

## Integrating Green Supply Chain Management and Total Quality Management: A SEM-ANN Analysis of Performance Enhancement in SMEs

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### ABSTRACT

The present research aimed to examine the impact of green supply chain management (GSCM) on organizational performance with the mediating role of total quality management (TQM). The research employed a descriptive correlational method using structural equation modeling. A sample of 152 managers, deputies, and supply chain experts from small and medium-sized enterprises (SMEs) in Iran participated in the study. Data analysis was analyzed using structural equation Modeling-Artificial Neural Network (SEM-ANN) approach. The results indicated that the effect of GSCM on TQM, environmental performance, and financial performance is positive and significant. Additionally, TQM has a positive and significant impact on both environmental performance and financial performance. The mediating role of TQM in the relationship between GSCM and both environmental and financial performance was also found to be positive and significant. Therefore, it can be concluded that GSCM leads to improvements in the environmental and financial performance of SMEs through TQM.

## 1. Introduction

Today, environmental issues and the preservation of the environment have become one of the most important criteria that consumers consider when making purchasing decisions. The concern for environmental preservation has led consumers to rethink the products they buy. Many consumers are willing to pay a premium for products that adhere to environmental standards [1]. Consequently, given that environmental and social issues are of paramount importance to customers today,

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adherence to environmental considerations in marketing activities can create a competitive advantage for companies, enabling them to establish a strong foothold in the market. Successful positioning starts when a company provides a unique offering that sets it apart from its rivals, delivering real value to customers. Consequently, a company's environmental performance can serve as a significant competitive advantage [2,3].

Moreover, some companies are required to implement environmental strategies to mitigate the adverse effects of their products on the environment in order to sell their products [31]. Therefore, the integration of environmental and financial performance is considered a major challenge for businesses seeking sustainable development in the current century [32]. To address these concerns, organizations have adopted various programs, including the utilization of clean technologies, modifications in production operations, and others that can lead to reductions in air pollution, energy consumption, solid waste, water wastage, and, generally, environmental pollution [4,5].

On a broader scale, addressing Green Supply Chain Management (GSCM) can be a crucial step toward enhancing sustainability in business. This is because supply chain management encompasses all stages of production from inception to end-of-life product management; thus, the integration of green practices and supply chain management can significantly impact business performance. Industry leaders, especially in developed countries, are seeking methods that not only support environmental sustainability but also enhance organizational performance. GSCM is one of the tools in this approach [6]. Recent advancements in predictive modeling, such as the Long Short-Term Memory (LSTM) model, have been effectively used in various financial applications, including the early warning systems for financial systemic risk [7]. These models can provide insights into the interdependencies between financial performance and risk management strategies, which is crucial for integrating approaches like and Total Quality Management (TQM).

The aim of this paper is to explore the intricate relationship between GSCM and organizational performance, specifically focusing on the mediating role of TQM in small and medium-sized enterprises (SMEs). By employing a robust analytical framework that incorporates Structural Equation Modeling and Artificial Neural Networks (SEM-ANN), this study seeks to provide empirical insights into how the adoption of GSCM practices can enhance both environmental and financial performance through the effective implementation of TQM principles.

## **2. Literature review**

The idea of "green" has become widely accepted in contemporary society [8]. Within management, there is an increasing focus on topics such as green marketing, green accounting, green management, and green human resource management. The rise of government regulations aimed at achieving environmental standards, coupled with heightened consumer interest in eco-friendly products, has given rise to the concept of GSCM. GSCM encompasses all processes related to the movement of goods from raw materials to final delivery, including the flow of information throughout the supply chain [9,10]. To enhance environmental performance within the supply chain, organizations must adopt environmental management practices throughout the entire product lifecycle [11]. GSCM is fundamentally about integrating environmental management with supply chain management to mitigate environmental impacts by fostering information sharing, coordination, and collaboration among all supply chain participants [12].

According to Srivastava [13], a green supply chain integrates environmental considerations into various aspects of the supply chain, including product design, material sourcing, manufacturing, delivery, and post-consumption management throughout the product's lifecycle. This process,

known as GSCM, seeks to ensure that environmental standards are met at every stage, from raw material selection to recycling and reuse. Zhu and Sarkis [14] emphasizes that GSCM takes a comprehensive approach, aligning supply chain activities with ecological requirements to improve both resource efficiency and overall supply chain effectiveness. Furthermore, research conducted by Nugroho et al. [15] indicates that GSCM plays a significant role in boosting organizational performance.

TQM is defined as the guidance and control of activities based on the leadership of senior management, and the extension of these activities to all employees and units. These managerial and control measures are focused on ensuring a centralized quality that is achieved through the quality created in services provided to clients [15]. The dimensions of quality management include: leadership, customer focus, employee involvement, mutually beneficial relationships with suppliers, realistic decision-making approaches, process orientation, quality assurance tools, internal results, and employee outcomes. Quality management is a management philosophy that considers the shared needs and objectives of the organization as inseparable, applicable in business, industry, and services. It ensures maximum efficiency and effectiveness, reinforces business leadership through governance of processes and systems, enhances efficiency, prevents errors in managerial decision-making processes, and ensures that all organizational objectives are aligned with meeting customer needs [16]. If the quality management system is implemented according to the conditions and requirements of the organization, it can significantly influence management improvement, effectiveness enhancement, and the refinement of decision-making processes and organizational performance [16, 17]. Agyabeng-Mensah et al. [18] found in their research that GSCM has a positive and significant impact on TQM and organizational performance. Other studies also indicate a positive and significant role of TQM in improving organizational performance [15, 16].

In general, considering that sustainable supply chain management integrates environmental, cultural, and economic factors with the supply chain through product design, material purchasing, manufacturing processes, delivery of the final product to customers, and product end-of-life management, contemporary organizations have adopted sustainable supply chain management to enhance competitive advantage and profitability [19]. GSCM enables organizations to achieve profit and market share by reducing environmental risks and impacts while enhancing their ecological efficiency. Overall, establishing a green supply chain and addressing environmental issues leads to cost reductions and improved environmental performance, thereby enhancing the company's credibility and reputation. Therefore, GSCM can significantly influence an organization's financial, environmental, and operational performance.

A review of the research background indicates that there has been no study examining the impact of GSCM on organizational performance with the mediating role of TQM within the framework of SEM-ANN, highlighting a research gap in this area. Consequently, the main research question of the present study is: What is the impact of GSCM on organizational performance with the mediating role of TQM? Based on the theoretical literature and the theoretical framework derived from previous research, the conceptual model of the study is illustrated in Figure 1. As shown, in this model, GSCM is considered the independent variable, TQM is the mediating variable, and environmental and financial performance are the dependent variables. Therefore, the research hypotheses are as follows:

- Hypothesis 1: GSCM has an impact on Environmental Performance.
- Hypothesis 2: GSCM has an impact on Financial Performance.
- Hypothesis 3: GSCM has an impact on TQM.
- Hypothesis 4: TQM has an impact on Environmental Performance.

Hypothesis 5: TQM has an impact on Financial Performance.

Hypothesis 6: TQM mediates the effect of GSCM on Environmental Performance.

Hypothesis 7: TQM mediates the effect of GSCM on Financial Performance.

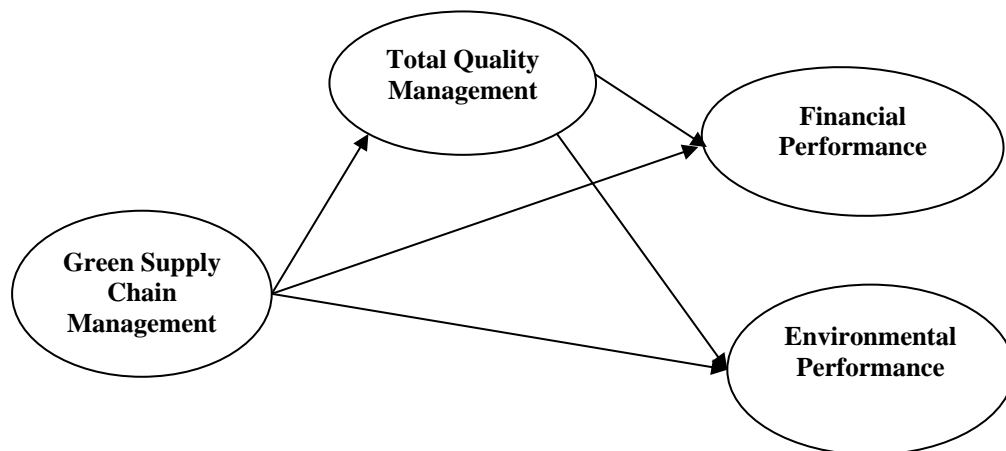


Fig. 1. The proposed Conceptual model

### 3. Research methodology

The research employs a descriptive correlational approach utilizing SEM-ANN approach.

#### 3.1. Population and sample

The statistical population comprises managers, deputy managers, and supply chain experts from SMEs in Iran. A total of 160 questionnaires were distributed among these professionals. After excluding incomplete responses, 152 valid questionnaires were analyzed.

#### 3.2. Data collection tools

GSCM: To measure the methods of GSCM, the questionnaire developed by Agyabeng-Mensah et al. [18] was utilized. This questionnaire consists of 8 items, which are rated on a five-point Likert scale.

TQM: To measure TQM, the questionnaire designed by Agyabeng-Mensah et al. [18] was employed. This questionnaire contains 9 items.

Environmental Performance: For measuring Environmental Performance, the questionnaire developed by Zhu and Sarkis [14] was used. This questionnaire includes 4 items.

Financial Performance: To measure Financial Performance, the questionnaire created by Flynn et al. [20] was utilized. This questionnaire consists of 5 items.

### 4. Finding

#### 4.1. SEM results

To evaluate reliability, Cronbach's alpha and composite reliability were employed, while validity was assessed through factor loadings, average variance extracted (AVE), and the Fornell-Larcker criterion. Composite reliability (CR) generally provides higher accuracy than Cronbach's alpha, with

both requiring an internal consistency score above 0.7. A factor loading of 0.6 or more indicates a well-defined construct [21]. As shown in Table 1, all research variables exceed this threshold. For convergent validity, an AVE of 0.5 or greater is recommended [17], confirming that the constructs adequately explain their indicators.

**Table 1**  
 Reliability and validity

Variable	Item	Factor loading	Cronbach's alpha	CR	AVE
GSCM	1	0.716	0.914	0.931	0.628
	2	0.725			
	3	0.765			
	4	0.762			
	5	0.792			
	6	0.837			
	7	0.866			
	8	0.859			
TQM	1	0.776	0.930	0.942	0.642
	2	0.823			
	3	0.807			
	4	0.899			
	5	0.785			
	6	0.725			
	7	0.762			
	8	0.836			
	9	0.788			
Environmental Performance	1	0.752	0.850	0.899	0.691
	2	0.843			
	3	0.845			
	4	0.879			
Financial Performance	1	0.801	0.864	0.901	0.647
	2	0.838			
	3	0.771			
	4	0.851			
	5	0.755			

Table 2 presents the results related to the correlation assessment and the second criterion for validity, which is the square root of the AVE.

**Table 2**  
 Correlation matrix and AVE

Variable	GSCM	TQM	Environmental Performance	Financial Performance
GSCM	0.79	-	-	-
TQM	0.62**	0.80	-	-
Environmental Performance	0.60**	0.67**	0.83	-
Financial Performance	0.53**	0.55**	0.54**	0.80

The study utilized SEM to evaluate a conceptual model predicting organizational performance. PLS method estimated the model, while bootstrapping with 300 subsamples calculated t-statistics for path coefficient significance. Figure 2 depicts the tested model, showing significant positive

impacts of GSCM on TQM, Environmental Performance, and Financial Performance, as well as TQM's positive effect on Environmental and Financial Performance.

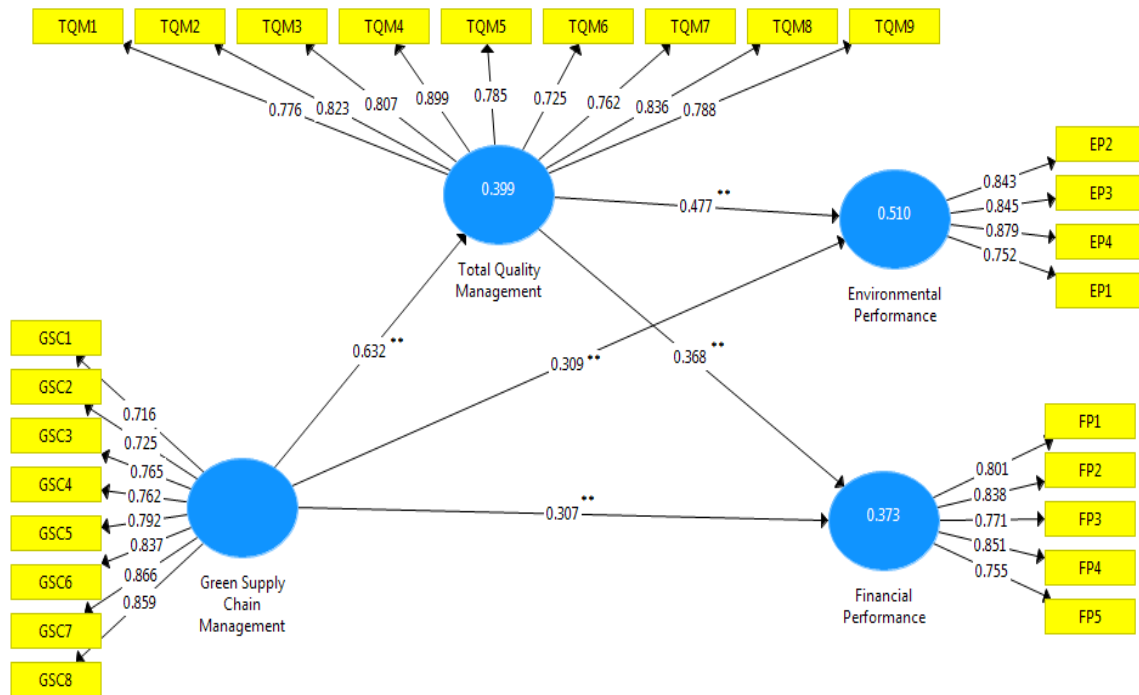


Fig. 2. The tested model

Table 3 presents the estimated path coefficients and explained variance for the study variables. To assess the significance of the indirect coefficients, the Sobel test was employed.

**Table 3**  
 Path coefficients and explained variance

Variable	Path Coefficient	T-Value	Explained Variance
Impact on Environmental Performance from:			
GSCM	0.309**	3.611	0.51
TQM	0.477**	7.418	
Impact on Financial Performance from:			
GSCM	0.307**	3.327	0.37
TQM	0.368**	4.087	
Impact on TQM from:			
GSCM	0.632**	8.202	0.4

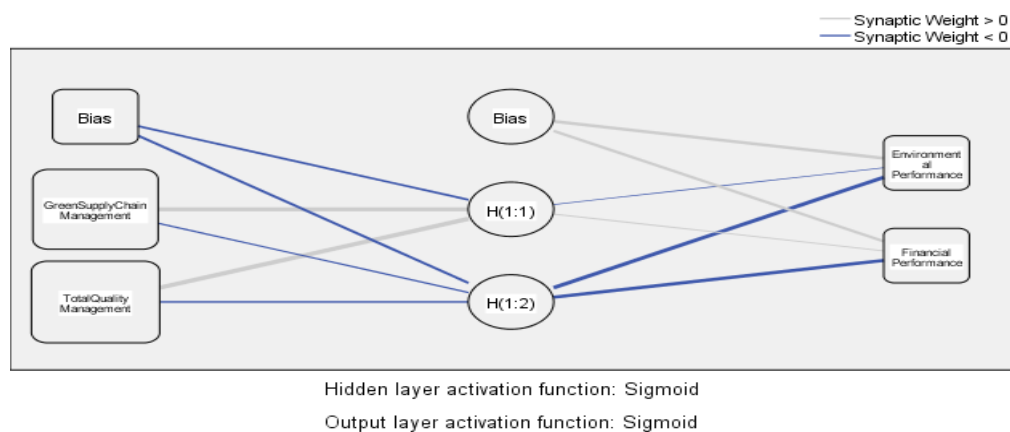
\*p<0.05, \*\*p<0.01

As shown in Table 3, the impact of GSCM on TQM, Environmental Performance, and Financial Performance is both positive and significant. Furthermore, the influence of TQM on Environmental Performance and Financial Performance is also positive and significant. Additionally, the model variables account for 51% of the variance in Environmental Performance, 37% of the variance in Financial Performance, and 40% of the variance in TQM. The mediating role of TQM in the impact of GSCM on both Environmental Performance and Financial Performance is positive and significant. In

this study, the Goodness of Fit value calculated for the model was 0.53, suggesting that the model demonstrates a satisfactory fit.

#### 4.2. ANN Results

The analysis utilizing ANN was conducted with IBM's SPSS neural network module. The model employed a feed-forward-backward-propagation (FFBP) algorithm, specifically using a multilayer perceptron (MLP) that incorporated significant predictors identified from PLS-SEM path analysis as input neurons. To prevent oversimplification, we implemented a 10-fold cross-validation with ten separate ANN networks. The activation for both the output and hidden layers was achieved using the sigmoid function, while the number of hidden nodes was automatically determined by the SPSS module. The ANN architecture featured one hidden layer comprising two nodes, as illustrated in Figure 3. The dataset was split into 90% for training and 10% for testing purposes. The error analysis was evaluated using the root-mean-square error (RMSE), with results indicating relatively low RMSE values of 0.158 for training and 0.161 for testing, as shown in Table 4. This suggests a strong model fit. Additionally, normalized importance was assessed through sensitivity analysis, expressing the relative importance as a percentage of the highest value. According to Table 7, TQM emerged as the most significant predictor at 100%, followed by GSCM at 86.25%.



**Fig. 3.** Artificial neural network diagram

**Table 4**  
 RMSE values and sensitivity analysis

Training			Testing			Sensitivity Analysis (Importance)		
N	SSE	RMSE	N	SSE	RMSE	Neural Networks	GSCM	TQM
137	3.429	0.158	15	0.346	0.152	ANN 1	0.459	0.541
136	3.551	0.162	16	0.320	0.141	ANN 2	0.473	0.527
132	3.189	0.155	20	0.539	0.164	ANN 3	0.491	0.509
139	4.002	0.170	13	0.484	0.193	ANN 4	0.433	0.567
135	3.233	0.155	17	0.579	0.185	ANN 5	0.437	0.563
134	3.394	0.159	18	0.293	0.128	ANN 6	0.449	0.551
138	3.477	0.159	14	0.418	0.173	ANN 7	0.487	0.513
138	3.770	0.165	14	0.244	0.132	ANN 8	0.479	0.521

136	2.866	0.145	16	0.564	0.188	ANN 9	0.449	0.551
137	3.111	0.151	15	0.344	0.151	ANN 10	0.474	0.526
Mean	3.402	0.158	Mean	0.413	0.161	Mean Importance	0.463	0.537
STD	0.311	0.007	STD	0.115	0.022	Normalized Importance	86.249	100.000

## 5. Discussion

The objective of the present study was to examine the impact of GSCM on organizational performance, with TQM serving as a mediating variable, using SEM. The results indicated that GSCM has a positive and significant effect on both environmental performance and financial performance. Therefore, GSCM leads to improvements in organizational performance. This finding aligns with the results of studies conducted by Nugroho et al. [15], Agyabeng-Mensah et al. [18], and Zaid et al. [22]. It can be argued that if a company employs green procurement methods in its supply chain processes, considers the greenness of its products during design, utilizes green information systems, adopts green marketing strategies, employs green auditing and evaluation methods, assesses the product life cycle, holds environmental and sustainability certifications, and takes the greenness of raw materials into account, it will enhance both environmental performance and financial performance. Consequently, GSCM is not only a necessary requirement for environmental protection but can also serve as an effective strategy for improving the financial performance of organizations. Moreover, the importance of clarity in communication and the articulation of ideas is critical in both educational and organizational contexts. Automated feedback systems, such as those discussed by Karizaki et al. [23], can provide valuable insights into how well individuals express their ideas, which can enhance learning outcomes and organizational effectiveness. These findings can be used by companies and managers as a rational approach for adopting green policies in supply chain processes.

The results also revealed that GSCM has a positive and significant impact on TQM. This finding is consistent with the research conducted by Agyabeng-Mensah et al. [18]. It can be explained that GSCM, by emphasizing the use of sustainable resources and waste reduction, contributes to the improvement of product quality [24]. When organizations collaborate with green suppliers and utilize high-quality raw materials, this leads to enhanced final product quality. Moreover, the implementation of green methods in the supply chain encourages employees to actively participate in improvement and innovation processes. This, in turn, leads to increased job satisfaction and efficiency, ultimately resulting in an overall improvement in organizational quality. Additionally, the role of social media in enhancing organizational agility and innovation capability, as discussed by Tehranian et al. [25], can further complement the findings of this study. By leveraging social media, organizations can improve their responsiveness to market changes and foster a culture of innovation, which aligns with the principles of TQM and GSCM. This highlights the interconnectedness of various management practices in driving performance outcomes. Moreover, considering that consumers are increasingly attentive to environmentally friendly products and services, organizations managing green supply chains can contribute to creating a positive brand image and enhancing customer satisfaction. This, in turn, supports the enhancement of TQM. Furthermore, recent research has shown that market reactions to capital increases, particularly in sectors like pharmaceuticals, can provide insights into how asset revaluation impacts financial performance [26]. This highlights the interconnectedness of financial strategies and operational practices, reinforcing the notion that GSCM and TQM not only improve environmental outcomes but also enhance financial performance through strategic resource management.

The findings also indicated that TQM positively and significantly affects both environmental performance and financial performance. This finding is consistent with studies conducted by Nugroho et al. [15], Mukenga & Awolusi [16], Agyabeng-Mensah et al. [18], Alghamdi et al. [27], and Zaid et al. [22]. It can be explained that TQM, by focusing on standards and process improvement, compels companies to pursue more efficient and cost-effective methods. This results in companies being able to reduce waste and energy consumption while supporting sustainable approaches in production and service delivery, which can help mitigate negative environmental impacts. Furthermore, by improving the quality of products and services, customers will not only be more satisfied with the quality of their purchased goods but will also be more inclined to choose environmentally conscious brands. In addition to enhancing Environmental Performance, TQM can also lead to improved Financial Performance, as optimizing processes and reducing errors can lower production costs. Moreover, TQM fosters innovation and creativity in processes and products, which can create competitive advantages for companies, leading to increased customer loyalty and, consequently, higher sales and market share.

The results indicate that the mediating role of TQM in the relationship between GSCM and both Environmental Performance and Financial Performance is significant and positive. The above findings suggest that TQM can act as a mediator that strengthens the impact of GSCM on environmental and financial performance. This highlights the importance of alignment and coordination between these two approaches. It can be argued that to achieve better performance in environmental and financial domains, SMEs should simultaneously focus on both GSCM and TQM. These two approaches can act as complementary tools and create sustainable values for organizations.

### *5.1. Practical Findings*

The research presents practical recommendations to enhance organizational performance through GSCM and TQM, positively impacting environmental and financial outcomes. Companies should adopt sustainable supply chain practices by collaborating with green suppliers and providing training on eco-friendly procurement. Developing green information systems for data analysis on production and waste management is crucial for informed decision-making. Organizations should foster an innovative culture, utilizing qualitative methods like Six Sigma and Lean for process optimization. Understanding customer preferences for eco-friendly products enhances brand image. Effective TQM and GSCM implementation requires training employees in quality management and environmental standards, promoting job satisfaction and efficiency. Fostering a green culture through workshops can motivate employees to improve environmental performance. Finally, investing in research and development of sustainable technologies is essential for resource optimization and minimizing environmental impact.

## **6. Conclusion**

This study investigates the impact of GSCM on organizational performance, with a mediating role of TQM, in SMEs using a two-staged SEM-ANN approach. The results obtained from the SEM indicate that GSCM positively and significantly affects both environmental and financial performance of organizations. These findings are consistent with previous studies that have demonstrated the positive impact of green systems on performance improvements.

Considering that GSCM involves the use of sustainable resources, waste reduction, and the engagement of green suppliers, it can be concluded that this management approach leads to enhanced efficiency and cost reduction through optimized processes. Furthermore, GSCM positively influences TQM, meaning that by collaborating with suppliers and utilizing high-quality raw materials, organizations can improve their product quality.

The positive relationship between TQM and environmental and financial performance underscores the importance of standards and process optimization in reducing waste and enhancing customer satisfaction. The results also emphasize the mediating role of TQM in the influence of GSCM on environmental and financial performance. In other words, by employing appropriate quality methods, organizations can experience greater productivity, thereby impacting their financial and environmental performance. This research represents a valuable step towards clarifying and encouraging the adoption of green practices in supply chain management in Iran. It is hoped that with increased awareness and commitment to implementing these practices, more positive effects on organizational performance and the environment will be observed.

### *6.1. Limitations and Future Directions*

One of the primary limitations of questionnaire-based research is the reliance on self-reporting by participants. This can lead to biases and distortions in responses, thereby impacting the research outcomes. Qualitative research can provide deeper insights into the role of GSCM in corporate performance. This study is limited to managers, vice-presidents, and supply chain experts in SMEs in Iran. The results may vary based on industry type or company scale, necessitating further research in different sectors and larger companies. This study has addressed only certain influential factors, and other elements such as organizational culture, government policies, and market conditions may also affect the findings. Future research should consider examining these factors. Finally, the nature of the current research is correlational, and causal inferences from the findings are not justified. Moreover, future research should employ advanced fusion models like Ramezani [28] and Askari, Karami [29], machine learning like Karami et al. [5] or deep learning like Tashakkori et al. [30] techniques to investigate the intricate relationships between GSCM, TQM, and organizational performance across diverse sectors, thereby enhancing the understanding of how various contextual factors influence these dynamics.

### **Author Contributions**

Conceptualization, S.H., M.Z., S.S.R.; methodology, S.H., M.Z., S.S.R., F.S., E.H., M.B.; software, S.S.R., F.S., E.H., M.B.; validation, S.H., M.Z., S.S.R.; formal analysis, F.S., E.H., M.B.; investigation, S.H., M.Z., S.S.R.; writing—original draft preparation, S.H., M.Z., S.S.R., F.S., E.H., M.B.; visualization, F.S., E.H., M.B.; supervision, S.H., M.Z., S.S.R.

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### **Data Availability Statement**

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request

### **Conflicts of Interest**

The authors declare no conflicts of interest.

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