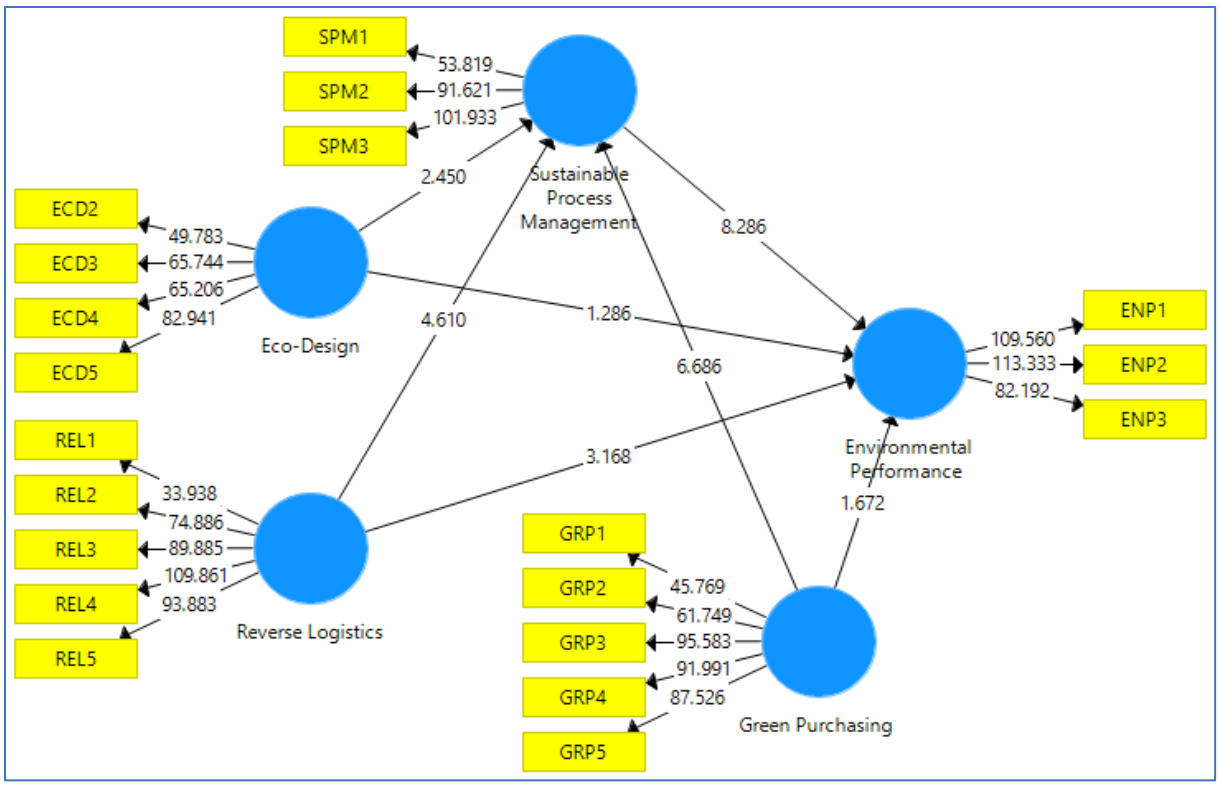

Figure 3: Measurement Model Assessment

Table 6: Direct Effect Results

	Beta Value	Mean	SD	T Statistics	P Values
Eco-Design -> Environmental Performance	0.075	0.075	0.059	1.286	0.199
Eco-Design -> Sustainable Process Management	0.147	0.152	0.06	2.45	0.015
Green Purchasing -> Environmental Performance	0.088	0.094	0.052	1.672	0.095
Green Purchasing -> Sustainable Process Management	0.396	0.396	0.059	6.686	0
Reverse Logistics -> Environmental Performance	0.245	0.242	0.077	3.168	0.002
Reverse Logistics -> Sustainable Process Management	0.362	0.359	0.078	4.61	0
Sustainable Process Management -> Environmental Performance	0.522	0.519	0.063	8.286	0

In-Direct Effect Results

The mediation effect in SPM between the GSCM practices and ENP are illustrated in Figures 4, 5 and 6. The results are shown in Table 7 along with the beta value, t-value and p-value. Regarding hypothesis 8, the findings show that SPM has a significant mediating effect between eco-design and ENP ($\beta = 0.077$; $p < 0.05$) as shown in Figure 4. Likewise, Figure 5 shows that SPM has a significant mediation effect on the linkage between reverse logistics and ENP ($\beta = 0.189$, $p < 0.05$) and supports hypothesis 9. Moreover, as shown in Figure 6, the mediator role of SPM between sustainable green purchasing and ENP was significant ($\beta = 0.207$, $p < 0.05$) which supported hypothesis 10. These results indicate that the application of GSCM can help to enhance environmental.

Table 7: In-Direct Effect Results

	Beta Value	Mean	SD	T Statistics	P Values
Reverse Logistics -> Sustainable Process Management -> Environmental Performance	0.189	0.185	0.042	4.473	0
Green Purchasing -> Sustainable Process Management -> Environmental Performance	0.207	0.206	0.044	4.724	0
Eco-Design -> Sustainable Process Management -> Environmental Performance	0.077	0.079	0.034	2.259	0.024

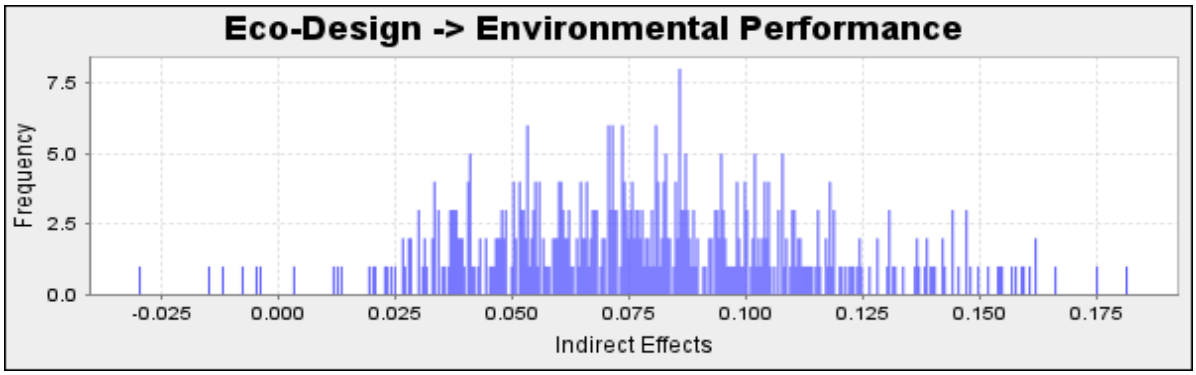

Figure 4: Eco-Design -> Sustainable Process Management -> Environmental Performance

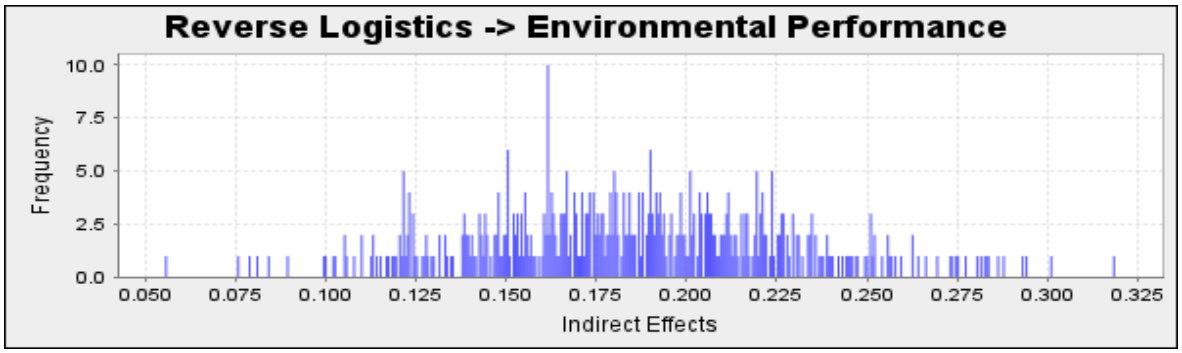

Figure 5: Reverse Logistics -> Sustainable Process Management -> Environmental Performance

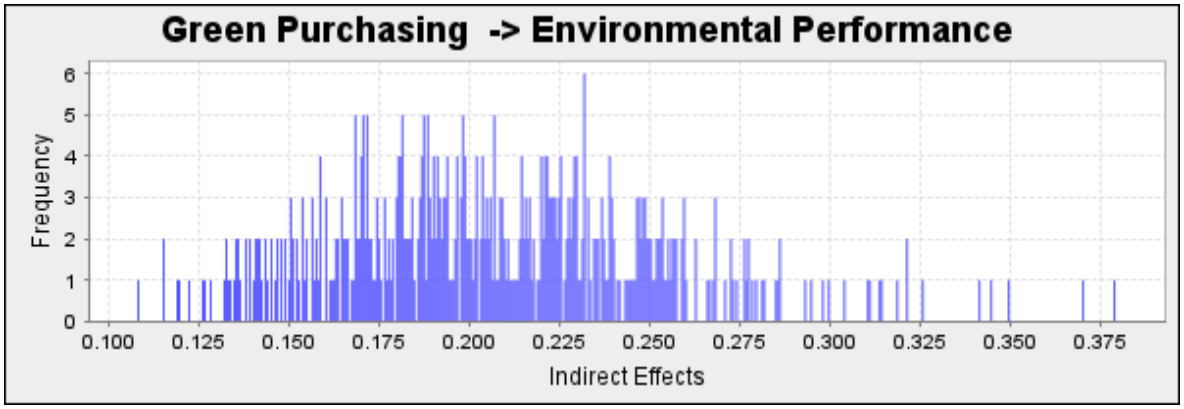

Figure 6: Green Purchasing -> Sustainable Process Management -> Environmental Performance

The R-square (R^2) values show how well the structural model explain the variance in the endogenous constructs (Chin, 1998). The results reveal the value of R^2 is 0.723, meaning that the SPM can be explained by 72.3% of the variance in the combination of eco-design, reverse logistics and green purchasing. Likewise, the R^2 for ENP is 0.760, meaning that the overall variability in ENP can be explained by the combination of the four factors: eco-design, reverse logistics, green purchasing and SPM.

DISCUSSION

The findings of this study provide important insights into the relationship between GSCM practices, SPM, and ENP within the chemical manufacturing industry of Pakistan. The findings related to eco-design revealed that eco-design does not significantly improve ENP directly. These findings deviate from a number of studies reporting positive relationship between eco-design and environmental sustainability results (Cappelletti et al., 2023; Li et al., 2024; Monteiro et al., 2019). Previous studies indicated that a green approach to product and process design can lead to waste reduction, pollution control and resource efficiency (El-Halwagi, 2011; Hraiga, 2023). The results from the study, however, do suggest that the change in eco-design might not be enough to drive immediate environmental benefits. This inconsistency could be attributed to the complexity of the chemical manufacturing processes, which may need to be integrated well in operations, and then go through longer implementation procedures, before meaningful results become apparent.

Furthermore, results highlighted that the development of reverse logistics has a positive affect on ENP, as opposed to forward logistics. The result is similar with prior studies which have focused on the importance of recycling, remanufacturing, product recovery and waste management (Singh et al., 2025; Wang et al., 2024; Yu & Solvang, 2016) to achieve environmental degradation reduction. Previous studies have consistently shown that reverse logistics contributes to the environment in an efficient manner by reducing waste and implementing mechanisms for the recovery of resources (Li et al., 2023; van der Wiel & Masurel, 2012). The results of the present study support the literature and validate that reverse logistics is one of the better GSCM practices to enhance the ENP, especially in the case of chemical industries where the environment is sensitive.

The results of green purchasing highlighted insignificant direct effect on ENP. This is contrary to some previous research that have linked green purchasing to positive impact on environmental sustainability (Duong et al., 2026; Khan et al., 2023). However, there were other studies that found conflicting or indirect impacts of green purchasing on environmental results, especially in sectors in which the purchasing process must be facilitated by internal sustainability processes. As such, the current results indicate that implementation of environmental responsibility in purchasing practices alone cannot directly lead to ENP unless there is a proper operation process to support environmental responsibility.

The results also confirmed that eco-design has a positive impact on SPM. This finding is in line with earlier studies that indicated that eco-design allows cleaner production systems, environmentally friendly operations and sustainably oriented manufacturing processes (Kouser et al., 2025; Moujoud et al., 2025; Othman et al., 2026). The research activities carried out earlier presented that the main value of eco-design is the possibility of incorporating sustainability principles by conserving resources and producing them in an environmentally responsible way. Therefore, eco-design can help to create an internal sustainability system more effectively than to produce direct environmental impacts. Likewise, the results found that reverse logistics has a positive impact on SPM. The result was consistent with other research highlighting implementation of reverse logistics helps organizations become more sustainable through enhanced waste management practices, recycling, and environmental management. Literature indicated that reverse logistics has a positive impact on the operational sustainability (Lude & Prügl, 2018) as it motivates companies to set up environmentally friendly recovery and disposal systems.

Moreover, results revealed that green purchasing has a positive impact on SPM. These results are in line with the preceding research which indicates the positive connection between green purchasing and SPM (Sugandini et al., 2020). According to previous studies, working with the environmentally responsible suppliers contributes to sustainability integration in the organization's operations (Andersén et al., 2020; Holt, 2004; Plambeck & Taylor, 2016). Additionally, the results of SPM revealed a significant positive impact on ENP. Companies that adopt environmentally sustainable practices in their operations can manage decreases in emissions, waste production and environmental risks. The results of the present study, therefore, reaffirm the fact that SPM is still an important organizational tool in order to enhance the ENP in manufacturing industries.

The mediation results highlighted that SPM plays a significant role as a mediator between eco-design, reverse logistics, green purchasing and ENP. The results are coherent with the literature highlighting that implementation of GSCM practices is reinforced by other operational systems that are aimed at sustainability. The literature review indicated that SPM enhances the environmental dimension of sustainable practices in the organization through cleaner production, environmental monitoring and utilization of resources. Therefore, the present results validate the notion that green supply chain initiatives have better chances to contribute to an improvement in ENP in the chemical industry.

CONCLUSION

This study investigated the influence of GSCM practices, including eco-design, reverse logistics, and green purchasing, on ENP in the chemical manufacturing industry of Pakistan. Additionally, this study considered the mediating role of SPM. The findings revealed that reverse logistics directly improves ENP, whereas eco-design and green purchasing do not show significant direct effects. However, all three practices of the GSCM significantly affect ENP through indirect effect of SPM. The results also identified that SPM has a significant influence on ENP and is a significant mediator of the relationships between the use of GSCM practices and ENP. The results suggest that environmentally responsible operational systems are a key enabler in the process of distributing environmental benefits from green supply chain programs. Therefore, the study establishes the significance of integrating operational processes of sustainability with green supply chain practices to boost the ENP in the chemical manufacturing industry.

THEORETICAL IMPLICATIONS

This study contributes to the existing literature on GSCM and environmental sustainability by extending the application of the NRBV theory within the chemical manufacturing industry of Pakistan. The results validate that GSCM practices can affect ENP better by SPM, not directly by GSCM practices. Therefore, the study contributes to the theory by bringing in the mediation of SPM as a key

organizational mechanism that addresses the link between environmental practices and environmental outcomes. Moreover, the negligible direct impacts of eco-design and green purchasing on ENP question some of the existing research assumptions and indicate that environmental capabilities need to be operationally integrated to achieve measurable environmental results. The study also brings empirical evidence from a relatively under-researched industrial and geographical context to expand GSCM literature.

PRACTICAL IMPLICATIONS

The findings of this study provide several practical implications for managers, policymakers, and environmental regulators in the chemical manufacturing industry of Pakistan. The results indicate that organizations should place greater emphasis on reverse logistics practices such as recycling, waste recovery, and remanufacturing to improve ENP. Besides, SPM systems should be reinforced as it is an important part of the process to achieve measurable environmental results from green supply chain efforts. Managers should involve sustainability in production processes, environmental monitoring systems and in purchasing to attain better ENP. The results also indicate that effective operational support and management systems, focusing on sustainability, need to be developed and implemented to achieve environmental benefits from eco-design and green purchasing practices. This research can also be utilized by industrial regulators and policymakers to guide industries towards environmentally sustainable operational standards and to promote the use of GSCM practices in industrial sectors.

LIMITATIONS AND FUTURE DIRECTIONS

This study has few limitations that provide opportunities for future research. First, the study emphasizes only on the chemical manufacturing industry in Pakistan. Therefore, it is limited to the Pakistan leads to the limitation of generalizability of the findings to other geographical contexts. Other industries or cross-country comparisons could be explored in future studies to increase external validity. Second, this study is of a cross-sectional research design, limiting the ability to look at changes in environmental practices over time. Researchers are advised to pursue longitudinal approaches in future research to examine sustainability outcomes over the long-term. Thirdly, the study only includes eco-design, reverse logistics and green purchasing as GSCM practices. Other factors like green innovation, environmental leadership or stakeholder pressure could be added in future research to gain a more comprehensive understanding of the ENP in industrial organizations.

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