

Article

The Impact of Green Supply Chain Management on Organizational Sustainability in the Libyan Manufacturing Sector: The Mediating Role of Technological Innovation and Environmental Performance

Mohamed Alakrod *  and Sami Mohammad 

Department of Business Administration, Cyprus Health and Social Sciences University, Güzelyurt 99700, Turkey; sami.hatem@kstu.edu.tr

* Correspondence: mohamedalkarod1986@gmail.com

Abstract

The purpose of this study was to examine the influence of green supply chain management on organizational sustainability, where technology innovation and environmental performance are taken as mediating factors. The focus of this study was on the increasing need for better protection of the environment and the increasing demands of the sustainable development of industries, especially in developing countries, where there are limited empirical data available on sustainability activities. The collected sample comprised 387 managers and technologists from Libyan manufacturing companies using a survey instrument and a stratified random sampling technique. Validity scales were used, and the measurements were done using the five-point Likert scale. The data analysis involved the use of PLS-SEM, where SmartPLS 4.0 was used. It entailed the analysis of the measurement model as well as the structural model, with the bootstrapping being done for 5000 samples. The findings show that GSCM significantly affects the OS. Specifically, it has a positive impact on environmental performance (EP) and technological innovation (TI), which, in turn, enhance the OS. Among the mediating factors, the EP was found to be the strongest predictor and mediator of the OS, followed by TI. The developed model proved to have a high explanatory power, with a coefficient of determination (R^2) of 0.660. Thus, the integration of GSCM with innovation and environmental activities can lead to the successful achievement of sustainability objectives among manufacturing enterprises. The study's limitations are associated with its cross-sectional design and its focus on managers. Future research could employ longitudinal designs and examine other contexts, such as digital transformation, the institutional environment, and the organizational culture.

Keywords: green supply chain management (GSCM); organizational sustainability; technological innovation; environmental performance; manufacturing sector; organizational sustainability performance; sustainable development; Libya



Academic Editor: Mirco Peron

Received: 5 June 2026

Revised: 11 July 2026

Accepted: 15 July 2026

Published: 21 July 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

Environmental degradation, global warming, resource shortages, energy deficits, and increasing stakeholder demands have placed organizations, especially manufacturers, under immense pressure to embrace sustainability in their business activities over the past decade [1]. In the past, supply chain management (SCM) focused primarily on achieving efficiencies and improving productivity without considering environmental consequences,

leading to higher levels of pollution, resource depletion, waste production, and various social issues [2]. This situation has prompted a shift in thinking about the supply chain management, resulting in the need to consider the entire supply chain and adopt sustainability practices via green supply chain management (GSCM). Accordingly, GSCM can be defined as the process by which organizations incorporate sustainability considerations into their SCM processes, rather than focusing solely on organizational activities within the supply chain, as in conventional SCM [3]. According to Wai-yawuththanapoom et al., the core practices of GSCM, which include green procurement, green design, reverse logistics, and green manufacturing, not only reduce negative environmental impacts, but also enhance organizational innovation, operational efficiency, and stakeholder satisfaction [4].

However, empirical research increasingly demonstrates that GSCM has a significant influence on organizational sustainability, particularly in terms of environmental, economic, and social sustainability. For instance, Al Masri and Wimanda [5] reported that GSCM has a significant influence on organizational sustainability (OS) through various GSCM practices that enhance the environmental and economic sustainability of manufacturing companies. Similarly, Ahmad et al. [6] found that green manufacturing, green design, green purchasing, and green information technology have a significant influence on the OS in different industries. However, evidence also suggests that the implementation of GSCM remains inconsistent. For instance, cooperation with customers was found to have an insignificant influence on OS. Therefore, despite the significant influence of GSCM on OS, its implementation varies across industries and companies. For instance, according to Rahman et al. [7], environmental degradation, the inefficient use of energy, and difficulties with regulation highlight the constraints inherent in conventional supply chain structures, especially in developing nations where organizational support is relatively low. Similarly, Sahoo and Vijayvargy [8] found that the awareness of engagement in environmental sustainability practices among manufacturing firms remains low, despite growing public concern for environmental sustainability. The gap between awareness and the implementation of GSCM creates uncertainty regarding its effectiveness in improving the organizational sustainability performance.

Organizational capabilities and operational limitations pose major challenges to the implementation of GSCM. Gao et al. [9] identified several critical failure factors affecting the implementation of GSCM, such as the lack of appropriate government guidance, managerial commitment, and technical expertise, especially among small and medium-sized enterprises. These limitations reduce supply chain coordination and limit the environmental and economic benefits derived from green supply chain initiatives. Singh et al. [10] also suggested that operational limitations and the lack of integration of lean management principles reduce the effectiveness of sustainability initiatives, possibly because of the lack of coordinated strategies within organizations to achieve operational excellence and environmental sustainability. Recently, the literature has suggested that organizational sustainability is largely driven by innovation and collaborative mechanisms within the supply chain. Mahar et al. [11] demonstrated that green technological and managerial innovation within the supply chain strengthens the relationship between GSCM and the sustainability performance, especially in the manufacturing industry. Similarly, Ahmadi-Gh and Bello-Pintado [12] suggested that internal and external sustainability practices enhance the organizational performance through innovation and cooperation within the supply chain. Additionally, institutional pressure and supply chain cooperation have been identified as important drivers of GSCM implementation, as the mimetic, normative, and coercive pressures encourage organizations to adopt green supply chain initiatives to achieve environmental and operational excellence [13].

Operational excellence practices have likewise been found to play an important role in enhancing the organizational sustainability performance through the integration of GSCM. Jum'a et al. [14] found that innovation management and quality improvement practices contribute to environmental and competitive performance through green supply chains; however, misaligned government policies may create barriers to environmental commitment. Similarly, Feng et al. [15] found that the integration of GSCM improves the operational efficiency, employee satisfaction, and organizational performance through stronger environmental commitment and internal process improvement. Nevertheless, organizations continue to face additional sustainability risks that affect their performance through poor working conditions, operational disruptions, and limited supply chain transparency. Ngo et al. [16] found that supply chain risks associated with the sustainability performance may have a detrimental effect on the organizational performance if adaptive management practices are not implemented. Furthermore, technological limitations and data integration challenges remain significant barriers to the effective integration of GSCM into organizational supply chains. Mageto [17] found that the lack of effective environmental and social monitoring systems creates significant gaps in transparency and accountability, which may hinder improvements in the sustainability performance across supply chains. Although empirical studies have found that GSCM improves the organizational performance and environmental outcomes [18,19], many organizations still implement green initiatives in a fragmented and isolated manner rather than achieving the full integration of sustainability practices into their supply chains. Studies such as that of Anthuvan and Maheshwari [20] have shown the effectiveness of GSCM strategies, such as sustainable procurement, renewable energy, and waste reduction in the protection of the environment; the enhancement of employee well-being; and the promotion of local community engagement. Nazeri et al. [21] also emphasized the effectiveness of GSCM practices in enhancing organizational competitiveness and developing green products, although certain organizational factors do not have a significant moderating effect on sustainability outcomes. The literature has consistently highlighted the importance of GSCM in enhancing organizational sustainability (OS), which is facilitated by environmental, operational, innovative, and cooperative practices. Although several empirical studies have examined the GSCM-OS relationship, industrial-specific empirical investigations remain limited, especially in the context of developing countries facing environmental and economic challenges. Therefore, this study aimed to examine the GSCM-OS relationship in the Libyan manufacturing sector, with technological innovation and environmental performance as mediating variables, thereby addressing the gap in the literature, especially within developing countries facing environmental challenges.

2. Literature Review and Hypothesis Development

2.1. Green Supply Chain Management and Organizational Sustainability

Green supply chain management (GSCM) is one approach that has been developed in order to promote organizational sustainability through the incorporation of environmental factors within supply chains, involving green procurement, eco-design, green production, reverse logistics, and environmentally oriented supplier relationship management [22,23]. Apart from its regulatory role, GSCM can help companies achieve high levels of resource productivity, cut down on waste and pollution, improve stakeholder relations, and become more competitive. Altogether, from what has been found in the existing literature, GSCM helps organizations perform better environmentally, economically, and socially. Consequently, GSCM is recognized as one of the key drivers of organizational sustainability [24,25]. Furthermore, recent research indicates that the relationship between GSCM and organizational sustainability is further strengthened by organizational capabilities,

rather than by environmental practices alone. Specifically, green innovation, technological capability, organizational cooperation, and internal environmental management have been identified as critical mechanisms that enhance the sustainability outcomes generated by GSCM [26–28]. Moreover, organizational pressures, continuous improvement practices, government policy support, and supply chain collaboration have been shown to create a favorable environment for GSCM implementation and improve the sustainability performance [29,30]. Previous studies have also demonstrated that the integration of GSCM with internal organizational resources, including green human resource management (green HRM) and environmental management systems, enhances the sustainability outcomes across different industries [31–35].

However, despite the increasing number of studies, several important research gaps remain. The use of different measures of sustainability performance used in previous research has led to inconsistent findings regarding the mechanisms through which GSCM affects organizational sustainability [4]. In addition, most empirical studies have been conducted in developed or rapidly growing economies, and empirical evidence from developing countries remains limited. More specifically, the mediating role of environmental performance and technological innovation in the relationship between GSCM and organizational sustainability within the Libyan manufacturing industry remains underexplored due to the sector's unique contextual characteristics [6,11,13,14]. Therefore, this study examined the direct effect of GSCM on organizational sustainability and the indirect effects of GSCM through environmental performance and technological innovation.

H1. *GSCM has a significant positive effect on OS.*

2.2. Green Supply Chain Management and Technological Innovation

Recent evidence suggests that GSCM serves as an effective drive of technological innovations. By adopting GSCM, companies become more inclined to adopt innovative clean production technologies, digital supply chain solutions, green product design and process innovations. In addition to being an environmentally oriented practice, GSCM promotes innovation through supplier collaboration, green procurement, eco-design, reverse logistics, and advanced information technologies, thereby improving the operational efficiency and supporting achievement sustainability goals [36–38]. Moreover, the existing scientific literature suggests that digital transformation and the integration of supply chain operations serve as indispensable tools for connecting GSCM and innovation. Firms utilizing advanced digital technologies, information systems, and integrated supply chains demonstrate an improved innovation capacity, allowing for the creation of innovations in green technologies and production processes, thereby improving the environmental and organizational performance [39,40]. In addition, many studies have shown that innovations in green technologies and managerial practices are essential factors explaining the influence of GSCM on sustainable performance and competitiveness [41–43]. Blockchain and other emerging technologies are being viewed as key instruments for the implementation of GSCM, providing opportunities for innovation and transparency in supply chains [44]. Even though the empirical evidence is compelling and proves the connection between GSCM and innovations, most studies on this issue have been carried out in developed or emerging economies. Research on developing countries and especially Libya's manufacturing industry is still scarce, despite its importance for achieving technological innovation and sustainable development. In addition, little attention has been paid to technological innovation as a mediating factor in GSCM–organizational sustainability linkages. Accordingly, the following hypothesis is proposed:

H2. *GSCM has a significant positive effect on TI.*

2.3. Green Supply Chain Management and Environmental Performance

It should be mentioned that green supply chain management (GSCM) is well known as an effective strategy for achieving a better environmental performance by integrating environmental aspects into supply chain management actions such as green procurement, eco-design, green manufacturing, reverse logistics, environment-friendly logistics and collaboration with suppliers [6,22]. It can be noted that the existing research clearly shows that firms utilizing GSCM practices demonstrate a successful reduction in terms of waste generation, greenhouse gas emissions, natural resource consumption, and environmental pollution while simultaneously increasing efficiency and compliance [45–47]. Therefore, GSCM contributes to environmental performance by means of internal process improvement and external collaboration among the participants of the supply chain. The existing literature also shows that the success of the implementation of GSCM practices is based on complementary organizational and institutional capabilities. An environmental management system, top management support, supplier integration, customer collaboration and institutional pressure increase the contribution of GSCM practices to the environmental performance, whereas circular economy practices and cross-functional environmental collaboration enhance the environmental performance of the organization [29,48–53]. It should be said that, despite existing empirical evidence, there are still some gaps in this field. First of all, most studies have analyzed the relationship between GSCM and the environmental performance in developed countries or developing, but rapidly industrializing, ones. There are no data about the relationship between GSCM practices and the environmental performance of organizations in developing countries such as Libya. Second, there is insufficient research concerning the role of environmental performance as a mediator between GSCM and organizational sustainability in the manufacturing industry. Thus, in view of increasing environmental problems and the modernization of production processes in the Libyan industry, it is important to study this problem. Accordingly, the following hypothesis is proposed:

H3. *GSCM has a significant positive effect on EP.*

2.4. Technological Innovation and Organizational Sustainability

Technological innovation (TI) has been found to be a strategic capability that allows organizations to achieve sustainability through efficiency improvement, resource efficiency, environmental protection, and competitiveness [54,55]. It has been established in the existing literature that organizations adopting cleaner technologies, digitization, innovation in processes and products, and sustainable product development are highly capable of enhancing organizational sustainability [56,57]. Recent studies have further indicated that the effect of TI on organizational sustainability is enhanced through the presence of complementary organizational capabilities such as organizational innovation, digitization, innovation-friendly culture, and green operations [58–60]. Likewise, the adoption of green TI along with a circular economy, environmental governance, and sustainable operations has been found to improve the economic, environmental, and social performance of organizations and, thus, enhance organizational sustainability [61–63]. All these pieces of evidence reveal that TI serves as the main instrument for achieving organizational sustainability through the implementation of sustainability programs. Despite the growing amount of evidence, some knowledge gaps still exist. Firstly, most empirical studies have focused on developed or rapidly industrialized economies, while relatively few studies have examined developing countries, particularly the Libyan manufacturing industry. In addition, few studies have comprehensively examined the role of technological innovation in linking green supply chain management to organizational sustainability. Considering

the ongoing industrial transformation and increasing sustainability challenges in Libya, further empirical investigation is needed to clarify the role of technological innovation in promoting sustainable organizational development. Accordingly, the following hypothesis is proposed:

H4. *TI has a significant positive effect on OS.*

2.5. Environmental Performance and Organizational Sustainability

Environmental performance (EP) is viewed as a critical factor in determining organizational sustainability (OS). It refers to the ability of an organization to reduce its environmental impact and improve its operational efficiency [64,65]. Empirical evidence shows that organizations with high levels of environmental performance benefit from improved sustainability outcomes, including reduced emissions, efficient resource utilization, waste minimization, energy conservation, and compliance with environmental regulations. Thus, environmental performance has become an important organizational capability that contributes to the environmental, economic, and social dimensions of sustainability [66,67]. The literature suggests that the influence of EP on organizational sustainability is further strengthened when it is combined with complementary organizational capabilities such as environmental management systems, organizational culture, technological capabilities, quality management, and strategic environmental orientation [68–70]. When strategic environmental goals are integrated into the organizational strategy and supported by green organizational practices, organizations can achieve a superior operational performance and long-term competitiveness. Furthermore, the recent literature indicates that organizations that integrate a strong environmental performance into their sustainability and ESG initiatives outperform companies with a weaker environmental management performance [71–73], highlighting the critical role of EP in achieving organizational sustainability. Although there is strong empirical evidence supporting the relationship between environmental performance and organizational sustainability, most research in this area has been conducted in developed or rapidly industrializing economies. Limited evidence exists from developing countries, especially within the Libyan manufacturing industry. Moreover, few studies have examined environmental performance as a mediating mechanism linking green supply chain management and organizational sustainability. Considering the environmental and sustainability challenges faced by Libyan manufacturing companies, further empirical research is warranted. Accordingly, the following hypothesis is proposed:

H5. *EP has a significant positive effect on OS.*

2.6. The Mediation Role of TI and EP in the GSCM–OS Relationship

Recent studies have found that the connection between GSCM and OS is not solely direct, but is also influenced by mediating organizational capabilities, namely technological innovation (TI) and environmental performance (EP). GSCM activities, including green procurement, cleaner production, eco-design, reverse logistics, supplier collaboration, and recycling, create opportunities for technological innovation and environmental improvement, thereby enhancing organizational sustainability [74–77]. The literature indicates that organizations achieve greater sustainability benefits when green supply chain activities are implemented in combination with innovation and environmental management rather than in isolation. Furthermore, technological innovation and environmental performance serve as complementary mediating mechanisms within the GSCM–OS framework. Green technological innovation, green managerial innovation, environmental management systems, and innovation-oriented organizational capabilities enhance the effect of GSCM by improving the operational efficiency, reducing negative environment impacts, and strengthening

competitive advantages [78–80]. Furthermore, contextual factors such as digital transformation, the absorptive capacity, governmental support, and organizational learning reinforce these mediating mechanisms, thereby enabling organizations to achieve a higher level of organizational sustainability through the implementation of GSCM initiatives [74,80,81]. Although many previous studies have demonstrated the mediating role of TI and EP, most empirical studies have been conducted in developed or rapidly industrialized economies. Empirical evidence from developing countries, particularly the Libyan manufacturing industry, remains limited, even though institutional conditions, technological capabilities, and environment factors may influence the effectiveness of GSCM implementation. Furthermore, few studies have simultaneously examined the mediating role of TI and EP within a single theoretical framework explaining how GSCM enhances organizational sustainability. Therefore, this study examines the joint mediating effects of TI and EP on the relationship between GSCM and organizational sustainability. Accordingly, the following hypotheses are proposed:

H6. *TI significantly mediates the relationship between GSCM and OS.*

H7. *EP significantly mediates the relationship between GSCM and OS.*

3. Study Model

The proposed study model illustrates that GSCM directly enhances organizational sustainability (OS), and indirectly influences it by increasing technological innovation (TI) and environmental performance (EP), both of which positively contribute to organizational sustainability outcomes (Figure 1).

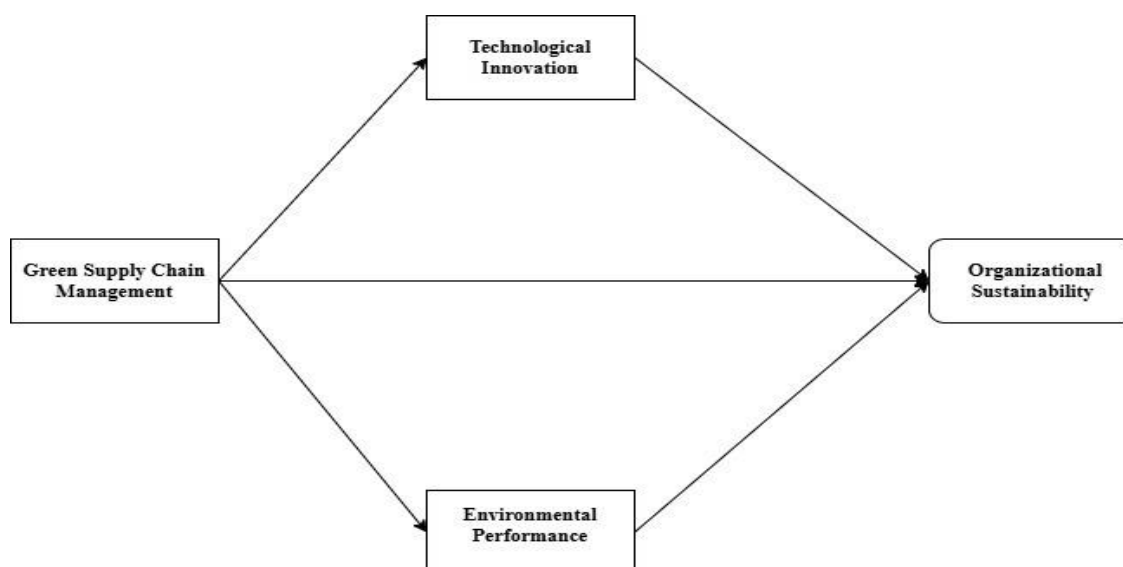


Figure 1. The conceptual framework.

4. Methods

This study adopted a quantitative research design to determine the impact of GSCM on OS in Libyan manufacturing companies while considering the mediating effects of TI and EP. To test the statistical significance of the proposed conceptual model and enable the generalization of the findings to the target population, a cross-sectional survey was conducted. The target population comprised managers, production supervisors, supply chain managers, environmental and quality managers, engineers, and strategic planning professionals working in Libyan manufacturing companies. This is because of the fact that

these people have an understanding of the operations related to supply chain management, environment management, technology innovations, and sustainable practices, making them suitable for the evaluation of the constructs in the study. It is estimated that there are about 400,000 to 575,000 employees working in the manufacturing industry in Libya, and the sampling frame consisted of professionals in the managerial and technical categories among these employees. The sampling frame comprised manufacturing firms that are registered under the Ministry of Industry and Minerals and also under the Chambers of Commerce of Libya. Manufacturing firms from the food and beverage, textile, electronics, chemical, building material, and automobile manufacturing industries were used in order to provide diversity in terms of the industrial sectors. A stratified random sampling technique was used in order to ensure the heterogeneity of the industrial, organizational, and managerial aspects in the sampling frame.

The required sample size was determined using the sample size determination table provided by Krejcie and Morgan [82]. The data were collected through the use of structured questionnaires that were sent out to the companies during April and May 2026, both electronically and on paper. A total of 450 questionnaires were distributed to the companies involved in the research, and 401 were returned. After data screening, 387 questionnaires were included in the analysis. Thus, the response rate of the study was 86.0%. The research followed all ethical standards of the research process. Before the data collection, the participants were made aware of the objectives of the study and their rights, as well as guarantees that all personal information would remain confidential.

There were five parts in the survey tool: (A) demographic data, (B) green supply chain management (GSCM), (C) technological innovation (TI), (D) environmental performance (EP), and (E) organizational sustainability (OS). The dependent variable in this research was GSCM, which was measured by seven questions from Bag et al. [38]. TI was measured by three questions derived from Liu and Cui [83]. Seven questions adopted from Haldorai et al. [84] and six questions adopted from Mollah et al. [85] were used to measure EP and OS, respectively. All the questions in this study used a five-point Likert Scale from 1 (strongly disagree) to 5 (strongly agree). Partial least-squares structural equation modeling (PLS-SEM) was used in SmartPLS 4.0 for the data analysis. PLS-SEM was chosen because of its compatibility with complex models having multiple mediating effects and low demands on multivariate normality. The process of analysis was done in two steps. First of all, the measurement model was analyzed for its reliability, convergent validity, discriminant validity, and multicollinearity. After that, the structural model was checked for its direct and indirect effects between different constructs. Bootstrapping was done by taking 5000 resamples for the significance of the proposed paths. Descriptive statistics were calculated to have the basic information about the respondents.

5. Results

The demographic characteristics of the 387 respondents from the Libyan manufacturing sector are presented in Table 1 below. It is evident that the sample population was diversified and represented a representative distribution in relation to gender, age group, educational qualification, managerial position, work experience, type of industry, and organization size. The male respondents represented 59.9% of the total respondents, whereas the female respondents represented 40.1%. This reflects the dominance of male employees in the manufacturing sector, but at the same time, there is a significant presence of females in professional and managerial levels. As far as the age is concerned, most of the respondents were 30–39 years old (35.7%), followed by the age groups 40–49 years (26.4%) and 20–29 years (24.8%), and 13.2% of the respondents were above 50 years. This reflects that the sample population consisted mainly of experienced and professionally

active people who can be considered appropriate to study the issues related to supply chain management, innovation, and sustainability. As far as educational qualifications are concerned, the respondents were well-educated professionals. For instance, 48.6% of the respondents had a bachelor's degree, 25.3% had a master's degree, 5.9% had a Ph.D. degree, and 20.2% had a diploma or technical qualification. With regard to the work experience of the respondents, the sample comprised professionals with considerable work experience, as 31.5% had 5–10 years of experience whereas 25.3% had 11–15 years of experience. With regard to the organizational tenure of the respondents, the sample comprised professionals with moderate organizational tenure, as 37.7% had worked in their organizations for 3–7 years. With regard to the industry types, the sample comprised professionals from diverse industries, as the food and beverage industry accounted for 27.4% whereas the textile industry accounted for 18.6%, the construction material industry accounted for 15%, the electronics industry accounted for 14%, the chemical industry accounted for 12.7%, and the automotive industry accounted for 12.4%. With regard to the organizational size, the sample comprised professionals from organizations of varying sizes.

Table 1. Demographic profile of the respondents.

Variable	Category	Frequency (N)	Percentage (%)
1. Gender	Male	232	59.9
	Female	155	40.1
2. Age Group	20–29 years	96	24.8
	30–39 years	138	35.7
	40–49 years	102	26.4
	50 years and above	51	13.2
3. Educational Qualification	Diploma/technical certification	78	20.2
	Bachelor's degree	188	48.6
	Master's degree	98	25.3
	Doctorate (Ph.D.)	23	5.9
4. Position/Job Title	Top management (CEO/director/GM)	42	10.9
	Middle management (manager/supervisor)	156	40.3
	Operational staff/specialist	189	48.8
5. Years of Work Experience	Fewer than 5 years	84	21.7
	5–10 years	122	31.5
	11–15 years	98	25.3
	More than 15 years	83	21.4
6. Years with Current Organization	Fewer than 3 years	112	28.9
	3–7 years	146	37.7
	8–12 years	78	20.2
	More than 12 years	51	13.2

Table 1. Cont.

Variable	Category	Frequency (N)	Percentage (%)
7. Type of Manufacturing Industry	Automotive	48	12.4
	Food and beverages	106	27.4
	Textiles and apparel	72	18.6
	Electronics/electrical	54	14.0
	Chemicals/petrochemicals	49	12.7
	Construction materials	58	15.0
8. Size of Organization (Employees)	Fewer than 50 (small)	64	16.5
	50–249 (medium)	143	36.9
	250–999 (large)	111	28.7
	1000 and above (very large)	69	17.8

5.1. Descriptive Statistics

Descriptive statistics for the variables measuring green supply chain management (GSCM), technological innovation (TI), environmental performance (EP), and organizational sustainability (OS) are provided in Table 2. Each of the constructs was measured using a five-point Likert scale, where 1 represented “strongly disagree” and 5 represented “strongly agree”. Mean values ranging between 2.842 and 3.171 indicated that the respondents tended to agree with the survey items, suggesting that Libyan manufacturing companies moderately implement green supply chain management and sustainability practices. The minimum and maximum values ranged from 1.000 to 5.000, indicating full utilization of the response scale and sufficient variability across all measurement items. The standard deviations ranged from 1.141 to 1.291, indicating adequate dispersion in the responses and significant variation in the respondents’ perceptions of GSCM, TI, EP, and OS. Furthermore, the skewness values varied, ranging from -0.073 to 0.214 , and the kurtosis ranged from -1.096 to -0.722 . All of them lie within the acceptable range of ± 2.00 [86], meaning that there is no significant deviation from normality in the data. In general, descriptive statistics demonstrated an adequate variability, well-balanced answers and an adequate univariate normality, which makes it possible to conduct further analyses using the method of PLS-SEM.

5.2. Reliability Analysis

The findings on the reliability and convergent validity of the research constructs based on Cronbach’s alpha, the composite reliability (ρ_A , ρ_C) and the average variance extracted (AVE) are presented in Table 3. It is clear from the results that all constructs in this study met the measurement standards. Cronbach’s alpha values ranged from 0.779 to 0.910, exceeding the recommended minimum value of 0.70 and indicating an adequate internal consistency reliability. Likewise, the composite reliability values ranged from 0.872 to 0.929, indicating a high construct reliability while remaining below the recommended upper limit of 0.95, suggesting that the constructs are reliable without being redundant. Convergent validity was also confirmed, since all the AVE values ranged from 0.608 to 0.694, exceeding the recommended minimum threshold of 0.50. This indicates that each construct explains more than 50% of the variance in its indicators. Among the constructs, green supply chain management (GSCM) demonstrated the highest reliability, while technological innovation (TI) exhibited the highest AVE value.

Table 2. Descriptive statistics.

	Mean	Observed Min	Observed Max	Standard Deviation	Excess Kurtosis	Skewness
EP_1	3.000	1.000	5.000	1.194	−0.939	−0.027
EP_2	2.984	1.000	5.000	1.218	−0.925	0.038
EP_3	3.034	1.000	5.000	1.162	−0.830	−0.006
EP_4	3.013	1.000	5.000	1.195	−0.856	0.057
EP_5	3.018	1.000	5.000	1.162	−0.795	0.004
EP_6	2.889	1.000	5.000	1.141	−0.726	0.135
EP_7	3.078	1.000	5.000	1.211	−0.851	0.000
GSCM_1	2.915	1.000	5.000	1.175	−0.722	0.214
GSCM_2	2.930	1.000	5.000	1.255	−1.026	0.006
GSCM_3	2.842	1.000	5.000	1.170	−0.883	0.037
GSCM_4	3.106	1.000	5.000	1.162	−0.833	−0.009
GSCM_5	2.974	1.000	5.000	1.261	−1.008	0.041
GSCM_6	3.021	1.000	5.000	1.222	−0.978	−0.031
GSCM_7	3.031	1.000	5.000	1.207	−0.905	−0.042
OS_1	2.941	1.000	5.000	1.203	−0.931	0.115
OS_2	2.974	1.000	5.000	1.163	−0.800	0.031
OS_3	3.171	1.000	5.000	1.160	−0.861	−0.027
OS_4	2.951	1.000	5.000	1.201	−0.878	0.104
OS_5	2.961	1.000	5.000	1.166	−0.841	0.134
OS_6	3.145	1.000	5.000	1.164	−0.826	−0.047
TI_1	2.964	1.000	5.000	1.222	−0.904	0.052
TI_2	3.078	1.000	5.000	1.228	−0.877	−0.073
TI_3	3.062	1.000	5.000	1.291	−1.096	−0.036

Table 3. Reliability.

	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
EP_	0.892	0.896	0.916	0.608
GSCM	0.910	0.913	0.929	0.651
OS	0.880	0.883	0.909	0.626
TI	0.779	0.780	0.872	0.694

5.3. Variance Inflation Factor

Table 4 presents the VIF values used to assess possible multicollinearity among the measurement indicators before evaluating the structural model. The observed VIF values, which ranged from 1.564 to 2.446, were well below the recommended maximum thresholds of 3.30 [86] and 5.00 [87]. Specifically, the VIF values ranged from 1.618 to 2.298 for EP, 1.873 to 2.446 for GSCM, 1.675 to 2.138 for OS, and 1.564 to 1.684 for TI. The highest VIF value was observed for GSCM-3 (2.446), while the lowest was recorded for TI-3 (1.564). Although some GSCM indicators exhibited relatively higher VIF values than others, all

values remained well within the acceptable threshold, indicating moderate correlation among the indicators without evidence of redundancy. Accordingly, the measurement model satisfies the multicollinearity assumption required for a PLS-SEM analysis. Therefore, these findings suggest that the measurement indicators are sufficiently independent and do not exhibit multicollinearity. Accordingly, the measurement model satisfies the multicollinearity assumption required for a PLS-SEM analysis.

Table 4. Variance inflation factor.

	VIF
EP_1	2.298
EP_2	1.743
EP_3	1.618
EP_4	2.047
EP_5	2.015
EP_6	2.144
EP_7	1.890
GSCM_1	1.873
GSCM_2	2.413
GSCM_3	2.446
GSCM_4	2.181
GSCM_5	2.305
GSCM_6	2.189
GSCM_7	1.929
OS_1	2.138
OS_2	1.956
OS_3	1.675
OS_4	1.937
OS_5	1.975
OS_6	1.921
TI_1	1.602
TI_2	1.684
TI_3	1.564

5.4. Correlation Matrix

Table 5 summarizes the Pearson correlation coefficients between GSCM, EP, TI, and OS. According to the findings presented, all four constructs are positively correlated, providing initial evidence that improvements in one construct are associated with improvements in the other constructs. More specifically, GSCM exhibited moderate to high positive correlations with EP ($r = 0.620$), TI ($r = 0.679$), and OS ($r = 0.699$), indicating that the implementation of green supply chain management practices is strongly related to an improved environmental performance, technological innovations, and organizational sustainability. In addition, EP was positively correlated with OS ($r = 0.725$) and TI ($r = 0.472$), while TI was also positively correlated with OS ($r = 0.611$). More importantly, none of the correlations exceeded the threshold of 0.90, as recommended by Hair et al. [86], indicating that there was no issue of multicollinearity among the variables at the construct level.

Table 5. Correlation matrix.

	EP_	GSCM	OS	TI
EP_				
GSCM	0.620			
OS	0.725	0.699		
TI	0.472	0.679	0.611	

5.5. Variance Testing

Table 6 shows the coefficient of determination (R^2) and the adjusted R^2 values of the endogenous constructs. It is evident from the results that GSCM explained 31.7% of the variance in EP ($R^2 = 0.317$) and 32.7% of the variance in TI ($R^2 = 0.327$), indicating an adequate predictive power for both mediating constructs. Importantly, OS had an R^2 value of 0.541, which means that 54.1% of its variance was jointly explained by GSCM, EP, and TI. This is consistent with the criteria established by Hair et al. [86] for moderate predictive validity, thus supporting the model's high explanatory capacity. The slight difference between the R^2 and adjusted R^2 values indicates the stability of the model and the absence of overfitting. Overall, these findings indicate that the proposed structural model has sufficient predictive power to serve as a framework for testing the proposed hypotheses.

Table 6. R-square.

	R-Square	R-Square Adjusted
EP_	0.317	0.315
OS	0.541	0.537
TI	0.327	0.325

5.6. Hypothesis Testing

The results from the structural model and hypotheses testing using the PLS-SEM method with a bootstrapping procedure consisting of 5000 resamples are presented in Table 7. These results provide strong empirical evidence to support all the hypotheses proposed in the study, implying the presence of significant direct and indirect relationships among GSCM, environmental performance (EP), technological innovation (TI), and organizational sustainability (OS). Specifically, GSCM was found to be a significant contributor to the improving environmental performance ($\beta = 0.623$, $p < 0.001$) and technological innovation ($\beta = 0.678$, $p < 0.001$), indicating that the implementation of green supply chain management practices improves the environmental performance and fosters technological innovation in Libyan manufacturing companies. In addition, both environmental performance ($\beta = 0.454$, $p < 0.001$) and technological innovation ($\beta = 0.207$, $p = 0.002$) significantly affected the organizational sustainability. The result further suggests that EP and TI are critical variables in improving the organizational sustainability. GSCM was also found to have a significant direct effect on OS ($\beta = 0.279$, $p < 0.001$), demonstrating the importance of GSCM not only as a direct predictor, but also through its mediating mechanisms. The mediation analysis revealed that both environmental performance ($\beta = 0.283$, $p < 0.001$) and technological innovation ($\beta = 0.141$, $p = 0.002$) significantly mediate the relationship between GSCM and organizational sustainability, with environmental performance exhibiting a stronger indirect effect on OS.

Table 7. Hypothesis testing.

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	p Values
EP_ -> OS	0.454	0.456	0.050	9.120	0.000
GSCM -> EP_	0.623	0.624	0.038	16.559	0.000
GSCM -> OS	0.279	0.279	0.075	3.705	0.000
GSCM -> TI	0.678	0.679	0.038	17.760	0.000
TI -> OS	0.207	0.207	0.066	3.134	0.002
GSCM -> EP_ -> OS	0.283	0.284	0.036	7.864	0.000
GSCM -> TI -> OS	0.141	0.140	0.046	3.028	0.002

6. Structural Model

This structural model in Figure 2 clearly demonstrates that GSCM has a strong influence on TI and EP, which in turn have a positive influence on OS. The R^2 statistics clearly show that the model has a substantial explanatory power, especially with respect to organizational sustainability.

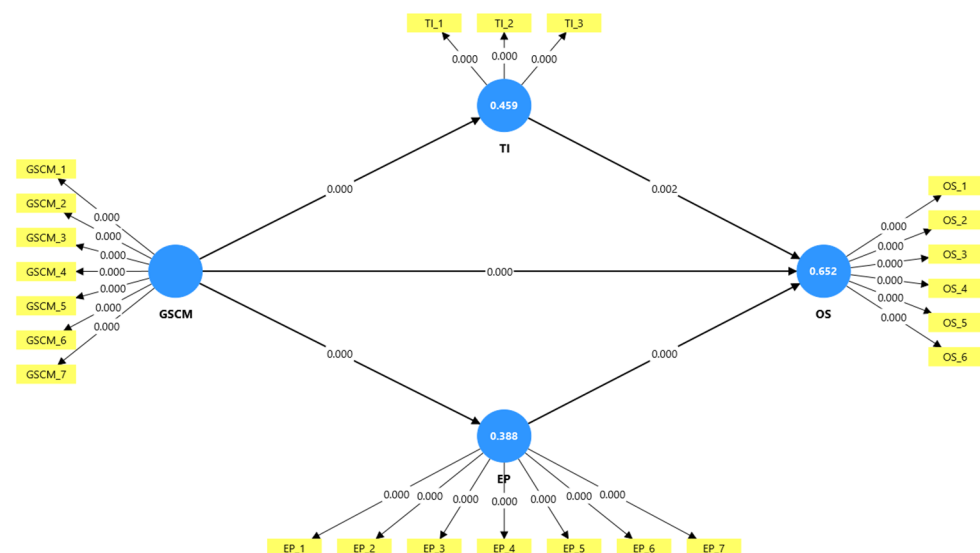


Figure 2. PLS-SEM study model.

7. Discussion

The impact of GSCM on OS among Libyan manufacturers was studied by considering the mediating effects of environmental performance (EP) and technological innovation (TI). The results from this study provide strong evidence to support the suggested theoretical model, in which GSCM positively impacts OS in both direct and indirect ways. In this regard, it is important to note that the structural model explains 54.1% of the variability in OS ($R^2 = 0.541$). This means that GSCM, environmental performance (EP), and technological innovation (TI) are key factors influencing the sustainability of the organizational performance among manufacturing organizations in Libya. The research findings are consistent with the NRVB theory, which suggests that innovation and environmental capability play important roles as organizational resources that confer a sustainable competitive advantage through the effective use of organizational resources. The results show that the GSCM construct has a significantly strong positive direct influence on organizational sustainability

($\beta = 0.279, p < 0.001$). The above result indicates that companies engaging in environmental responsibility practices within their supply chains are likely to achieve sustainability performance across economic, environmental, and social dimensions. This implies that activities such as green procurement, collaboration with suppliers, eco-production, waste minimization, and resource-based logistics practices should be viewed as business capabilities rather than merely environmental responsibility activities. The results are consistent with recent research conducted by Al Masri and Wimanda [5], which established that the full implementation of GSCM practices is associated with significant improvements in the triple-bottom-line performance. Similarly, research by Waiyawuththanapoom et al. [4] showed that the comprehensive integration of activities including green procurement, eco-design, reverse logistics, and green manufacturing is associated with an increased efficiency, innovation and competitiveness. One of the most important findings of the current study is that green supply chain management (GSCM) has an extremely significant positive effect on environmental performance ($\beta = 0.623, p < 0.001$). This implies that companies engaging in green supply chain activities are able to achieve substantial improvements in terms of pollution prevention, waste management, energy efficiency, and compliance with relevant regulations. The finding is supported by the results obtained by Ahmad et al. [6], who found that green manufacturing, green procurement, eco-design, and green information systems had a significant impact on environmental performance. Moreover, according to Nazeri et al. [21], green activities performed internally are crucial for obtaining positive environmental performance outcomes, and Waiyawuththanapoom et al. [4] concluded that green supply chain activities lead to a reduction in the environmental impact and an improvement in efficiency. In the case of Libya, it seems that environmental performance improvements are the main result of green supply chains. Another significant conclusion drawn from the findings is the powerful impact of GSCM on technological innovation ($\beta = 0.678, p < 0.001$), which is the most robust relationship among those revealed in the conceptual model. It means that environment-related supply chain management stimulates companies to use clean production technologies and innovative manufacturing methods and tools. The findings correspond to the conclusions made by Mahar et al. [11] that green technological and managerial innovations increase the positive effect of GSCM on sustainable performance. Moreover, according to Bag et al. [38] and Liu and Cui [83], the environmentally sound supply chain management practices contribute to the development of innovative technologies that are efficient and environmentally friendly. It is especially relevant for Libyan manufacturing companies that are at a stage of modernizing their old production facilities. Therefore, GSCM becomes the catalyst of technological innovations and enables the achievement of environmental and economic goals at once.

Environmental performance showed a strong influence on organizational sustainability ($\beta = 0.454, p < 0.001$) and may be considered the major direct determinant of organizational sustainability in the model under study. In other words, a better environmental performance leads not only to organizational benefits, but also to some other advantages, such as an improved efficiency, better resource management, increased stakeholder trust and organizational legitimacy. It supports the conclusion reached by Nazeri et al. [21], who found that improvements in environmental performance contribute to the sustainable development of organizations. Al Masri and Wimanda [5] are of the same opinion and argue that organizations with a better environmental performance have higher levels of sustainable development in all three dimensions—economic, environmental and social. Overall, these results are compatible with the assumptions of NRBV theory and show how environmental capabilities can act as strategic resources providing a sustainable competitive advantage. Despite its relatively weak impact on organizational sustainability ($\beta = 0.207, p = 0.002$), technological innovation still plays a statistically significant and meaningful role.

Namely, the use of environmentally friendly technologies, the digitalization of production processes and innovation make organizations sustainable through improved productivity and flexibility. These conclusions are consistent with the findings of Mahar et al. [11], who found that technological innovation contributes to the improvement of the sustainable performance together with GSCM practices. Liu and Cui [83] added that technological capability makes it possible for organizations to achieve a higher efficiency and respond to changes in the environment. Thus, technological upgrades will play an increasingly important role as one of the drivers of sustainable industrial development in Libya. The findings of the mediation analysis shed more light on the mechanisms behind the influence of GSCM on organizational sustainability. In particular, the environmental performance acts as a mediator between GSCM and organizational sustainability ($\beta = 0.283, p < 0.001$), whereas technological innovation is a mediator as well ($\beta = 0.141, p = 0.002$). A better mediating role of environmental performance means that the considerable part of sustainability gains made by GSCM practices can be explained by an improved environmental performance. These findings are in line with Mahar et al. [11]'s assertion that green innovation partly mediates the relationship between GSCM and the sustainable performance and with Nazeri et al. [21]'s findings showing that green management increases sustainability through the environmental performance. Additionally, Waiyawuththanapoom et al. [4] found that the highest sustainability gains are achieved through the combination of environmental management and innovation capabilities in GSCM. The study adds to the growing body of research on sustainable supply chain management by providing evidence from the Libyan manufacturing industry, which has been largely unexplored to date. The study findings indicate that the adoption of green supply chain management serves as a strategic capability for organizations, positively influencing the organizational sustainability both directly and indirectly through the environmental performance and technological innovation. Therefore, manufacturing companies need to adopt green purchasing practices, enhance their environmental performance through cleaner technologies, strengthen environmental collaboration with suppliers, implement environmental management practices, and promote technological innovation within their organizational strategies.

8. Theoretical and Practical Implications

These theoretical and empirical contributions made by this study to the body of knowledge on green supply chain management (GSCM) and organizational sustainability are relevant and significant, especially given their applicability in developing nations. First, from a theoretical point of view, the research findings expand the scope of the Natural Resource-Based View (NRBV) by confirming the direct and indirect relationships between the environmental performance (EP) and technological innovation (TI) and organizational sustainability. The results of this study demonstrate that organizations become sustainable not only as a result of implementing green supply chain management, but also through the development of additional organizational capabilities that positively affect their environmental performance and promote innovation. Second, from an empirical perspective, this research contributes to the literature on sustainability by providing evidence from one of the developing economies, Libya, and offering empirical data on its manufacturing industry, which remains largely underexplored in sustainability research.

In terms of practical implications, a number of recommendations can be made to manufacturing organizations, policymakers, and industry stakeholders. Manufacturing organizations are advised to adopt GSCM as a strategic approach, involving green procurement, the selection of environment-friendly suppliers, eco-design, cleaner production, waste reduction, reverse logistics and resource-efficient practices. Additionally, manufacturing organizations are encouraged to increase their investments in cleaner technologies,

digital manufacturing, automation, and environmental monitoring systems. The green competencies of employees need to be enhanced through training and capacity-building programs. As the environmental performance proved to be the most important predictor of organizational sustainability, organizations were also encouraged to introduce environmental performance metrics, perform environmental audits, and adopt internationally recognized environmental management systems such as ISO 14001 [88]. The government of Libya should support GSCM implementation through the introduction of financial incentives and green investments initiatives, the establishment of favorable environmental regulations, and the promotion of cooperation among industry, universities, and research organizations. Industry associations are advised to share the information on the best practices adopted by green manufacturing companies.

9. Conclusions and Future Research

In this research, the impact of GSCM on organizational sustainability (OS) in the Libyan manufacturing industry was examined, with an emphasis on the mediating effects of environmental performance (EP) and technological innovation (TI). Based on the data gathered from 387 managers and engineers using partial least-squares structural equation modeling (PLS-SEM), the empirical evidence shows strong support for the conceptual model developed. It was found out that GSCM positively impacts organizational sustainability, either directly or indirectly through an environmental performance (EP) and technological innovation (TI). In terms of a mediating effect, EP had the strongest effect, which means that a better EP is the dominant mediator in relation to GSCM and organizational sustainability. Overall, the structural model was able to explain up to 54.1% of the organizational sustainability variance.

The results of the study can be linked to the theoretical concepts of NRBV framework, since, according to it, green supply chain management (GSCM) practices, environmental capabilities, and innovation serve as strategic resources that help firms maintain competitiveness and sustainability. From an empirical standpoint, the study makes a valuable contribution to the literature on sustainability because it provides fresh evidence based on the manufacturing organizations of Libya that are still insufficiently explored in the context of developing economies. In practical terms, the study shows that manufacturing companies should incorporate GSCM into their strategic management processes through such practices as green purchasing, green production, collaboration with suppliers, waste minimization, environmental performance measurement, and investment in clean technologies. Having taken into account the contributions of the study, some limitations can be outlined as directions for future research. Firstly, longitudinal research is necessary to evaluate the sustainability performance of companies over time. Secondly, the inclusion of more supply chain participants (such as suppliers and customers) as well as other mediating or moderating variables (such as digitalization, organizational culture, institutional pressures, circular economy, and environmental governance) would be useful. Thirdly, comparative research conducted in different industries and developing countries would provide additional information about how GSCM helped with the sustainable development of the industry.

Author Contributions: Conceptualization, M.A.; Methodology, M.A.; Software, M.A.; Validation, M.A.; Investigation, S.M.; Resources, M.A.; Data curation, M.A.; Writing—original draft, M.A.; Visualization, S.M.; Supervision, S.M.; Project administration, S.M.; Funding acquisition, S.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Scientific Research Ethics Committee of Cyprus Health and Social Sciences University (Project No. KSTU/2025/085, date of approval 2 April 2026).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Lisniak, B.A. Global Environmental Problems and Their Impact on International Business. Bachelor's Thesis, Sumy State University, Sumy, Ukraine, 2024.
2. Nweje, U.; Taiwo, M. Supply chain management: Balancing efficiency and environmental responsibility. *World J. Adv. Res. Rev.* **2025**, *25*, 1547–1564. [\[CrossRef\]](#)
3. Le, T.T.; Vo, X.V.; Venkatesh, V.G. Role of green innovation and supply chain management in driving sustainable corporate performance. *J. Clean. Prod.* **2022**, *374*, 133875. [\[CrossRef\]](#)
4. Waiyawuththanapoom, P.; Aunyawong, W.; Muedkhuntod, S.; Legino, R. A Conceptual Review of Green Supply Chain Management Practices and their Impact on Organizational, Environmental, and Economic Performance. *J. Adv. Res. Bus. Manag. Stud.* **2025**, *39*, 53–60. [\[CrossRef\]](#)
5. Al Masri, R.; Wimanda, E. The role of green supply chain management in corporate sustainability performance. *J. Energy Environ. Policy Options* **2024**, *7*, 1–9.
6. Ahmad, A.; Ikram, A.; Rehan, M.F.; Ahmad, A. Going green: Impact of green supply chain management practices on sustainability performance. *Front. Psychol.* **2022**, *13*, 973676. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Rahman, T.; Ali, S.M.; Moktadir, M.A.; Kusi-Sarpong, S. Evaluating barriers to implementing green supply chain management: An example from an emerging economy. *Prod. Plan. Control* **2020**, *31*, 673–698.
8. Sahoo, S.; Vijayvargy, L. Green supply chain management practices and its impact on organizational performance: Evidence from Indian manufacturers. *J. Manuf. Technol. Manag.* **2021**, *32*, 862–886. [\[CrossRef\]](#)
9. Gao, S.; Lim, M.K.; Qiao, R.; Shen, C.; Li, C.; Xia, L. Identifying critical failure factors of green supply chain management in China's SMEs with a hierarchical cause–effect model. *Environ. Dev. Sustain.* **2022**, *24*, 5641–5666.
10. Singh, J.; Singh, H.; Kumar, A. Impact of lean practices on organizational sustainability through green supply chain management—An empirical investigation. *Int. J. Lean Six Sigma* **2020**, *11*, 1035–1068. [\[CrossRef\]](#)
11. Mahar, A.S.; Zhang, Y.; Sadiq, B.; Gul, R.F. Sustainability transformation through green supply chain management practices and green innovations in Pakistan's manufacturing and service industries. *Sustainability* **2025**, *17*, 2204. [\[CrossRef\]](#)
12. Ahmadi-Gh, Z.; Bello-Pintado, A. The effect of sustainability on new product development in manufacturing—Internal and external practices. *Adm. Sci.* **2021**, *11*, 115. [\[CrossRef\]](#)
13. Samad, S.; Nilashi, M.; Almulihi, A.; Alrizq, M.; Alghamdi, A.; Mohd, S.; Ahmadi, H.; Azhar, S.N.F.S. Green Supply Chain Management practices and impact on firm performance: The moderating effect of collaborative capability. *Technol. Soc.* **2021**, *67*, 101766. [\[CrossRef\]](#)
14. Jum'a, L.; Alkalha, Z.; Alaraj, M. Towards environmental sustainability: The nexus between green supply chain management, total quality management, and environmental management practices. *Int. J. Qual. Reliab. Manag.* **2024**, *41*, 1209–1234. [\[CrossRef\]](#)
15. Feng, T.; Qamruzzaman, M.; Sharmin, S.S.; Karim, S. Bridging environmental sustainability and organizational performance: The role of green supply chain management in the manufacturing industry. *Sustainability* **2024**, *16*, 5918. [\[CrossRef\]](#)
16. Ngo, V.M.; Quang, H.T.; Hoang, T.G.; Binh, A.D.T. Sustainability-related supply chain risks and supply chain performances: The moderating effects of dynamic supply chain management practices. *Bus. Strategy Environ.* **2024**, *33*, 839–857.
17. Mageto, J. Big data analytics in sustainable supply chain management: A focus on manufacturing supply chains. *Sustainability* **2021**, *13*, 7101. [\[CrossRef\]](#)
18. Khanal, G.; Shrestha, R.; Devkota, N.; Sakhakarmy, M.; Mahato, S.; Paudel, U.R.; Acharya, Y.; Khanal, C.K. An investigation of green supply chain management practices on organizational performance using multivariate statistical analysis. *Supply Chain Anal.* **2023**, *3*, 100034. [\[CrossRef\]](#)
19. Al-Awamleh, H.K.; Alhalalmeh, M.I.; Alatyat, Z.A.; Saraireh, S.; Akour, I.; Alneimat, S.; Alathamneh, F.F.; Abu-Farha, Y.S.; Al-Hawary, S.I.S. The effect of green supply chain on sustainability: Evidence from the pharmaceutical industry. *Uncertain Supply Chain Manag.* **2022**, *10*, 1261–1270. [\[CrossRef\]](#)
20. Anthuvan, T.; Maheshwari, K. Green Inside, Silent Outside? The Sustainability Branding Dilemma in Indian Pharma. *SSRN* **2025**, in preprint.

21. Nazeri, A.; Gholami, S.; Safaie, N. The effect of internal and external practices of green supply chain management on performance and competitiveness of a company. *Eur. J. Int. Manag.* **2024**, *22*, 439–483. [\[CrossRef\]](#)
22. Wiredu, J.; Yang, Q.; Sampene, A.K.; Gyamfi, B.A.; Asongu, S.A. The effect of green supply chain management practices on corporate environmental performance: Does supply chain competitive advantage matter? *Bus. Strategy Environ.* **2024**, *33*, 2578–2599.
23. Bu, X.; Dang, W.V.; Wang, J.; Liu, Q. Environmental orientation, green supply chain management, and firm performance: Empirical evidence from Chinese small and medium-sized enterprises. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1199. [\[CrossRef\]](#) [\[PubMed\]](#)
24. Wilhelm, M.; Villena, V.H. Cascading sustainability in multi-tier supply chains: When do Chinese suppliers adopt sustainable procurement? *Prod. Oper. Manag.* **2021**, *30*, 4198–4218. [\[CrossRef\]](#)
25. Ahmadi-Gh, Z.; Bello-Pintado, A. Why is manufacturing not more sustainable? The effects of different sustainability practices on sustainability outcomes and competitive advantage. *J. Clean. Prod.* **2022**, *337*, 130392. [\[CrossRef\]](#)
26. Nasir, A.; Zakaria, N.; Do, N.; Velasquez, S. The impact of knowledge management on sustainable performance with mediation effect of green innovation in Malaysian SMEs. *VINE J. Inf. Knowl. Manag. Syst.* **2024**, *56*, 1149–1170. [\[CrossRef\]](#)
27. Sun, Y.; Sun, H. Green innovation strategy and ambidextrous green innovation: The mediating effects of green supply chain integration. *Sustainability* **2021**, *13*, 4876. [\[CrossRef\]](#)
28. Anjum, N.A.; Shahid, Z.A.; Mubarik, M.S.; Mazhar, U. Role of green innovation and sustainable supply chain management in firm internationalization. *Rev. Int. Bus. Strategy* **2024**, *34*, 292–310. [\[CrossRef\]](#)
29. Kalyar, M.N.; Shoukat, A.; Shafique, I. Enhancing firms' environmental performance and financial performance through green supply chain management practices and institutional pressures. *Sustain. Account. Manag. Policy J.* **2020**, *11*, 451–476.
30. Hariyadi, E.; Wong, W.K.; Negash, Y.T. Sustainable supply chain collaboration in construction and demolition waste management: Green innovation for sustainability performance. *J. Mater. Cycles Waste Manag.* **2025**, *27*, 3335–3351. [\[CrossRef\]](#)
31. Raffay, A. Evaluating the Impact of Green HRM on Environmental Sustainability (ES) Directly and Indirectly Through Internal and External SCM in SMEs of Punjab. Ph.D. Thesis, Superior University, Lahore, Pakistan, 2025.
32. Hofman, P.S.; Blome, C.; Schleper, M.C.; Subramanian, N. Supply chain collaboration and eco-innovations: An institutional perspective from China. *Bus. Strategy Environ.* **2020**, *29*, 2734–2754. [\[CrossRef\]](#)
33. Letunovska, N.; Offei, F.A.; Junior, P.A.; Lyulyov, O.; Pimonenko, T.; Kwilinski, A. Green supply chain management: The effect of procurement sustainability on reverse logistics. *Logistics* **2023**, *7*, 47. [\[CrossRef\]](#)
34. Alkaraan, F.; Elmarzouky, M.; de Sousa Jabbour, A.B.L.; Jabbour, C.J.C.; Gulko, N. Maximising sustainable performance: Integrating servitisation innovation into green sustainable supply chain management under the influence of governance and Industry 4.0. *J. Bus. Res.* **2025**, *186*, 115029. [\[CrossRef\]](#)
35. Afum, E.; Osei-Ahenkan, V.Y.; Agyabeng-Mensah, Y.; Amponsah Owusu, J.; Kusi, L.Y.; Ankomah, J. Green manufacturing practices and sustainable performance among Ghanaian manufacturing SMEs: The explanatory link of green supply chain integration. *Manag. Environ. Qual. Int. J.* **2020**, *31*, 1457–1475. [\[CrossRef\]](#)
36. Khan, M.T.; Idrees, M.D.; Rauf, M.; Sami, A.; Ansari, A.; Jamil, A. Green supply chain management practices' impact on operational performance with the mediation of technological innovation. *Sustainability* **2022**, *14*, 3362. [\[CrossRef\]](#)
37. Dong, Z.; Tan, Y.; Wang, L.; Zheng, J.; Hu, S. Green supply chain management and clean technology innovation: An empirical analysis of multinational enterprises in China. *J. Clean. Prod.* **2021**, *310*, 127377. [\[CrossRef\]](#)
38. Bag, S.; Gupta, S.; Kumar, S.; Sivarajah, U. Role of technological dimensions of green supply chain management practices on firm performance. *J. Enterp. Inf. Manag.* **2021**, *34*, 1–27. [\[CrossRef\]](#)
39. Oubrahim, I.; Sefiani, N.; Happonen, A. The influence of digital transformation and supply chain integration on overall sustainable supply chain performance: An empirical analysis from manufacturing companies in Morocco. *Energies* **2023**, *16*, 1004. [\[CrossRef\]](#)
40. Li, X.; Wang, R.; Nan, M.; Shi, Y. Research on the impact of green supply chain integration on enterprises' green innovation. *Sustainability* **2025**, *17*, 2859. [\[CrossRef\]](#)
41. Nureen, N.; Sun, H.; Irfan, M.; Nuta, A.C.; Malik, M. Digital transformation: Fresh insights to implement green supply chain management, eco-technological innovation, and collaborative capability in manufacturing sector of an emerging economy. *Environ. Sci. Pollut. Res.* **2023**, *30*, 78168–78181. [\[CrossRef\]](#)
42. Junaid, M.; Zhang, Q.; Syed, M.W. Effects of sustainable supply chain integration on green innovation and firm performance. *Sustain. Prod. Consum.* **2022**, *30*, 145–157. [\[CrossRef\]](#)
43. Novitasari, M.; Agustia, D. Green supply chain management and firm performance: The mediating effect of green innovation. *J. Ind. Eng. Manag.* **2021**, *14*, 391–403. [\[CrossRef\]](#)
44. Keskin, H.; Tatoglu, E.; Akgün, A.E.; Esen, E. Linking green supply chain management and blockchain technology to green marketing and environmental performance: The mediating role of green technology innovation. *Int. Mark. Rev.* **2025**, 1–40. [\[CrossRef\]](#)

45. Rupa, R.A.; Saif, A.N.M. Impact of green supply chain management (GSCM) on business performance and environmental sustainability: Case of a developing country. *Bus. Perspect. Res.* **2022**, *10*, 140–163.
46. Balon, V. Green supply chain management: Pressures, practices, and performance—An integrative literature review. *Bus. Strategy Dev.* **2020**, *3*, 226–244.
47. Fu, L.; Yang, D.; Liu, S.; Mei, Q. The impact of green supply chain management on enterprise environmental performance: A meta-analysis. *Chin. Manag. Stud.* **2023**, *17*, 274–289.
48. Garcia Alcaraz, J.L.; Díaz Reza, J.R.; Arredondo Soto, K.C.; Hernandez Escobedo, G.; Happonen, A.; Vidal, R.P.I.; Jiménez Macías, E. Effect of green supply chain management practices on environmental performance: Case of Mexican manufacturing companies. *Mathematics* **2022**, *10*, 1877. [\[CrossRef\]](#)
49. Yang, K.; Thoo, A.C.; Ab Talib, M.S.; Huam, H.T. How reverse logistics and sustainable supply chain initiatives influence sustainability performance: The moderating role of organisational learning capability. *J. Manuf. Technol. Manag.* **2024**, *35*, 141–163.
50. Nazir, S.; Zhaolei, L.; Mehmood, S.; Nazir, Z. Impact of green supply chain management practices on the environmental performance of manufacturing firms considering institutional pressure as a moderator. *Sustainability* **2024**, *16*, 2278. [\[CrossRef\]](#)
51. Huang, L.; Liu, H.; Oghenerobor, E.; Chen, C.S. Collaborating digitalization and green supply chain to promote green development of manufacturing firms—An analysis from a configurational perspective. *Chin. Manag. Stud.* **2025**, *ahead-of-print*.
52. Ali, S.R.; Al Masud, A.; Hossain, M.A.; Islam, K.Z.; Alam, S.S. Weaving a greener future: The impact of green human resources management and green supply chain management on sustainable performance in Bangladesh's textile industry. *Clean. Logist. Supply Chain* **2024**, *10*, 100143. [\[CrossRef\]](#)
53. Teixeira, A.A.; Moraes, T.E.; Teixeira, T.B.; Battistelle, R.A.; Araújo, E.G.; de Seabra, Q.A.C. The role of green supply chain management practices on environmental performance of firms: An exploratory survey in Brazil. *Sustainability* **2023**, *15*, 11843. [\[CrossRef\]](#)
54. Alraja, M.N.; Imran, R.; Khashab, B.M.; Shah, M. Technological innovation, sustainable green practices and SMEs sustainable performance in times of crisis (COVID-19 pandemic). *Inf. Syst. Front.* **2022**, *24*, 1081–1105. [\[CrossRef\]](#) [\[PubMed\]](#)
55. Yuan, Q.; Zhang, G.; Wang, R.; Ma, X.; Niu, J. Does technological innovation in national sustainable development agenda innovation demonstration zones promote green development?—The case from Chengde city, China. *PLoS ONE* **2024**, *19*, e0300315. [\[CrossRef\]](#) [\[PubMed\]](#)
56. Zeebaree, M.; Ismael, G.Y.; Nakshabandi, O.A.; Saleh, S.S.; Aqel, M. Impact of innovation technology in enhancing organizational management. *Stud. Appl. Econ.* **2020**, *38*. [\[CrossRef\]](#)
57. Kuzma, E.; Padilha, L.S.; Sehnem, S.; Julkovski, D.J.; Roman, D.J. The relationship between innovation and sustainability: A meta-analytic study. *J. Clean. Prod.* **2020**, *259*, 120745. [\[CrossRef\]](#)
58. Donbesuur, F.; Ampong, G.O.A.; Owusu-Yirenkyi, D.; Chu, I. Technological innovation, organizational innovation and international performance of SMEs: The moderating role of domestic institutional environment. *Technol. Forecast. Soc. Change* **2020**, *161*, 120252. [\[CrossRef\]](#)
59. Weber, P.; Siriyota, K.; Quddus, A. Measuring the influence of technological innovation and social sustainability via the mediating role of organizational innovation and digital entrepreneurship. *J. Infrastruct. Policy Dev.* **2024**, *8*, 5432. [\[CrossRef\]](#)
60. Bhatta, D.D.; Sarfraz, M.; Ivascu, L.; Pislaru, M. The nexus of corporate affinity for technology and firm sustainable performance in the era of digitalization: A mediated model. *Sustainability* **2023**, *15*, 9765. [\[CrossRef\]](#)
61. Opazo-Basáez, M.; Monroy-Osorio, J.C.; Marić, J. Evaluating the effect of green technological innovations on organizational and environmental performance: A treble innovation approach. *Technovation* **2024**, *129*, 102885. [\[CrossRef\]](#)
62. Rodríguez-Espíndola, O.; Cuevas-Romo, A.; Chowdhury, S.; Díaz-Acevedo, N.; Albores, P.; Despoudi, S.; Malesios, C.; Dey, P. The role of circular economy principles and sustainable-oriented innovation to enhance social, economic and environmental performance: Evidence from Mexican SMEs. *Int. J. Prod. Econ.* **2022**, *248*, 108495. [\[CrossRef\]](#)
63. Omonijo, O.N.; Zhang, Y. Examining the relationship between technological innovation, environmental social governance and corporate sustainability: The moderating role of green operational innovation. *Humanit. Soc. Sci. Commun.* **2025**, *12*, 107. [\[CrossRef\]](#)
64. Amjad, F.; Abbas, W.; Zia-Ur-Rehman, M.; Baig, S.A.; Hashim, M.; Khan, A.; Rehman, H.U. Effect of green human resource management practices on organizational sustainability: The mediating role of environmental and employee performance. *Environ. Sci. Pollut. Res.* **2021**, *28*, 28191–28206. [\[CrossRef\]](#)
65. Malik, S.Y.; Hayat Mughal, Y.; Azam, T.; Cao, Y.; Wan, Z.; Zhu, H.; Thurasamy, R. Corporate social responsibility, green human resources management, and sustainable performance: Is organizational citizenship behavior towards environment the missing link? *Sustainability* **2021**, *13*, 1044. [\[CrossRef\]](#)
66. Al Doghan, M.A.; Abdelwahed, N.A.A.; Soomro, B.A.; Ali Alayis, M.M.H. Organizational environmental culture, environmental sustainability and performance: The mediating role of green HRM and green innovation. *Sustainability* **2022**, *14*, 7510. [\[CrossRef\]](#)
67. Al-Swidi, A.K.; Al-Hakimi, M.A.; Al-Hattami, H.M. Fostering environmental preservation: Exploring the synergy of green human resource management and corporate environmental ethics. *Bottom Line* **2024**, *37*, 1–26. [\[CrossRef\]](#)

68. Afzal, F.; Lim, B. Organizational factors influencing the sustainability performance of construction organizations. *Sustainability* **2022**, *14*, 10449. [\[CrossRef\]](#)
69. Fok, L.; Morgan, Y.C.; Zee, S.; Mock, V.E. The impact of organizational culture and total quality management on the relationship between green practices and sustainability performance. *Int. J. Qual. Reliab. Manag.* **2023**, *40*, 1564–1586.
70. Huang, X.; Ullah, M.; Wang, L.; Ullah, F.; Khan, R. Green supply chain management practices and triple bottom line performance: Insights from an emerging economy with a mediating and moderating model. *J. Environ. Manag.* **2024**, *357*, 120575. [\[CrossRef\]](#)
71. Nogueira, E.; Gomes, S.; Lopes, J.M. Unveiling triple bottom line's influence on business performance. *Discov. Sustain.* **2025**, *6*, 43. [\[CrossRef\]](#)
72. Vu, T.N. ESG performance and sustainability concerns exposure. *Financ. Res. Lett.* **2025**, *71*, 106434. [\[CrossRef\]](#)
73. Lăzăroi, G.; Ionescu, L.; Andronie, M.; Dijmărescu, I. Sustainability management and performance in the urban corporate economy: A systematic literature review. *Sustainability* **2020**, *12*, 7705. [\[CrossRef\]](#)
74. Eltalhi, M.; Ojekemi, O.S.; Öz, T. The role of government support in adopting green supply chain management: The influence of green market orientation and employee environmental commitment in Libya. *Sustainability* **2025**, *17*, 3012. [\[CrossRef\]](#)
75. Zaidi, A.; Lakhal, L. The impact of lean manufacturing practices on green supply chain management and corporate sustainable performance: Evidence from manufacturing firms operating in Tunisia. *Int. J. Product. Perform. Manag.* **2025**, *74*, 3423–3454. [\[CrossRef\]](#)
76. Bhatti, M.A.; Aljoghaiman, A.; Kaliani Sundram, V.P.; Ghouri, A. Effect of industry 4 emerging technology on environmental sustainability of textile companies in Saudi Arabia: Mediating role of green supply chain management. *Manag. Environ. Qual. Int. J.* **2025**, *36*, 1945–1966.
77. Al-Khatib, A.W. Big data analytics capabilities and green supply chain performance: Investigating the moderated mediation model for green innovation and technological intensity. *Bus. Process Manag. J.* **2022**, *28*, 1446–1471. [\[CrossRef\]](#)
78. Hejazi, M.T.; Habani, M.A. Impact of green supply chain integration management on business performance: A mediating role of supply chain resilience and innovation the case of Saudi Arabian manufacturing sector. *Cogent Bus. Manag.* **2024**, *11*, 2392256. [\[CrossRef\]](#)
79. Mohamed, S.K.; Haddad, S.; Barakat, M.; Rosi, B. Blockchain technology adoption for improved environmental supply chain performance: The mediation effect of supply chain resilience, customer integration, and green customer information sharing. *Sustainability* **2023**, *15*, 7909. [\[CrossRef\]](#)
80. Al Sheyadi, A.; Mohsin Ba Awain, A.; Abbas, H. Zero Waste Management Towards Environmental and Operational Performance: The Mediating Role of Green Innovative Supply Chain Management. In *Proceedings of the IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2025; Volume 1520, p. 012009.
81. AlWadi, B.M.; Junejo, I.; Ejaz, S.; Ejaz, F.; Hossain, M.B. Factors Affecting Green Performance of Food Supply Chain Firms: A Parallel Mediation Model. *Emerg. Sci. J.* **2025**, *9*, 2215–2228. [\[CrossRef\]](#)
82. Krejcie, R.V.; Morgan, D.W. Determining sample size for research activities. *Educ. Psychol. Meas.* **1970**, *30*, 607–610. [\[CrossRef\]](#)
83. Liu, H.; Cui, J. Framework for evaluating technological innovation, CSR and ESG performance in Chinese art industrial: A quantitative analysis. *J. Infrastruct. Policy Dev.* **2024**, *8*, 6366. [\[CrossRef\]](#)
84. Haldorai, K.; Kim, W.G.; Garcia, R.F. Top management green commitment and green intellectual capital as enablers of hotel environmental performance: The mediating role of green human resource management. *Tour. Manag.* **2022**, *88*, 104431. [\[CrossRef\]](#)
85. Mollah, M.A.; Choi, J.H.; Hwang, S.J.; Shin, J.K. Exploring a pathway to sustainable organizational performance of South Korea in the digital age: The effect of digital leadership on IT capabilities and organizational learning. *Sustainability* **2023**, *15*, 7875. [\[CrossRef\]](#)
86. Kock, N. Common method bias in PLS-SEM: A full collinearity assessment approach. *Int. J. E-Collab.* **2015**, *11*, 1–10. [\[CrossRef\]](#)
87. Hair, J.F.; Risher, J.J.; Sarstedt, M.; Ringle, C.M. When to use and how to report the results of PLS-SEM. *Eur. Bus. Rev.* **2019**, *31*, 2–24. [\[CrossRef\]](#)
88. ISO 14001:2026; Environmental Management Systems—Requirements with Guidance for Use. ISO: Geneva, Switzerland, 2026.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.