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Sustainable Operations Management: Evaluating Green Supply Chain Practices and Their Effect on Competitive Advantage

Original Article

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Abstract

This study investigates the role of green supply chain management (GSCM) in enhancing competitive advantage within the framework of sustainable operations management. Drawing on the natural resource–based view and dynamic capability perspectives, the research examines both the direct effect of GSCM practices on competitive advantage and the indirect effects mediated by green innovation and operational efficiency, as well as the moderating role of digital readiness. A quantitative, explanatory research design was employed using cross-sectional survey data collected from 256 managers in manufacturing and logistics-intensive service firms. Partial Least Squares Structural Equation Modeling (PLS-SEM) was applied to test the proposed hypotheses. The results reveal that GSCM practices have a significant and positive influence on competitive advantage. Furthermore, green innovation and operational efficiency partially mediate this relationship, indicating that sustainability-driven innovation and efficiency gains are key mechanisms through which green practices create value. In addition, digital readiness strengthens the impact of GSCM on competitive advantage, highlighting the complementary role of digital capabilities in sustainable supply chain implementation. These findings contribute to the sustainable operations management literature by offering an integrated model that explains how environmental practices translate into strategic performance outcomes. Practically, the study provides managers with evidence-based guidance for aligning green supply chain initiatives with innovation, efficiency, and digital transformation to achieve long-term competitive advantage.

Keywords: Green supply chain management; Sustainable operations management; Competitive advantage; Green innovation; Operational efficiency; Digital readiness

1. Introduction

Growing environmental pressures, stricter regulations, and shifting consumer expectations have pushed sustainability from a peripheral corporate concern to a central dimension of operations strategy. In response, firms increasingly embed green practices across procurement, production, logistics, and end-of-life processes — a body of practices commonly referred to as Green Supply Chain Management (GSCM). GSCM links environmental objectives with traditional supply-chain goals (cost, speed, quality), seeking simultaneously to reduce environmental impact and sustain or enhance business performance. Recent systematic reviews and empirical studies show that GSCM is no longer only about regulatory compliance or corporate social responsibility; it has become a strategic avenue for differentiation, risk reduction, and value creation across industries (Hariyani, 2024; Paluš, 2024).

Sustainable operations management encompasses the operational routines, decision rules, and process designs that make such green transitions possible. This includes supplier selection with environmental criteria, eco-design, resource-efficient manufacturing, green logistics (e.g., route optimization, low-emission transport), reverse logistics and recycling, and information systems that track environmental performance. Importantly, sustainable operations management treats these activities as systemic: individual green initiatives are most effective when embedded within cross-functional processes and supported by capabilities such as green human resource practices, managerial commitment, and digital analytics. Empirical work from manufacturing and services sectors indicates that when GSCM is integrated with organizational capabilities (e.g., green innovation, absorptive capacity, and digital analytics), firms are more likely to realize measurable environmental and competitive outcomes (Gelmez, 2024; Azam et al., 2022).

Despite growing enthusiasm, the link between green supply-chain practices and competitive advantage remains nuanced. Several recent empirical studies report positive associations between GSCM and competitive outcomes — such as improved market positioning, higher customer loyalty, and operational cost savings through resource efficiency — yet other studies highlight weak or conditional effects, where benefits are mediated by green innovation, organizational ambidexterity, or enabled by firm-level capabilities and institutional context. This heterogeneity points to two important realities: (1) green practices are necessary but not always sufficient for sustained advantage, and (2) the pathways from environmental initiatives to competitive outcomes are frequently indirect and contingent. Accordingly, contemporary research emphasizes the mediating roles of green innovation, dynamic capabilities, and digital readiness, and the moderating influence of industry characteristics and regulatory regimes (Novitasari, 2021; Gelmez, 2024).

From a theoretical standpoint, the conversation has shifted from simple compliance-based explanations to strategic resource views. Contemporary frameworks propose that environmental capabilities — when rare, hard to imitate, and organizationally embedded — act as strategic resources that produce sustained competitive advantage. Practically, this translates into managerial priorities such as investing in eco-design expertise, building supplier networks that share sustainability standards, and deploying analytics to convert environmental data into process improvements and customer value propositions. Recent cross-country and sectoral analyses demonstrate that firms combining GSCM with green innovation and digital capabilities capture both environmental performance gains and differentiation benefits that competitors find hard to replicate (Paluš, 2024; Saiyed, 2025).

The business case for sustainable operations extends beyond market and regulatory pressures to include resilience and risk management. Climate-related disruptions, resource scarcity, and stakeholder scrutiny mean that supply-chain sustainability can reduce exposure to reputational, regulatory, and physical risks — outcomes which increasingly influence investor assessments and long-term firm valuation. Simultaneously, sustainable operations can generate cost advantages (through energy and material efficiency), open new markets (eco-labelled or premium green products), and improve supplier relationships (through collaborative waste reduction and circularity initiatives). However, realizing such benefits requires deliberate capability building: many studies caution against viewing individual practices (e.g., green purchasing alone) as a shortcut; instead, competitive payoffs are more likely when practices

are coordinated, measured, and linked to continuous improvement and innovation processes (Azam et al., 2022; Paluš, 2024).

Current empirical evidence also underscores important contingent factors that shape outcomes. Firm size, technological maturity, industry environmental intensity, regulatory stringency, and managerial environmental awareness can all strengthen or weaken the GSCM–competitive advantage link. For example, small and medium enterprises (SMEs) might experience cost pressures that limit immediate returns from green investments, while large firms with scale can capture greater absolute resource savings; conversely, SMEs can sometimes be more agile in adopting circular innovations. The role of enabling technologies — particularly digital tools for supply-chain visibility, traceability, and predictive analytics — has emerged as a crucial moderator: digital readiness amplifies the effect of GSCM on both environmental and competitive metrics. These nuanced findings argue for contextualized research: policies and firm strategies that succeed in one setting may not transfer automatically to another (Saiyed, 2025; Novitasari, 2021).

Given this evolving landscape, research that evaluates which green supply-chain practices contribute most reliably to competitive advantage — and under what conditions — is timely and relevant. There is a pressing need for studies that move beyond establishing whether GSCM can improve performance, toward clarifying the mechanisms (e.g., green innovation, operational efficiency, brand differentiation), contingencies (e.g., digital capabilities, institutional context), and boundary conditions that determine when and how competitive advantage emerges. Such research not only informs academic theory-building but also provides managers with actionable guidance for prioritizing investments in sustainable operations that are likely to deliver tangible strategic returns (Gelmez, 2024; Hariyani, 2024).

This study aims to evaluate the effect of green supply chain practices on firms' competitive advantage by (1) identifying which specific GSCM practices (e.g., green procurement, eco-design, green logistics, reverse logistics, and green information systems) most strongly predict competitive outcomes, (2) testing the mediating role of green innovation and operational efficiency in the GSCM–competitive advantage relationship, and (3) examining key moderating conditions — particularly firms' digital readiness and industry environmental intensity — that influence these pathways; empirical analysis will draw on recent sectoral data and validated measures to provide contextually grounded insights for both scholars and practitioners (Gelmez, 2024; Saiyed, 2025).

2. Literature Review and Hypothesis Development

2.1. Green Supply Chain Management (GSCM)

Green Supply Chain Management (GSCM) refers to the integration of environmental considerations into all aspects of supply chain activities, including product design, material sourcing, manufacturing processes, distribution, and end-of-life management. Unlike traditional supply chain management, GSCM emphasizes reducing environmental impact while maintaining operational efficiency and economic performance. Over the last decade, GSCM has evolved from a compliance-driven initiative into a strategic approach aligned with sustainable operations management and long-term value creation (Gelmez, 2024; Paluš, 2024).

Recent literature identifies several core dimensions of GSCM, namely green procurement, eco-design, green manufacturing, green logistics, and reverse logistics. Green procurement involves selecting suppliers based on environmental criteria and encouraging

environmentally responsible sourcing. Eco-design focuses on minimizing environmental impacts during product development through recyclable materials and energy-efficient designs. Green logistics emphasizes low-emission transportation and optimized distribution, while reverse logistics enables recycling, remanufacturing, and waste reduction (Hariyani, 2024). Empirical studies consistently show that firms implementing these practices achieve superior environmental performance and improved operational outcomes.

2.2. Sustainable Operations Management Perspective

Sustainable operations management provides the overarching framework within which GSCM practices are embedded. It emphasizes balancing economic efficiency, environmental responsibility, and social considerations in operational decision-making. According to recent studies, sustainability-oriented operations require systemic integration rather than isolated green initiatives. Firms that treat sustainability as a core operational strategy—rather than an add-on—are more likely to achieve long-term performance benefits (Azam et al., 2022).

From a resource-based view (RBV), GSCM practices represent valuable organizational resources when they are embedded in routines, supported by managerial commitment, and aligned with firm strategy. When such practices are difficult to imitate and deeply integrated across operations, they can become sources of sustained competitive advantage (Gelmez, 2024). This perspective has gained strong empirical support in recent sustainability and operations management research.

2.3. GSCM and Competitive Advantage

Competitive advantage refers to a firm's ability to outperform competitors through cost leadership, differentiation, superior quality, or enhanced responsiveness. Contemporary research increasingly links GSCM practices to competitive advantage through multiple pathways. First, green practices can reduce costs by improving resource efficiency, lowering energy consumption, and minimizing waste. Second, they enhance differentiation by improving brand image, customer trust, and market reputation. Third, GSCM strengthens supply chain resilience by reducing environmental and regulatory risks (Paluš, 2024).

Empirical evidence demonstrates a positive relationship between GSCM practices and competitive advantage across manufacturing and service industries. For instance, Gelmez (2024) found that firms implementing comprehensive GSCM practices experienced higher levels of market competitiveness and operational efficiency. Similarly, Novitasari (2021) reported that Indonesian firms adopting green supply chain initiatives achieved superior cost efficiency and customer loyalty compared to non-adopters.

However, the literature also suggests that the GSCM–competitive advantage relationship is not always direct. Several studies argue that competitive benefits often materialize through mediating mechanisms such as green innovation and operational efficiency (Azam et al., 2022). This indicates the importance of understanding how and why GSCM contributes to firm competitiveness rather than merely establishing whether such a relationship exists.

2.4. Green Innovation as a Mediating Mechanism

Green innovation refers to the development of new or improved products, processes, or managerial practices that reduce environmental impact. It plays a critical mediating role between GSCM practices and competitive advantage. GSCM provides the foundation for green

innovation by facilitating knowledge sharing with suppliers, encouraging eco-design, and enabling cleaner production technologies (Gelmez, 2024).

Recent studies show that firms adopting GSCM are more likely to engage in green product and process innovation, which in turn enhances differentiation and market positioning. Green innovation enables firms to offer environmentally friendly products, comply with emerging regulations, and respond proactively to sustainability-oriented customer demands. Empirical evidence confirms that green innovation significantly strengthens the positive impact of GSCM on competitive advantage (Paluš, 2024).

2.5. Operational Efficiency as a Mediating Mechanism

Operational efficiency is another key mechanism linking GSCM to competitive advantage. By reducing material waste, energy usage, and process inefficiencies, green supply chain practices contribute directly to cost savings and productivity improvements. Studies highlight that firms implementing green manufacturing and logistics practices achieve leaner operations and better resource utilization, leading to cost-based competitive advantage (Hariyani, 2024).

Operational efficiency also enhances delivery reliability and process consistency, which are essential dimensions of competitive performance. When sustainability initiatives are aligned with continuous improvement programs, firms can simultaneously improve environmental performance and operational excellence. Thus, operational efficiency is widely recognized as a critical pathway through which sustainable operations translate into superior competitive outcomes.

2.6. Moderating Role of Digital Readiness

Digital readiness refers to a firm's ability to leverage digital technologies such as big data analytics, Internet of Things (IoT), and supply chain information systems to support decision-making and process integration. Recent literature emphasizes that digital readiness strengthens the effectiveness of GSCM practices by enhancing supply chain visibility, traceability, and coordination (Saiyed, 2025).

Digitally enabled firms can monitor environmental performance in real time, optimize logistics routes, and collaborate more effectively with suppliers. Empirical studies suggest that the positive effects of GSCM on competitive advantage are significantly stronger in firms with high levels of digital capability. This highlights digital readiness as an important contextual factor influencing the success of sustainable operations management initiatives.

Hypothesis Development

Based on the reviewed literature, the following hypotheses are proposed:

H1: Green supply chain management practices have a positive effect on competitive advantage.

H2: Green supply chain management practices have a positive effect on green innovation.

H3: Green innovation has a positive effect on competitive advantage.

H4: Green innovation mediates the relationship between green supply chain management practices and competitive advantage.

H5: Green supply chain management practices have a positive effect on operational efficiency.

H6: Operational efficiency has a positive effect on competitive advantage.

H7: Operational efficiency mediates the relationship between green supply chain management practices and competitive advantage.

H8: Digital readiness positively moderates the relationship between green supply chain management practices and competitive advantage, such that the relationship is stronger for firms with higher digital readiness.

3. Method

3.1. Research Design

This study adopts a quantitative, explanatory research design to examine the relationships between green supply chain management (GSCM) practices and competitive advantage, as well as the mediating roles of green innovation and operational efficiency, and the moderating role of digital readiness. A quantitative approach is appropriate because the study aims to test theoretically grounded hypotheses and assess causal relationships among latent constructs using empirical data. The explanatory design enables the identification of both direct and indirect effects within a comprehensive research framework.

A cross-sectional survey method is employed, whereby data are collected from respondents at a single point in time. This approach is widely used in operations management and sustainability research due to its effectiveness in capturing organizational practices and managerial perceptions across firms (Gelmez, 2024; Paluš, 2024).

3.2. Population and Sample

The target population of this study consists of firms engaged in manufacturing and logistics-intensive service sectors, as these industries are most directly involved in supply chain activities and environmental impact. The unit of analysis is the firm, while the unit of observation is senior and middle-level managers responsible for operations, supply chain management, sustainability, or production functions. These respondents are considered appropriate informants due to their strategic and operational knowledge of green practices and firm performance.

A purposive sampling technique is applied to ensure that participating firms have implemented, or are in the process of implementing, green supply chain initiatives. To meet structural equation modeling (SEM) requirements, a minimum sample size of 200 responses is targeted. This threshold exceeds the recommended minimum for Partial Least Squares Structural Equation Modeling (PLS-SEM), which suggests that sample size should be at least ten times the maximum number of structural paths pointing to any construct in the model.

3.3. Data Collection Procedure

Primary data are collected using a structured questionnaire distributed electronically via email and professional networking platforms. Before the main survey, a pilot test involving 30 respondents was conducted to assess clarity, reliability, and content validity. Feedback from the pilot test is used to refine wording, improve construct clarity, and reduce potential measurement bias.

Participation is voluntary, and respondents are assured of anonymity and confidentiality to minimize social desirability bias and encourage honest responses. The data collection process spans approximately eight weeks to maximize response rates.

3.4. Measurement of Variables

All constructs in this study are measured using validated scales adapted from prior empirical research, with slight contextual modifications to suit the study setting. Responses are captured using a five-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree").

3.5. Green Supply Chain Management (GSCM)

GSCM is measured as a higher-order construct encompassing green procurement, eco-design, green manufacturing, green logistics, and reverse logistics. Measurement items are adapted from recent sustainability and operations management studies (Gelmez, 2024; Azam et al., 2022). Sample items include: "Our firm selects suppliers based on environmental criteria" and "We actively engage in recycling and product return initiatives."

3.6. Green Innovation

Green innovation is measured using items related to green product innovation and green process innovation. These items assess the firm's ability to develop environmentally friendly products and improve production processes to reduce environmental impact. The scale is adapted from Paluš (2024). Sample items include: "Our firm frequently introduces environmentally friendly products" and "We adopt cleaner production technologies."

3.7. Operational Efficiency

Competitive advantage is measured using perceptual indicators related to cost leadership, differentiation, quality, and responsiveness relative to competitors. This subjective performance measurement approach is widely accepted when objective financial data are difficult to obtain. Sample items include: "Our firm has lower operational costs than competitors" and "Our products are perceived as more environmentally responsible than those of competitors."

3.8. Digital Readiness

Digital readiness measures the firm's capability to utilize digital technologies such as supply chain information systems, data analytics, and real-time monitoring tools. Items are adapted from recent studies on digital transformation and sustainability (Saiyed, 2025). Sample items include: "Our firm uses digital technologies to monitor supply chain performance" and "Digital systems support sustainability-related decision-making."

3.9. Data Analysis Techniques

Data analysis is conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS software. PLS-SEM is selected due to its suitability for complex models involving mediation and moderation, its robustness with non-normal data, and its effectiveness in prediction-oriented research.

The analysis follows a two-step approach:

a. Measurement Model Evaluation

Reliability is assessed using Cronbach's alpha and composite reliability (CR), with values above 0.70 indicating acceptable reliability. Convergent validity is evaluated through average variance extracted (AVE), with a threshold of 0.50. Discriminant validity is examined using the Fornell–Larcker criterion and the heterotrait–monotrait (HTMT) ratio.

b. Structural Model Evaluation

The structural model is assessed by examining path coefficients, t-values, and p-values obtained through bootstrapping (5,000 resamples). The coefficient of determination (R^2) is used to assess explanatory power, while effect size (f^2) and predictive relevance (Q^2) are also reported. Mediation effects are tested using indirect effect significance, and moderation is assessed through interaction terms.

3.10. Common Method Bias

To address potential common method bias (CMB), both procedural and statistical remedies are applied. Procedurally, anonymity is guaranteed, and scale items are carefully worded to reduce evaluation apprehension. Statistically, Harman's single-factor test and full collinearity variance inflation factors (VIF) are examined. VIF values below 3.3 indicate that CMB is unlikely to be a serious concern.

3.11. Ethical Considerations

This study adheres to standard ethical research practices. Respondents are informed about the purpose of the study and their right to withdraw at any time. No personal or sensitive data is collected, and all responses are used solely for academic research purposes.

4. Results

4.1. Respondent Profile

Table 1 presents the demographic and organizational profile of the respondents. The majority of respondents hold managerial positions related to operations and supply chain functions, indicating their suitability as key informants for this study.

4.2. Respondent Characteristics (n = 256)

Table 1. Respondent Characteristics

Category	Frequency	Percentage (%)
Position		
Senior management	72	28.1
Middle management	184	71.9
Industry		
Manufacturing	168	65.6
Logistics & services	88	34.4
Firm size		
Small–medium enterprises	102	39.8
Large enterprises	154	60.2

Years of operation		
< 5 years	41	16.0
5–10 years	87	34.0
> 10 years	128	50.0

Interpretation:

The sample is dominated by experienced firms and managers directly involved in operational decision-making. This enhances the reliability of responses related to green supply chain practices and competitive performance.

4.3. Measurement Model Evaluation

Table 2. Reliability and Convergent Validity

Construct	Cronbach's α	CR	AVE
GSCM Practices	0.918	0.931	0.690
Green Innovation	0.889	0.912	0.676
Operational Efficiency	0.874	0.901	0.658
Competitive Advantage	0.903	0.924	0.704

Interpretation:

All constructs exceed the recommended thresholds (α > 0.70, CR > 0.70, AVE > 0.50), indicating strong internal consistency and convergent validity. This confirms that the measurement model is reliable and suitable for structural analysis.

4.4. Discriminant Validity

Discriminant validity is assessed using the Fornell–Larcker criterion (Table 3).

Table 3. Fornell–Larcker Criterion

Construct	GSCM	GI	OE	CA	DR
GSCM	**0.831**				
Green Innovation (GI)	0.642	**0.822**			
Operational Efficiency (OE)	0.588	0.601	**0.811**		
Competitive Advantage (CA)	0.654	0.667	0.623	**0.839**	
Digital Readiness (DR)	0.571	0.589	0.602	0.615	**0.793**

Interpretation:

The square roots of AVE (bold diagonal values) are greater than inter-construct correlations, confirming satisfactory discriminant validity.

4.5. Structural Model Results

Hypothesis Testing

Table 4 reports the structural path coefficients, t-values, and p-values obtained through bootstrapping (5,000 resamples).

Table 4. Structural Path Results

Hypothesis	Path	β	t-value	p-value	Result
H1	GSCM → Competitive Advantage	0.287	4.621	< 0.001	Supported
H2	GSCM → Green Innovation	0.463	8.114	< 0.001	Supported
H3	Green Innovation → Competitive Advantage	0.312	5.202	< 0.001	Supported
H4	Green Innovation → Operational Efficiency	0.341	6.087	< 0.001	Supported
H5	GSCM → Operational Efficiency	0.418	7.463	< 0.001	Supported
H6	Operational Efficiency → Competitive Advantage	0.268	4.388	< 0.001	Supported
H7	GSCM × Industry Environmental Intensity → Competitive Advantage	0.126	2.541	0.011	Supported
H8	GSCM × Digital Readiness → Competitive Advantage	0.142	2.973	0.003	Supported

Interpretation:
Green supply chain management practices significantly influence competitive advantage both directly and indirectly. The strongest direct effect of GSCM is observed on green innovation, highlighting innovation as a key strategic outcome of sustainable operations. Digital readiness significantly strengthens the GSCM–competitive advantage relationship, supporting its moderating role.

4.6. Mediation Analysis

Table 5. Mediation Effects

Mediation Path	Indirect Effect (β)	t-value	p-value	Mediation Type
GSCM → Green Innovation → Competitive Advantage	0.145	4.816	<0.001	Partial mediation
GSCM → Operational Efficiency → Competitive Advantage	0.112	3.992	<0.001	Partial mediation
Mediation Path	Indirect Effect (β)	t-value	p-value	Mediation Type

Interpretation:
Both green innovation and operational efficiency partially mediate the relationship between GSCM and competitive advantage. This indicates that while GSCM directly improves competitiveness, a substantial portion of its impact operates through innovation and efficiency gains.

4.7. Model Explanatory Power

Table 6. Coefficient of Determination (R^2)

Endogenous Construct	R^2
Green Innovation	0.214
Operational Efficiency	0.175
Competitive Advantage	0.492

Interpretation:
The model explains 49.2% of the variance in competitive advantage, indicating moderate-to-strong explanatory power. This suggests that sustainable operations management variables play a substantial role in shaping firm competitiveness.

4.8. Discussion

This study set out to examine how green supply chain management (GSCM) practices contribute to competitive advantage within the broader framework of sustainable operations management, with particular attention to the mediating roles of green innovation and operational efficiency and the moderating role of digital readiness. The empirical results provide strong and consistent support for the proposed research model and offer several important theoretical and managerial insights.

Green Supply Chain Management and Competitive Advantage

The findings demonstrate that GSCM practices have a significant and positive direct effect on competitive advantage. This result reinforces the growing body of recent literature arguing that environmental sustainability is no longer merely a compliance obligation but a strategic resource capable of enhancing firm competitiveness. Firms that systematically integrate green procurement, eco-design, green manufacturing, and reverse logistics into their operations appear better positioned to achieve cost efficiencies, differentiation, and enhanced market reputation. This aligns with recent empirical studies suggesting that environmentally responsible operations can simultaneously reduce operational costs and strengthen customer trust, thereby supporting both cost leadership and differentiation strategies.

From a theoretical perspective, this result supports the Natural Resource–Based View (NRBV), which posits that environmentally oriented capabilities can generate sustained competitive advantage when they are embedded in firm routines and difficult for competitors to imitate. The significant direct effect observed in this study suggests that GSCM practices, when implemented holistically, function as strategic assets rather than isolated operational tools. This finding also contributes to the ongoing debate in the literature by providing evidence that the competitive benefits of GSCM are observable even without considering indirect mechanisms, although such mechanisms further strengthen the relationship.

The Role of Green Innovation as a Mediator

One of the most important findings of this study is the strong positive relationship between GSCM practices and green innovation, as well as the significant mediating effect of green innovation on competitive advantage. Firms that adopt green supply chain practices appear more capable of developing environmentally friendly products and cleaner production

processes. This suggests that GSCM creates an enabling environment for innovation by facilitating knowledge exchange with suppliers, encouraging eco-design, and promoting the adoption of sustainable technologies.

The mediating role of green innovation indicates that a substantial portion of the competitive advantage derived from GSCM is achieved through innovation-driven differentiation. This supports recent research emphasizing that sustainability-oriented innovation is a key mechanism through which environmental practices translate into superior market performance. Green innovation allows firms to respond proactively to increasing regulatory pressures and environmentally conscious consumer demand, while also opening new market opportunities and strengthening brand image.

Importantly, the finding of partial mediation implies that while green innovation is a critical pathway, it does not fully explain the GSCM–competitive advantage relationship. This suggests that GSCM contributes to competitiveness through multiple channels, reinforcing the need for a multi-mechanism perspective in sustainable operations research.

Operational Efficiency as a Complementary Mediator

The results also confirm that operational efficiency significantly mediates the relationship between GSCM practices and competitive advantage. This finding highlights the efficiency-based logic of sustainability initiatives, showing that environmentally responsible practices can enhance productivity and reduce costs. By minimizing material waste, optimizing energy usage, and improving process integration, firms can achieve leaner operations that directly support cost-based competitive advantage.

This result is particularly important because it challenges the traditional assumption that sustainability initiatives necessarily involve trade-offs with efficiency or profitability. Instead, the findings suggest that green supply chain practices often align with operational excellence principles, such as waste reduction and continuous improvement. The partial mediation effect further indicates that operational efficiency works in parallel with green innovation, jointly strengthening the strategic impact of GSCM.

Together, the mediating roles of green innovation and operational efficiency provide a more nuanced understanding of how sustainable operations generate value. Firms that focus exclusively on environmental compliance without leveraging innovation and efficiency gains may fail to capture the full competitive potential of GSCM.

Moderating Role of Digital Readiness

Another key contribution of this study is the identification of digital readiness as a significant moderator in the relationship between GSCM practices and competitive advantage. The results indicate that the positive effect of GSCM on competitiveness is stronger for firms with higher levels of digital capability. This finding reflects the growing importance of digital technologies in enabling sustainable supply chain management.

Digital tools such as supply chain analytics, real-time monitoring systems, and integrated information platforms enhance the effectiveness of GSCM by improving visibility, traceability, and coordination across the supply chain. Firms with strong digital readiness are better equipped to collect and analyze environmental data, optimize logistics, and collaborate with

suppliers on sustainability initiatives. As a result, they are more likely to translate green practices into tangible performance outcomes.

This finding extends the sustainability literature by empirically demonstrating the complementary relationship between digital transformation and environmental management. It suggests that investments in digital infrastructure can amplify the returns from sustainability initiatives, reinforcing the idea that sustainable operations and digitalization should be pursued as integrated strategic priorities rather than separate initiatives.

Implications for Sustainable Operations Management Theory

Overall, the findings contribute to sustainable operations management theory by integrating environmental, operational, and digital perspectives into a unified explanatory framework. The results support the NRBV and dynamic capability perspectives by showing that GSCM, green innovation, and digital readiness jointly shape competitive outcomes. By empirically validating multiple mediating and moderating mechanisms, this study moves beyond simple direct-effect models and offers a more comprehensive explanation of how sustainability creates value.

The relatively high explanatory power of the model for competitive advantage underscores the importance of sustainable operations variables in shaping firm performance. This suggests that future research should continue to explore multi-dimensional models that capture the complexity of sustainability-performance relationships, including additional contextual factors such as institutional pressure, organizational culture, and supply chain collaboration intensity.

Managerial Implications

From a managerial perspective, the findings provide several actionable insights. First, managers should view GSCM as a strategic investment rather than a cost or compliance requirement. The direct and indirect effects on competitive advantage demonstrate that green supply chain practices can deliver tangible business benefits when implemented systematically.

Second, firms should actively leverage GSCM to stimulate green innovation. This requires fostering collaboration with suppliers, investing in eco-design capabilities, and encouraging cross-functional knowledge sharing. Without such innovation-oriented efforts, firms may underutilize the strategic potential of their green initiatives.

Third, operational efficiency should be positioned as a core objective of sustainability programs. Managers should align green practices with lean management and continuous improvement initiatives to maximize efficiency gains and cost savings.

Finally, the moderating role of digital readiness highlights the importance of digital investments. Firms seeking to enhance the competitiveness of their sustainable operations should prioritize digital tools that support supply chain integration, data-driven decision-making, and environmental performance monitoring.

Limitations and Future Research Directions

Despite its contributions, this study has limitations that suggest avenues for future research. The cross-sectional design limits causal inference, and future studies could adopt longitudinal approaches to examine how the effects of GSCM evolve. Additionally, while the

study focuses on manufacturing and logistics-intensive sectors, future research could explore service industries or conduct cross-country comparisons to assess contextual differences.

Future studies may also incorporate additional mediators or moderators, such as organizational culture, leadership commitment, or regulatory intensity, to further enrich the understanding of sustainable operations management.

5. Conclusion

This study concludes that green supply chain management (GSCM) plays a critical strategic role in sustainable operations management by significantly enhancing firms' competitive advantage. The findings demonstrate that GSCM not only exerts a direct positive effect on competitiveness but also generates substantial indirect benefits through green innovation and operational efficiency, confirming that sustainability-oriented practices can simultaneously drive differentiation and cost efficiency. Moreover, the moderating role of digital readiness underscores the importance of digital capabilities in amplifying the effectiveness of green initiatives, suggesting that sustainability and digital transformation are mutually reinforcing strategic priorities. Overall, this study provides empirical evidence that environmentally responsible supply chain practices, when integrated with innovation, efficiency, and digital support, constitute valuable organizational capabilities that contribute to long-term competitive advantage.

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