

The Mediating Role of Green Supply Chain Management between Lean Manufacturing Practices and Sustainable Performance

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Abstract

The Philippine Economic Zone Authority (PEZA)-registered multinational manufacturing companies in Laguna continue to face financial, social, and sustainability challenges despite adopting Lean Manufacturing Practices (LMP). However, evidence remains limited on how Green Supply Chain Management (GSCM) enhances the sustainability outcomes of lean initiatives in the Philippine manufacturing context. This study examined GSCM's mediating role in the relationship between LMP and Sustainable Performance (SP) among PEZA-registered multinational manufacturing companies in Laguna. Using a quantitative descriptive-correlational research design, data were collected from middle- to upper-level managers through a researcher-made questionnaire and analyzed using descriptive statistics, regression analysis, and mediation analysis. The findings revealed that selected LMP dimensions significantly influenced SP, while GSCM significantly mediated the effects of selected LMP on financial, social and environmental performance. The results indicate that environmentally responsible supply chain practices can serve as an important pathway linking selected lean manufacturing practices with sustainable performance. Based on these findings, the study proposed a strategic plan to help PEZA promote sustainable manufacturing practices and enhance the competitiveness of multinational manufacturing companies. The study provides empirical evidence that integrating lean and green practices is essential to achieving long-term sustainable performance and advancing the Philippines' goal of becoming a leading sustainable manufacturing hub in Asia.

Keywords: *Green Supply Chain Management, Lean Manufacturing Practices, Multinational Manufacturing Companies, Philippine Economic Zone Authority, Sustainable Performance*

INTRODUCTION

Manufacturing firms are increasingly expected to improve productivity while responding to climate, resource, and regulatory pressures. Global initiatives such as the Paris Agreement have encouraged manufacturers to adopt sustainable production practices that balance economic, social, and environmental performance ([United Nations Framework Convention on Climate Change \[UNFCCC\], 2015](#)). Consequently, organizations have increasingly implemented Lean Manufacturing Practices (LMP) to improve process efficiency and reduce waste, and Green Supply Chain Management (GSCM) that extends environmental responsibility across sourcing, production, logistics, suppliers, and product recovery. Recent manufacturing studies show that the sustainability value of these approaches depends less on adopting isolated practices than on how operational and environmental capabilities are integrated ([Awan et al., 2022](#); [Gupta et al., 2025](#); [Javed et al., 2025](#); [Kosasih et al., 2023](#); [Zaidi & Lakhal, 2025](#)).

In the Philippines, PEZA-registered multinational manufacturing companies, particularly those in Laguna, are major contributors to industrial development. However, recent Laguna Ecozone Export Enterprises Sustainability Reports indicate persistent challenges, including moderate operating costs, workforce-related issues, increasing waste generation, and rising energy consumption, despite improvements in green innovation ([Philippine Economic Zone Authority](#)

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[PEZA], 2022, 2023, 2024). These findings suggest the need for stronger integration of operational efficiency and environmental management strategies.

Prior research generally links lean systems to stronger operational outcomes and GSCM to improved environmental and organizational performance, but these relationships are not uniform across sustainability dimensions. Evidence from manufacturing contexts indicates that GSCM can strengthen social and environmental outcomes even when lean practices have stronger direct economic effects (Zaidi & Lakhali, 2025). Other recent studies likewise emphasize supply-chain collaboration, green innovation, and management commitment as mechanisms through which environmental practices translate into sustainable performance (Al-Ayed, 2025; Ning et al., 2025). Despite this growing evidence, the mediating role of GSCM remains underexamined among PEZA-registered multinational manufacturers in the Philippines.

The study was grounded in the natural-resource-based view (NRBV), which treats resource-efficient and environmentally responsive organizational practices as capabilities that can contribute to sustainable outcomes (Hart, 1995). From this perspective, LMP provides internal operational capabilities for eliminating waste, improving resource utilization, and strengthening coordination with employees, suppliers, and customers, while GSCM extends these capabilities across environmentally responsible sourcing, product design, manufacturing, logistics, and product recovery. The study adopted the conceptual framework of Awan et al. (2022), which positions LMP as the independent variable, SP as the dependent variable, and GSCM as the mediator. Accordingly, the framework proposes that the six dimensions of LMP may directly influence financial, social, and environmental performance and may also produce indirect effects through GSCM.

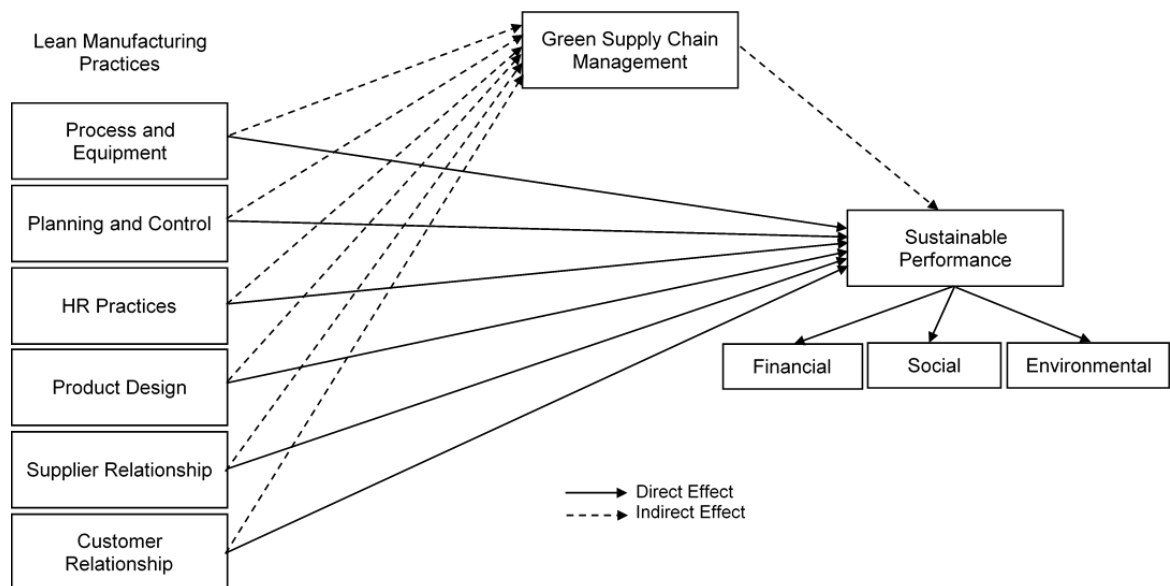


Figure 1. Conceptual Framework of the Mediating Role of GSCM between LMP and SP
(Adapted from Awan et al. (2022) and theoretically grounded in the NRBV theory)

Accordingly, the general objective of this study was to examine the mediating role of Green Supply Chain Management in the relationship between Lean Manufacturing Practices and Sustainable Performance among PEZA-registered multinational manufacturing companies in Laguna. By examining the direct and mediated relationships among these variables, the study sought to provide empirical evidence from an export-oriented, regulated industrial setting and to serve as a basis for developing a strategic plan to support sustainable manufacturing.

Specifically, this study addressed the following objectives:

1. To assess the level of Sustainable Performance of PEZA-registered multinational manufacturing companies in Laguna in terms of financial performance, social performance, and environmental performance;
2. To measure the extent of implementation of Lean Manufacturing Practices across areas of process and equipment, planning and control, HR practices, product design, supplier relationship, and customer relationship;
3. To evaluate the Green Supply Chain Management practices of PEZA-registered multinational manufacturing companies in Laguna;
4. To determine the effect of Lean Manufacturing Practices on Sustainable Performance;
5. To examine the mediating role of Green Supply Chain Management in the relationship between Lean Manufacturing Practices and Sustainable Performance; and
6. To develop a strategic plan for PEZA based on the study's findings to strengthen its role in positioning the Philippines as a sustainable manufacturing hub in Asia.

LITERATURE REVIEW

Sustainable Performance (SP)

Sustainable Performance (SP) treats financial, environmental, and social outcomes as interdependent dimensions of organizational performance. For manufacturers, efficiency and profitability must be achieved without shifting costs onto the environment, employees, or communities. This multidimensional perspective is reflected in studies that assess sustainable alternatives using economic, technical, environmental, and socioeconomic criteria ([Sihombing & Putro, 2024](#)). Green supply chain practices can support low-carbon manufacturing and broader societal outcomes, but these benefits depend on their integration into organizational decision-making ([Agyabeng-Mensah et al., 2020](#); [Gupta et al., 2025](#)). Operational improvements may reduce waste and costs, while environmental management, innovation, collaboration, and management commitment determine whether these gains translate into environmental and social performance ([Al-Ayed, 2025](#); [Javed et al., 2025](#); [Ning et al., 2025](#)).

Accordingly, lean and green management are increasingly viewed as complementary. LMP strengthens process discipline and efficiency, while GSCM integrates environmental considerations across purchasing, production, logistics, supplier management, and product recovery. GSCM may therefore translate lean improvements into social and environmental benefits beyond their direct economic effects ([Zaidi & Lakhal, 2025](#)). Because these relationships vary by practice, outcome, and context, this study examines the six LMP dimensions and the three SP outcomes separately, given the limited evidence from PEZA-registered multinational manufacturers in the Philippines.

Lean Manufacturing Practices (LMP)

Lean Manufacturing Practices (LMP) have evolved from a waste-reduction philosophy into a strategic approach that supports operational excellence and sustainability. Through continuous improvement and customer value creation, LMP eliminates non-value-adding activities, improves process efficiency, and enhances responsiveness to market demands ([Dolci et al., 2024](#)). Lean also supports sustainability through efficient resource use, improved product quality, and value-chain collaboration ([Awan et al., 2022](#); [Sinkamba et al., 2023](#)). In this study, LMP comprises process and equipment, planning and control, HR practices, product design, supplier relationships, and customer relationships. These dimensions represent technical and relational capabilities that affect resource use, employee participation, product lifecycle decisions, and collaboration beyond the factory boundary ([Costa et al., 2024](#); [Mathiyazhagan et al., 2021](#); [Yadav et al., 2023](#)).

However, lean practices do not uniformly affect all sustainability outcomes. Some primarily

improve cost and operational performance, while environmental and social benefits may depend on complementary green capabilities. [Zaidi and Lakhal \(2025\)](#), for example, found that lean directly improved economic performance, whereas GSCM contributed more strongly to social and environmental outcomes. This supports examining the individual LMP dimensions and the mediating role of GSCM rather than assuming a uniform sustainability effect. Such evidence remains limited among PEZA-registered multinational manufacturers in the Philippines, particularly regarding how specific lean practices contribute directly to SP and through GSCM.

Green Supply Chain Management (GSCM)

Green Supply Chain Management (GSCM) is a key strategy for organizations seeking to enhance environmental sustainability and business performance. GSCM integrates environmental considerations throughout the supply chain, including product design, procurement, manufacturing, logistics, and end-of-life product recovery ([Herrmann et al., 2021](#)). Recent studies indicate that organizations adopt GSCM not only to meet sustainability requirements but also to improve resource efficiency, reduce environmental impacts, and strengthen long-term competitiveness ([Agyabeng-Mensah et al., 2020](#); [Uddin et al., 2022](#)).

Accordingly, GSCM improves organizational performance through green procurement, eco-design, green manufacturing, reverse logistics, and robust supplier collaboration ([Alakrod & Mohammad, 2026](#)). Together, these practices help organizations reduce waste and emissions, use resources more efficiently, strengthen stakeholder relationships, and build more resilient supply chains ([Bag & Pretorius, 2020](#); [Khan et al., 2024](#); [Ortega Carrasco et al., 2025](#); [Paluš et al., 2024](#)). Recent studies also highlight those digital technologies, particularly Industry 4.0 applications, enhance GSCM by improving environmental monitoring, information sharing, and coordination across the supply chain ([Costa et al., 2024](#); [Dolci et al., 2024](#)).

However, research shows that GSCM does not always improve sustainability performance. While many studies report positive results, some find that green initiatives are less effective without strong operational processes, cross-functional collaboration, and supplier engagement ([Bhattacharya et al., 2019](#); [Ferreira et al., 2025](#); [Herrmann et al., 2021](#)). These findings suggest that the effectiveness of GSCM depends on how well green practices are integrated into existing operational processes rather than on implementing them as standalone environmental initiatives.

Given these findings, researchers are increasingly examining how to integrate GSCM with LMP. Lean Manufacturing focuses on operational efficiency through waste reduction and continuous improvement, while GSCM incorporates environmental considerations across sourcing, production, logistics, and supplier relationships. Evidence suggests that integrating these approaches enables organizations to achieve stronger financial, environmental, and social performance than implementing either strategy alone ([Agyabeng-Mensah et al., 2020](#); [Bag & Pretorius, 2020](#); [Khan et al., 2024](#)).

Lean Manufacturing Practices and Sustainable Performance

The direct LMP-SP relationship is expected to vary across sustainability dimensions. In line with the [Department of Trade and Industry \(DTI, 2018\)](#) promotion of resource-efficient manufacturing, LMP have gained recognition for improving operational efficiency and supporting sustainability initiatives. Originating in the Toyota Production System, lean emphasizes waste elimination, continuous improvement, and value creation ([Varadaraj & Ananth, 2020](#); [Womack & Jones, 2016](#)). These principles have become increasingly relevant in resource-constrained manufacturing environments, where firms seek to balance productivity with sustainability goals ([Sinkamba et al., 2023](#)). Evidence from the Moroccan industry likewise reports that lean tools can reduce waste and energy use while improving productivity ([Bouazza & Lajjam, 2023](#)).

Recent studies reinforce the need to separate these outcomes. [Zaidi and Lakhal \(2025\)](#) found a significant economic benefit from lean practices but no comparable direct effect on social and environmental performance, whereas GSCM strengthened the latter outcomes. At the same time, employee-related evidence from manufacturing cautions that organizational performance indicators can obscure workforce pressures and insecurity, making the social dimension important to assess independently ([Fujitha et al., 2025](#)). Several studies contend that environmental improvements are greater when lean is complemented by green initiatives rather than implemented as a stand-alone approach ([Ahmad et al., 2021](#); [Aladaileh et al., 2024](#); [Huo et al., 2019](#); [Songkhwan et al., 2025](#)). Likewise, findings on SP remain inconsistent. Although lean has been associated with greater employee involvement and engagement ([Anshima et al., 2025](#); [Uddin et al., 2022](#); [Varadaraj & Ananth, 2020](#)), other studies report increased work pressure and employee strain ([Bouville & Schmidt, 2019](#)). These mixed findings justify testing the direct effects of the six LMP dimensions rather than assuming that lean produces uniform SP gains. Given these inconsistencies and the limited evidence from PEZA-registered multinational manufacturing firms in the Philippines, the direct effect of LMP on SP warrants further empirical examination.

The NRBV suggests that lean capabilities may influence SP by reducing waste, improving resource efficiency, strengthening employee involvement, and enhancing coordination with suppliers and customers. However, empirical findings indicate that the effects of LMP may vary by lean practice, performance dimension, and organizational context ([Awan et al., 2022](#); [Huo et al., 2019](#); [Iranmanesh et al., 2019](#); [Zaidi & Lakhal, 2025](#)). To determine whether the individual LMP dimensions have statistically significant effects on financial, social, and environmental performance, the following hypothesis was tested:

H₀₁: Lean Manufacturing Practices has no significant effect on Sustainable Performance.

The Mediating Role of Green Supply Chain Management (GSCM)

GSCM has become an important strategy for manufacturing firms seeking to achieve SP by integrating environmental considerations across product design, sourcing, production, logistics, and end-of-life management ([Al Mamun et al., 2025](#); [Hariyani et al., 2024](#); [Khan et al., 2024](#); [Uddin et al., 2022](#)). As environmental regulations and sustainability expectations continue to rise, GSCM is increasingly recognized as a capability that complements LMP. Lean manufacturing emphasizes waste elimination, resource efficiency, and continuous improvement, creating operational conditions that facilitate GSCM ([Awan et al., 2022](#); [Huo et al., 2019](#)). However, several studies argue that operational improvements alone do not consistently translate into environmental or social gains unless reinforced by green initiatives ([Abobakr et al., 2023](#); [Aladaileh et al., 2024](#); [Bhattacharya et al., 2019](#)). This suggests that GSCM may be the mechanism through which lean practices contribute to SP.

Further studies indicate that GSCM translates lean-driven operational improvements into broader sustainability outcomes. Through green procurement, eco-design, supplier collaboration, and environmentally responsible logistics, GSCM extends the benefits of lean beyond internal operations, yielding lower environmental impacts, improved resource efficiency, and stronger stakeholder relationships ([Dubey et al., 2017](#); [Geng et al., 2017](#); [Khaleeli et al., 2021](#)). Consistent with this view, organizations that integrate lean and green practices generally achieve better sustainability outcomes than those implementing lean alone ([Iranmanesh et al., 2019](#); [Thekkootte, 2022](#)). [Dubey et al. \(2017\)](#) reported that GSCM partially mediated the relationship between lean practices and environmental and social sustainability, while [Awan et al. \(2022\)](#) identified green procurement and eco-design as key mechanisms linking lean-driven process improvements to SP. Although these findings support the mediating role of GSCM, evidence remains limited in the context of PEZA-registered multinational manufacturing firms in the Philippines.

The NRBV further suggests that GSCM can serve as an environmental capability that extends lean-generated operational improvements across procurement, product design, manufacturing, logistics, supplier collaboration, and product recovery. Previous studies provide evidence that GSCM may transmit the effects of selected lean practices to SP, although the strength of this mediation may vary across practices and performance outcomes ([Awan et al., 2022](#); [Dubey et al., 2017](#); [Huo et al., 2019](#); [Zaidi & Lakhali, 2025](#)). To determine whether the estimated indirect effects were statistically significant, the following hypothesis was tested:

H₀₂: Green Supply Chain Management does not significantly mediate the effect of Lean Manufacturing Practices on Sustainable Performance.

RESEARCH METHOD

This study employed a quantitative, cross-sectional, descriptive-correlational research design, specifically an explanatory correlational approach. Quantitative research was appropriate because the variables were measured numerically and analyzed using statistical procedures. [Creswell and Creswell \(2023\)](#) explained that quantitative non-experimental research is suitable for examining statistical relationships among variables without manipulating the conditions under which they occur. The descriptive component assessed the levels of Lean Manufacturing Practices (LMP), Green Supply Chain Management (GSCM), and Sustainable Performance (SP). The explanatory correlational component examined how the six dimensions of LMP were related to financial, social, and environmental performance and whether GSCM statistically mediated these relationships. Accordingly, the design allowed the study to estimate direct and indirect statistical relationships but did not establish definitive causal relationships.

The PEZA sampling frame included 411 registered manufacturing companies in Laguna. Of these, 320 were identified as multinational, 236 reported implementing lean manufacturing, and 196 also met the GSCM implementation criterion. Thus, the eligible population comprised 196 PEZA-registered multinational manufacturing companies that: (1) operated in Laguna; (2) engaged in manufacturing; (3) were multinational in ownership or corporate structure; and (4) had implemented both LMP and GSCM.

Respondents were mid- to top-level managers or officers who were directly involved in or had substantial knowledge of their companies' lean practices, green supply chain initiatives, and sustainability performance. They included plant, supply chain, HR, environmental health and safety, operations, logistics, QA, and sustainability managers or officers. These respondents were selected because their positions provided access to organization-level information on operational practices, supplier and customer relationships, environmental initiatives, and performance outcomes. The one-respondent-per-company approach maintained the company as the unit of analysis and prevented firms with multiple respondents from being overrepresented.

The minimum sample size was estimated using the Raosoft sample-size calculator. Based on an eligible population of 196 companies, a 95% confidence level, a 5% margin of error, and a 50% response proportion, the calculation yielded a minimum required sample of 131 companies. The 50% response proportion was used as the most conservative assumption because it produces the largest required sample when the expected distribution of responses is unknown. The final sample consisted of 131 participating companies, with one qualified respondent representing each company; thus, the achieved sample met the minimum requirement. Simple random sampling was employed using a computerized random-selection procedure so that each of the 196 eligible companies had an equal probability of selection. Nonresponding companies were replaced through random selection from the remaining eligible population until the required sample was obtained.

Data were collected using a researcher-developed questionnaire based on established definitions, measures, and item domains reported in prior studies of LMP, GSCM, and SP ([Awan et](#)

al., 2022; Bhattacharya et al., 2019; Chardine-Baumann & Botta-Genoulaz, 2014; Iranmanesh et al., 2019; Srivastava, 2007). The questionnaire included 5 company-profile questions and 70 substantive items. SP comprised 21 items: 7 for financial performance, 7 for social performance, and 7 for environmental performance. LMP comprised 42 items, with 7 items each for process and equipment, planning and control, HR practices, product design, supplier relationship, and customer relationship. GSCM was measured with 7 items covering green procurement, eco-design, environmentally responsible production and logistics, supplier and employee environmental development, environmental reporting, and reverse logistics.

Items were measured using a seven-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). The electronic questionnaire allowed respondents to enter values between the scale anchors. Higher scores indicated greater practice implementation or a higher level of SP.

Table 1. Scoring and Interpretation

Response Scale	Mean Score	Level of Agreement	Verbal Interpretation
7	6.50 – 7.00	Strongly Agree	Very High
6	5.50 – 6.49	Agree	High
5	4.50 – 5.49	Partially Agree	Moderately High
4	3.50 – 4.49	Neutral	Moderate
3	2.50 – 3.49	Partially Disagree	Moderately Low
2	1.50 – 2.49	Disagree	Low
1	1.00 – 1.49	Strongly Disagree	Very Low

The questionnaire underwent content validation by the thesis adviser and panel members, who evaluated the clarity, relevance, and alignment of the items with their intended constructs. Their recommendations were incorporated before pilot testing. A pilot test was conducted in the first two weeks of October 2025 with 33 respondents from PEZA-registered multinational manufacturing companies in Batangas who were not included in the main study. Cronbach's alpha coefficients ranged from 0.8846 to 0.9737 across the constructs and subdimensions, exceeding the minimum acceptable value of 0.70 and indicating good to excellent internal consistency.

Table 2. Internal Consistency Reliability of the Study Constructs

Construct or Dimension	Number of Items	Cronbach's alpha	Interpretation
Financial Performance	7	0.9090	Excellent
Social Performance	7	0.8846	Good
Environmental Performance	7	0.9578	Excellent
Process and Equipment	7	0.9637	Excellent
Planning and Control	7	0.9660	Excellent
HR Practices	7	0.9737	Excellent
Product Design	7	0.9689	Excellent
Supplier Relationship	7	0.9596	Excellent
Customer Relationship	7	0.9671	Excellent
GSCM	7	0.9657	Excellent

Formal permission to conduct the study was first obtained from the PEZA Region IV-A Cluster Head. Permission was then requested from the management or designated representatives of the randomly selected companies via letters, primarily by email, with telephone follow-ups. Each participating company designated one qualified respondent who met the study's inclusion criteria.

The validated questionnaire was administered online via Google Forms over approximately five weeks, from October to November 2025. Before accessing the survey items, respondents received an informed consent statement outlining the study's purpose, voluntary participation,

confidentiality, the right to withdraw, and the secure handling of information under the Philippine [Data Privacy Act of 2012](#). Completion took approximately 10–15 minutes. Weekly follow-ups were conducted, and companies that remained nonresponsive after three weeks were replaced by random selection from the remaining eligible population. Completed responses were reviewed, coded, cleaned, and prepared for statistical analysis.

Analyses were conducted in jamovi version 2.4 using the jAMM module. Frequencies and percentages summarized company characteristics, and composite means described the levels of LMP, GSCM, and SP. Separate multiple linear regression models were estimated for financial, social, and environmental performance. In each model, the six LMP dimensions were entered simultaneously as predictors. Multiple regression was appropriate because it estimated the unique statistical effect of each LMP dimension on a particular performance outcome while accounting for the other lean dimensions included in the model. LMP dimensions with statistically significant direct effects were then entered into General Linear Model-based mediation analyses with GSCM as the mediator. Indirect effects were evaluated using B, standard error, z, and p values, with statistical significance defined as $p < 0.05$. This sequence allowed the analysis to distinguish direct LMP effects from effects transmitted through GSCM.

Common Method Bias Assessment

Common method bias was also examined using the full-collinearity variance inflation factor (FCVIF) approach. Composite scores for the ten study constructs were calculated by averaging their respective questionnaire items. Each construct was then treated as a dependent variable and regressed on the remaining nine constructs. The FCVIF for each construct was calculated as $1/(1-R^2)$. Following [Kock \(2015\)](#), FCVIF values of 3.3 or lower were interpreted as indicating that common method bias was unlikely.

Table 3. Initial Full-Collinearity VIF Assessment for CMB

Construct	FCVIF	Assessment
Financial Performance	3.694	Exceeds Threshold
Social Performance	2.514	Within Threshold
Environmental Performance	4.131	Exceeds Threshold
Process and Equipment	7.027	Exceeds Threshold
Planning and Control	11.387	Exceeds Threshold
HR Practices	5.709	Exceeds Threshold
Product Design	4.386	Exceeds Threshold
Supplier Relationship	12.460	Exceeds Threshold
Customer Relationship	8.542	Exceeds Threshold
Green Supply Chain Management	7.871	Exceeds Threshold

The initial full collinearity assessment indicated that several constructs exceeded the applied threshold of 3.3, suggesting potential collinearity concerns. In response, indicators associated with constructs exceeding the FCVIF criterion were reassessed for item redundancy, construct overlap, internal consistency, and conceptual relevance. Item deletion was undertaken conservatively, with indicators removed only when statistical evidence of redundancy or cross-construct overlap was supported by conceptual considerations and when the remaining indicators continued to demonstrate satisfactory construct reliability.

Table 4. Indicator Deletions and Basis for Model Re-specification

Construct	Deleted Indicators	Basis for Deletion
Financial Performance	FP4, FP5	Cross-construct overlap with sustainability and operational/product-related practices.
Environmental Performance	EP5	Overlap with Process and Equipment; reliability remained satisfactory after deletion.
Process and Equipment	Process4, Process6	Cross-construct overlap with Product Design and HR-related practices.
Planning and Control	Planning1, Planning4, Planning5, Planning6	Substantial overlap with Customer Relationship and Product Design/operational practices.
HR Practices	HR5, HR6	Shared variance with operational constructs; removal reduced collinearity while preserving reliability.
Product Design	Product3, Product4	Cross-construct overlap with HR Practices and GSCM.
Supplier Relationship	Supplier1, Supplier2, Supplier6	Cross-construct overlap, particularly with Customer Relationship and HR Practices.
Customer Relationship	Customer3, Customer4, Customer7	Shared variance with Supplier Relationship and Planning/operational practices; reliability remained strong.
Green Supply Chain Management	GSCM1, GSCM5, GSCM6, GSCM7	Cross-construct overlap, particularly with Supplier and Customer Relationship practices.

The construct scores were recomputed using the retained indicators, and the reliability, full-collinearity, structural, and mediation analyses were rerun with the revised specifications.

Table 5. Revised Factorability and Reliability Assessment of the Constructs

Construct or Dimension	Number of Retained Items	KMO	Bartlett's p-value	Factor Loading Range	Cronbach's alpha	Interpretation
Financial Performance	5	0.760	<0.001	0.588–0.856	0.8100	Good
Social Performance	7	0.794	<0.001	0.498–0.737	0.8846	Good
Environmental Performance	6	0.876	<0.001	0.729–0.891	0.9056	Excellent
Process and Equipment	5	0.827	<0.001	0.686–0.906	0.8947	Good
Planning and Control	3	0.722	<0.001	0.762–0.906	0.8617	Good
HR Practices	5	0.834	<0.001	0.592–0.914	0.8652	Good
Product Design	5	0.897	<0.001	0.835–0.952	0.9604	Excellent
Supplier Relationship	4	0.777	<0.001	0.600–0.853	0.8236	Good
Customer Relationship	4	0.810	<0.001	0.848–0.964	0.9423	Excellent
GSCM	3	0.691	<0.001	0.645–	0.8030	Good

0.847

Following reassessment of the indicators, the retained indicators were re-evaluated using Principal Axis Factoring and reliability analysis. KMO values ranged from 0.691 to 0.897, with significant Bartlett's tests ($p < 0.001$). Factor loadings ranged from 0.498 to 0.964. The borderline loading of 0.498 for one Social Performance indicator was retained based on conceptual relevance and satisfactory construct reliability. Combined factor assessment also showed strong sampling adequacy (KMO = 0.908; Bartlett's test $p < 0.001$). Although some secondary loadings remained among conceptually related constructs, no further indicators were removed solely to improve the factor structure. Cronbach's alpha values ranged from 0.8030 to 0.9604, indicating good to excellent internal consistency.

Table 6. Revised Full-Collinearity VIF Assessment for CMB

Construct	FCVIF	Assessment
Financial Performance	1.799	Within Threshold
Social Performance	2.179	Within Threshold
Environmental Performance	3.175	Within Threshold
Process and Equipment	3.115	Within Threshold
Planning and Control	3.289	Within Threshold
HR Practices	3.289	Within Threshold
Product Design	2.320	Within Threshold
Supplier Relationship	3.226	Within Threshold
Customer Relationship	2.941	Within Threshold
Green Supply Chain Management	3.125	Within Threshold

Following the reassessment of factorability and reliability and theoretically justified item deletions, the revised FCVIF values ranged from 1.799 to 3.289, with all constructs below the applied threshold of 3.3. Thus, the revised model did not indicate problematic multicollinearity.

FINDINGS AND DISCUSSION

Level of Sustainable Performance

The participating PEZA-registered multinational manufacturing companies reported high SP across all three dimensions. Environmental performance had the highest composite mean (6.22), followed by social performance (5.98) and financial performance (5.83). This pattern indicates that environmental and social outcomes are comparatively stronger, while financial sustainability, though still rated highly, remains an area for further strengthening.

Table 7. Summary of the Level of Sustainable Performance

Dimension	Composite Mean	Verbal Interpretation
Financial Performance	5.83	High
Social Performance	5.98	High
Environmental Performance	6.22	High

Operational efficiency was the most strongly perceived financial outcome of lean implementation, whereas financial resilience during market fluctuations was comparatively lower. This aligns with [Iranmanesh et al. \(2019\)](#), who linked lean practices to stronger operational and financial outcomes. However, the weaker resilience rating indicates that lean efficiency does not fully offset external pressures such as demand uncertainty, exchange-rate movements, and logistics disruptions. For social performance, workplace safety was strongest, while community

development and diversity and inclusion received the lowest ratings, both with a weighted mean of 5.54. This is consistent with [Huo et al. \(2019\)](#) and [Paluš et al. \(2024\)](#), who observed that firms often develop internal employee and safety practices more strongly than broader community-oriented initiatives. Environmental performance was the strongest sustainability dimension, yet carbon-emission and footprint reduction was its lowest-rated indicator, with a weighted mean of 5.74. Although prior studies associate environmental standards and ISO-based systems with improved environmental performance ([Huo et al., 2019](#); [Khan et al., 2024](#)), the present result shows that compliance can be strong even when carbon measurement and reduction remain less mature. This gap between generally strong environmental systems and less mature carbon reduction is consistent with the strategic challenge identified by [Prasetyo and Putro \(2024\)](#), who emphasize the need to align operational decisions with explicit carbon-reduction priorities. This distinction is important in the PEZA context because respondents identified baseline setting and the inclusion of supplier and logistics emissions as continuing challenges.

Extent of Lean Manufacturing Practices (LMP) Implementation

Table 8. Summary of the Extent of LMP Implementation

LMP Dimension	Composite Mean	Verbal Interpretation
Process and Equipment	6.31	High
Planning and Control	6.33	High
HR Practices	5.97	High
Product Design	6.08	High
Supplier Relationship	6.01	High
Customer Relationship	6.34	High

All six LMP dimensions were rated highly, with Customer Relationship achieving the highest composite mean (6.34), followed by Planning and Control (6.33) and Process and Equipment (6.31), reflecting strong customer responsiveness, production coordination, and operational practices. Product Design (6.08), Supplier Relationship (6.01), and HR Practices (5.97) were comparatively lower but still high. The Product Design result may partly reflect the multinational setting, where design and R&D decisions are often centralized at headquarters, limiting local influence over design-related practices. Meanwhile, the relatively lower Supplier Relationship and HR Practices results suggest opportunities to strengthen supplier collaboration and employee capability-building. Overall, the findings indicate consistently high LMP implementation, although the relative strength of specific practices varies across dimensions.

Green Supply Chain Management (GSCM) Assessment

Table 9. Respondents' Assessment of GSCM Practices

Question Items	Weighted Mean	Verbal Interpretation
GSCM.2	6.21	High
GSCM.3	6.35	High
GSCM.4	5.51	High
COMPOSITE MEAN	6.02	High

GSCM practices were generally well implemented, with a composite mean of 6.02. Initiatives to reduce emissions, waste, and pollution received the highest rating (WM = 6.35), consistent with [Geng et al. \(2017\)](#), who identify pollution prevention and resource efficiency as prominent GSCM practices. However, this high assessment contrasts with the continued increases in waste

generation, energy consumption, and water use reported in the PEZA sustainability data for 2022 – 2024 (PEZA, 2022, 2023, 2024), suggesting that implementation does not automatically yield proportional reductions when manufacturing activity expands. Reverse logistics and product take-back programs received the lowest rating (WM = 5.51). This aligns with Hebaz and Oulfarsi (2021) and Salas-Navarro et al. (2024), who describe reverse logistics as difficult because of collection requirements, cost, infrastructure, and multi-actor coordination. The present study further shows that some firms rely mainly on disposal instructions or third-party arrangements after products reach customers, indicating that internally controlled green practices are more mature than end-of-life responsibility.

Effects of Lean Manufacturing Practices (LMP) on Sustainable Performance (SP)

Table 10. Effects of LMP on Financial Performance

Financial Performance	B	Std. Error	t-value	p-value	Decision on H_0	Interpretation
Constant	1.9638	0.7284	2.6959	0.0080	-	-
Process and Equipment	0.1807	0.0944	1.9150	0.0578	Failed to Reject	No Significant Effect
Planning and Control	-0.0296	0.1315	-0.2251	0.8222	Failed to Reject	No Significant Effect
HR Practices	0.0873	0.1247	0.7000	0.4852	Failed to Reject	No Significant Effect
Product Design	0.1803	0.0894	2.0166	0.0459	Reject	Significant Effect
Supplier Relationship	0.1399	0.1229	1.1384	0.2571	Failed to Reject	No Significant Effect
Customer Relationship	0.0718	0.1819	0.3947	0.6938	Failed to Reject	No Significant Effect
Model Summary:	R = 0.5916		R ² = 0.3500			

The six LMP dimensions together explained 35% of the variation in financial performance ($R^2 = 0.3500$). Among the dimensions, only Product Design showed a significant positive effect ($B = 0.1803$, $p = 0.0459$), so H_{01} was rejected for this relationship. This suggests that designing products for manufacturability can reduce material use, production complexity, defects, and rework, thereby lowering production costs. This finding aligns with the NRBV, which recognizes resource-efficient organizational capabilities as potential sources of economic value, and with studies linking lean design practices to improved economic outcomes (Bhattacharya et al., 2019; Dieste et al., 2021; Favi & Marconi, 2025).

In contrast, Process and Equipment ($B = 0.1807$, $p = 0.0578$), Planning and Control ($B = -0.0296$, $p = 0.8222$), HR Practices ($B = 0.0873$, $p = 0.4852$), Supplier Relationship ($B = 0.1399$, $p = 0.2571$), and Customer Relationship ($B = 0.0718$, $p = 0.6938$) showed no significant effects; thus, H_{01} was not rejected for these relationships. Process and equipment improvements may initially yield operational benefits through improved reliability, reduced downtime, and waste reduction, while planning and control primarily support production continuity and resource coordination. Similarly, HR, supplier, and customer practices may contribute through employee capability, supply reliability, quality, and long-term stakeholder relationships rather than through immediate financial returns. Prior research also indicates that supply-chain capabilities can serve as mechanisms through which lean manufacturing contributes to financial performance, supporting the possibility that some lean practices generate financial value indirectly rather than

independently ([Awan et al., 2022](#)).

Table 11. Effects of LMP on Social Performance

Social Performance	B	Std. Error	t-value	p-value	Decision on H_0	Interpretation
Constant	1.2690	0.6108	2.0774	0.0398	-	-
Process and Equipment	0.0138	0.0791	0.1744	0.8619	Failed to Reject	No Significant Effect
Planning and Control	-0.3159	0.1102	-2.8660	0.0049	Reject	Significant Effect
HR Practices	0.1266	0.1046	1.2106	0.2283	Failed to Reject	No Significant Effect
Product Design	0.2031	0.0750	2.7093	0.0077	Reject	Significant Effect
Supplier Relationship	0.3399	0.1030	3.2981	0.0013	Reject	Significant Effect
Customer Relationship	0.3806	0.1525	2.4955	0.0139	Reject	Significant Effect
Model Summary: R = 0.6628 R ² = 0.4393						

The six LMP dimensions jointly explained 43.93% of the variation in social performance ($R^2 = 0.4393$). Planning and Control ($B = -0.3159$, $p = 0.0049$), Product Design ($B = 0.2031$, $p = 0.0077$), Supplier Relationship ($B = 0.3399$, $p = 0.0013$), and Customer Relationship ($B = 0.3806$, $p = 0.0139$) significantly affected social performance; thus, H_{01} was rejected for these relationships. The positive effects of Product Design, Supplier Relationship, and Customer Relationship indicate that product-related and relational lean capabilities are particularly relevant to social performance. This is consistent with the NRBV, which recognizes that organizational capabilities can create broader stakeholder value when sustainability considerations are incorporated into operational and interorganizational practices. Product Design may contribute through manufacturability, safety, and resource efficiency, while Supplier and Customer Relationships may strengthen coordination, responsiveness, responsible practices, and stakeholder engagement. These findings are consistent with prior studies linking lean and relationship-oriented practices with broader sustainability outcomes ([Huo et al., 2019](#); [Iranmanesh et al., 2019](#); [Wang et al., 2020](#)).

Planning and Control showed a significant negative effect on social performance ($B = -0.3159$, $p = 0.0049$). This finding suggests that the efficiency-oriented nature of planning and control may not necessarily translate into improved social outcomes. Practices related to production scheduling, inventory control, and resource utilization are primarily intended to maintain operational continuity and efficiency, whereas social performance encompasses broader employee- and stakeholder-related outcomes. The negative coefficient therefore suggests that improvements in operational planning alone may be insufficient to generate corresponding social benefits when human- and stakeholder-centered considerations are not similarly emphasized.

In contrast, Process and Equipment ($B = 0.0138$, $p = 0.8619$) and HR Practices ($B = 0.1266$, $p = 0.2283$) showed no significant effects; thus, H_{01} was not rejected for these relationships. Process and Equipment primarily strengthen technical and operational efficiency, which may not directly translate into employee- or community-oriented outcomes. Similarly, HR Practices may influence social performance gradually through employee capability, participation, and continuous improvement rather than through immediate, direct effects. This aligns with evidence that lean efficiency does not automatically produce favorable social outcomes unless human-centered considerations are explicitly incorporated ([Bouville & Schmidt, 2019](#)).

Table 12. Effects of LMP on Environmental Performance

Environmental Performance	B	Std. Error	t-value	p-value	Decision on H_0	Interpretation
Constant	-0.1436	0.5323	-0.2698	0.7878	-	-
Process and Equipment	0.1282	0.0690	1.8590	0.0654	Failed to Reject	No Significant Effect
Planning and Control	0.0909	0.0961	0.9459	0.3460	Failed to Reject	No Significant Effect
HR Practices	0.0399	0.0912	0.4377	0.6624	Failed to Reject	No Significant Effect
Product Design	0.0432	0.0653	0.6612	0.5097	Failed to Reject	No Significant Effect
Supplier Relationship	0.3667	0.0898	4.0836	<0.0001	Reject	Significant Effect
Customer Relationship	0.3582	0.1329	2.6953	0.0080	Reject	Significant Effect
Model Summary:	R = 0.8029	R ² = 0.6447				

For environmental performance, the six LMP dimensions jointly explained 64.47% of the variation ($R^2 = 0.6447$), indicating substantial explanatory power of the model. Among the dimensions, Supplier Relationship ($B = 0.3667$, $p < 0.0001$) and Customer Relationship ($B = 0.3582$, $p = 0.0080$) had significant positive effects on environmental performance; thus, H_{01} was rejected for these relationships. These findings indicate that environmental performance among the respondent firms is particularly associated with lean practices that extend beyond internal operations and involve coordination with external supply chain partners. Strong supplier relationships can facilitate information sharing, quality improvement, waste reduction, and collaboration on materials and processes, while customer relationships can communicate environmental expectations and encourage firms to respond to sustainability requirements. This is consistent with the NRBV, which recognizes collaborative capabilities as a means of extending resource-efficient and environmentally responsible practices across organizational boundaries. The findings also support previous research demonstrating the importance of supplier and customer interfaces in achieving sustainability and environmental outcomes (Huo et al., 2019; Iranmanesh et al., 2019).

In contrast, Process and Equipment ($B = 0.1282$, $p = 0.0654$), Planning and Control ($B = 0.0909$, $p = 0.3460$), HR Practices ($B = 0.0399$, $p = 0.6624$), and Product Design ($B = 0.0432$, $p = 0.5097$) did not have significant effects on environmental performance; thus, H_{01} was not rejected for these relationships. Although these practices can support resource efficiency, waste reduction, employee involvement, and environmentally conscious operations, their environmental benefits may not appear as independent direct effects. Instead, their contribution may depend on how effectively they are integrated with environmental and supply chain practices. This interpretation aligns with prior empirical evidence showing that individual lean and green practices may contribute differently to environmental performance and that the environmental benefits of lean practices can be strengthened when complemented by green practices (Huo et al., 2019).

Mediating Role of Green Supply Chain Management (GSCM)

Table 13. GSCM Mediation as to Financial Performance

Path	B	Std. Error	95% C.I.		z-value	p-value	Decision on H_0	Interpretation
			Lower	Upper				
Product Design → GSCM → Financial Performance	0.1434	0.0473	0.0506	0.2361	3.0303	0.0024	Reject	Mediate

GSCM significantly mediated the effect of Product Design on Financial Performance ($B = 0.1434$, $p = 0.0024$), with a 95% confidence interval that excludes zero; therefore, H_{02} was rejected. This finding indicates that the financial contribution associated with Product Design is not limited to its direct effect but can also operate through GSCM. Consistent with the NRBV, GSCM can extend product-related lean capabilities beyond internal operations through environmentally responsible supply chain practices, allowing resource-efficient product decisions to contribute to broader economic value. This supports studies showing that lean and green practices can produce stronger sustainability outcomes when integrated rather than implemented independently (Dubey et al., 2017; Iranmanesh et al., 2019). It is also consistent with Awan et al. (2022), who identified GSCM as a mechanism linking selected lean practices with SP. Thus, the significant indirect effect provides evidence that GSCM serves as a pathway through which Product Design contributes to Financial Performance.

Table 14. GSCM Mediation as to Social Performance

Path	B	Std. Error	95% C.I.		z-value	p-value	Decision on H_0	Interpretation
			Lower	Upper				
Planning and Control → GSCM → Social Performance	0.2873	0.0580	0.1736	0.4010	4.9522	<0.0001	Reject	Mediate
Product Design → GSCM → Social Performance	0.2086	0.0449	0.1205	0.2966	4.6430	<0.0001	Reject	Mediate
Supplier Relationship → GSCM → Social Performance	0.2829	0.0709	0.1439	0.4218	3.9901	<0.0001	Reject	Mediate
Customer Relationship → GSCM → Social Performance	0.0616	0.0477	-0.0319	0.1550	1.2913	0.1966	Failed to Reject	Does not Mediate

GSCM significantly mediated the effects of Planning and Control ($B = 0.2873$, $p < 0.0001$), Product Design ($B = 0.2086$, $p < 0.0001$), and Supplier Relationship ($B = 0.2829$, $p < 0.0001$) on Social Performance. Therefore, H_{02} was rejected for these paths. These findings indicate that the social benefits associated with these lean practices can be transmitted through GSCM. Planning and Control can facilitate the integration of environmental considerations into operations; Product Design can incorporate environmental requirements into product-related decisions; and Supplier Relationship can extend responsible practices across organizational boundaries. Through GSCM, these capabilities may support responsible sourcing, environmental collaboration, and stakeholder-oriented practices that contribute to broader social outcomes. This aligns with

previous evidence that integrating lean and green supply chain practices can extend operational improvements toward broader sustainability outcomes (Dubey et al., 2017; Awan et al., 2022; Zaidi & Lakhal, 2025).

In contrast, GSCM did not significantly mediate the effect of Customer Relationship on Social Performance ($B = 0.0616$, $p = 0.1966$). Thus, H_{02} was not rejected for this path. Although Customer Relationship had a significant direct effect on Social Performance in Table 11, the nonsignificant indirect effect indicates that GSCM did not explain this relationship in the present model. Customer Relationship may therefore contribute to social outcomes through other mechanisms, such as responsiveness, stakeholder engagement, and relationship-building, rather than necessarily through environmentally oriented supply chain practices.

Table 15. GSCM Mediation as to Environmental Performance

Path	B	Std. Error	95% C.I.		z-value	p-value	Decision on H_0	Interpretation
			Lower	Upper				
Supplier Relationship → GSCM → Environmental Performance	0.3085	0.0647	0.1816	0.4353	4.7662	<0.0001	Reject	Mediate
Customer Relationship → GSCM → Environmental Performance	0.4222	0.0780	0.2694	0.5750	5.4153	<0.0001	Reject	Mediate

GSCM significantly mediated the effects of Supplier Relationship ($B = 0.3085$, $p < 0.0001$) and Customer Relationship ($B = 0.4222$, $p < 0.0001$) on Environmental Performance; therefore, H_{02} was rejected for both paths. These findings indicate that supplier and customer relationships contribute to environmental performance not only through direct collaboration, as shown in Table 12, but also through their link to GSCM. Supplier coordination can facilitate environmentally responsible sourcing and joint environmental practices, while customer requirements can encourage the integration of environmental considerations into production and supply chain decisions. GSCM can connect these relational capabilities to broader environmental practices across the supply chain. This aligns with studies emphasizing the importance of supplier collaboration, customer involvement, and the integration of lean and green practices to improve environmental performance (Huo et al., 2019; Iranmanesh et al., 2019; Awan et al., 2022).

Theoretical Implications

First, the findings refine the natural-resource-based view (NRBV) by showing that the performance value of lean capabilities is outcome-specific rather than uniform. Product Design had a positive direct effect on Financial Performance; Product Design, Supplier Relationship, and Customer Relationship positively affected Social Performance; and Supplier Relationship and Customer Relationship positively affected Environmental Performance. Planning and Control also significantly affected Social Performance, but negatively. These differences indicate that individual lean capabilities do not contribute equally across the economic, social, and environmental dimensions of sustainability. The findings therefore add specificity to the NRBV by showing that the value derived from organizational capabilities depends on the particular sustainability outcome being pursued, consistent with evidence that individual lean practices may produce different performance effects (Huo et al., 2019; Awan et al., 2022; Zaidi & Lakhal, 2025).

Second, the results position GSCM as a selective bridging capability rather than a universal mediator between LMP and SP. GSCM mediated the Product Design–Financial Performance

relationship; the Planning and Control, Product Design, and Supplier Relationship relationships with Social Performance; and the Supplier and Customer Relationship relationships with Environmental Performance. However, GSCM did not mediate the Customer Relationship–Social Performance relationship. This pattern indicates that the ability of GSCM to transmit the performance value of lean practices depends on both the specific LMP dimension and the sustainability outcome involved. This refines existing explanations of lean–green integration by identifying the conditions under which lean capabilities are translated into sustainability outcomes through GSCM (Dubey et al., 2017; Awan et al., 2022).

Third, the findings broaden the NRBV's applicability by highlighting the role of interorganizational relational capabilities in sustainability performance. Supplier Relationship positively affected both Social and Environmental Performance and operated through GSCM for both outcomes, whereas Customer Relationship directly affected both dimensions but operated through GSCM only for Environmental Performance. These differences indicate that supplier- and customer-facing capabilities do not generate sustainability value through identical pathways. The findings therefore add a relational perspective to the NRBV by showing that sustainability value can arise not only from internally developed capabilities but also from the firm's ability to mobilize and integrate capabilities across supply chain relationships.

Lastly, the contrasting results for Planning and Control offer a more nuanced understanding of lean–green complementarity. Planning and Control had a significant negative direct relationship with Social Performance, yet its indirect effect through GSCM was positive and significant. This indicates that the contribution of an operational capability may differ depending on whether it operates independently or through an environmentally oriented supply chain capability. The finding therefore suggests that complementarity between lean and green capabilities is not simply additive; rather, GSCM may alter the pathway through which an operational capability contributes to sustainability outcomes. This provides a more process-oriented extension of the NRBV by emphasizing the importance of capability configuration in explaining how sustainability value is generated.

Practical Implications and Proposed Strategic Plan for PEZA

The combined findings provide an empirical basis for PEZA to strengthen sustainable manufacturing through targeted lean-green initiatives rather than uniform interventions across all organizational practices. Accordingly, the proposed strategic plan focuses on strengthening sustainability measurement, organizational capabilities, stakeholder collaboration, and green supply chain integration, while addressing areas needing further improvement, including carbon monitoring, eco-design, supplier capability development, and reverse logistics.

Table 16. Proposed Five-Year Strategic Plan for PEZA

Implementation Phase	Strategic Priority	Key PEZA Initiatives
Year 1: Sustainability Foundation	Establish reliable sustainability baselines	Strengthen carbon, energy, water, waste, and resource-efficiency monitoring; establish common sustainability indicators and awareness programs.
Year 2: Smart Manufacturing and Industrial Innovation	Strengthening operational and product-related capabilities	Support equipment modernization, digitalization, predictive maintenance, resource-efficient product design, and lean-green capability development.
Year 3: ESG Transparency and	Improve sustainability measurement and	Establish benchmarking, sustainability reporting guidance, recognition

Alignment	stakeholder engagement	programs, stakeholder engagement mechanisms, and internationally aligned ESG indicators.
Year 4: Integrated Green Supply Chain Leadership	Extend sustainability across supplier and customer relationships	Strengthen green procurement, supplier capability development, customer sustainability collaboration, eco-design, reverse logistics, product recovery, and circular-economy initiatives.
Year 5: Sustainable Manufacturing Hub Leadership	Institutionalize and expand integrated lean-green practices	Integrate successful programs, promote inter-agency and industry collaboration, share best practices, and position PEZA zones as sustainable manufacturing leaders.

The proposed five-year strategic plan translates the findings into a clear, progressive institutional direction for PEZA. The sequence begins with establishing reliable sustainability information and strengthening organizational capabilities, then advances to stakeholder engagement and integrated green supply chain practices. This progression reflects the finding that LMP's contribution to SP varies across financial, social, and environmental outcomes and that GSCM provides an important pathway for selected lean practices. By strengthening product-related capabilities, supplier and customer collaboration, and green supply chain integration, the proposed plan provides PEZA with a structured approach to supporting sustainable manufacturing among its registered enterprises.

CONCLUSIONS

The study found high levels of SP, LMP implementation, and GSCM among PEZA-registered multinational manufacturing companies in Laguna, though specific areas warrant further attention. Carbon reduction, social sustainability, eco-design, supplier capability development, and reverse logistics emerged as areas for continued improvement. Analyses further showed that the effects of lean practices varied across financial, social, and environmental performance, and that GSCM mediated selected relationships rather than serving as a common pathway for all lean practices and sustainability outcomes.

These findings demonstrate that the relationships among LMP, GSCM, and SP are dimension- and outcome-specific rather than uniform, underscoring the importance of integrating lean and green practices in line with the sustainability areas being addressed. The findings provide an empirical basis for PEZA to pursue targeted initiatives that strengthen resource efficiency, product sustainability, supplier and customer collaboration, and green supply chain integration, thereby supporting the continued development of sustainable manufacturing among PEZA-registered enterprises.

Recommendations

Based on the findings, PEZA may consider using the proposed five-year strategic plan presented in Table 16 as an institutional guide for strengthening the integration of lean manufacturing and green supply chain practices among its registered manufacturing locators. Implementation may begin with common sustainability indicators and baseline monitoring for carbon emissions, energy, water, waste, and resource efficiency, followed by initiatives on technological capability, ESG reporting, sustainability benchmarking, eco-design, supplier development, reverse logistics, and circular-economy practices. PEZA may facilitate these initiatives through technical assistance, capability-building activities, recognition mechanisms, and collaboration with relevant government agencies, industry associations, academic institutions, and

supply chain partners.

PEZA-registered multinational manufacturing companies may further align operational practices with environmental and social objectives. Greater attention may be given to resource-efficient product design, supplier capability development, customer sustainability engagement, and green supply chain integration, while employee development and sustainability responsibilities may be integrated into capability-building and performance systems. Supplier and customer collaboration may also be expanded to include environmental requirements, sustainability communication, product feedback, responsible sourcing, take-back arrangements, and other product recovery initiatives.

Companies may also adopt an integrated monitoring approach to assess whether improvements in lean and green practices translate into measurable financial, social, and environmental outcomes. Because the findings indicate that GSCM mediates selected rather than all relationships between LMP and SP, sustainability programs may be tailored to the specific capability and performance outcome being addressed, rather than assuming that the same lean-green interventions will produce uniform results.

LIMITATION & FURTHER RESEARCH

The findings should be interpreted in light of several limitations. First, using one respondent per company may have introduced perceptual and common method bias and may not fully capture differences across functional areas. Although the revised full-collinearity assessment showed FCVIF values below the applied threshold of 3.3, the possibility of common method bias cannot be completely ruled out given the single-source, self-reported nature of the data. Second, the study was limited to PEZA-registered multinational manufacturing companies in Laguna that implemented LMP and GSCM, limiting the generalizability of the findings to other regions, industries, non-PEZA firms, and companies with limited or no lean implementation. Third, the measurement reassessment involved post hoc, theoretically and statistically justified indicator deletions to address item redundancy, cross-construct overlap, and collinearity. Although the retained constructs demonstrated acceptable reliability and the revised FCVIF values met the applied criterion, the resulting measurement structure warrants validation in independent samples and other manufacturing contexts. Differences in corporate culture and environmental requirements across the multinational firms' countries of origin were also not examined. Finally, the cross-sectional design captured LMP, GSCM, and SP at a single point in time and therefore limits causal inference and the assessment of how these relationships develop over time.

Further research may validate the revised measurement structure and extend the study to other economic zones, regions, industries, and non-PEZA or non-lean manufacturing firms to assess the robustness and generalizability of the findings. Future studies may also collect responses from multiple functional areas within each company and employ longitudinal or multi-source designs to mitigate common method bias and examine changes in lean-green integration and sustainable performance over time. Comparative studies may investigate whether country of origin, corporate culture, or environmental regulatory requirements influence the relationships among LMP, GSCM, and SP. Finally, additional mediating or moderating factors may be examined to explain why some lean practices influence sustainability outcomes directly, while others operate through GSCM or other mechanisms.

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