

Article

Disentangling Technical and Behavioral Green Supply Chain Management Practices: The Mediating Role of Green Innovation Culture in Logistics Firms' Triple-Bottom-Line Performance

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Abstract

Background: Although green supply chain management (GSCM) has been widely examined, prior studies have often treated it as a homogeneous construct and have paid limited attention to how different types of GSCM practices operate in logistics firms. This study addresses this gap by distinguishing between technical GSCM practices and behavioral GSCM practices and examining how both dimensions influence organizational performance through green innovation culture (GIC). **Methods:** Drawing on data from a cross-sectional survey of 426 logistics practitioners involved in supply chain, operations, and sustainability-related functions in Guangzhou, China, the study tested the proposed model using structural equation modeling (SEM). **Results:** Both technical and behavioral GSCM practices positively influence GIC, with behavioral practices having a stronger effect. GIC significantly improves organizational performance. Technical and behavioral GSCM practices also directly enhance organizational performance, indicating partial mediation. The indirect effect of behavioral GSCM practices through GIC is stronger, suggesting that behavioral governance is especially important for developing an innovation-oriented green culture. **Conclusions:** The study advances GSCM and green innovation literature and suggests logistics firms can achieve more sustainable performance improvements by combining technological upgrading with leadership support, employee involvement, stakeholder collaboration, and an innovation-oriented green culture.

Keywords: green supply chain management; technical GSCM practices; behavioral GSCM practices; green innovation culture; organizational performance



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1. Introduction

Global temperatures are still rising, and environmental sustainability remains a crucial issue across all sectors. The logistics sector is gradually being regarded as a key industry in the sustainability revolution since it links production, circulation, and consumption on a large scale [1]. With the increasing time sensitivity and service intensity of supply chains, logistics companies are experiencing mounting pressures to be highly efficient and less environmentally impactful [2]. This pressure has been amplified in China with the increase in e-commerce and the further development of the national freight and express delivery networks that have boosted the rate of transportation, warehousing turnovers, and packaging consumption in the normal operations [3].

The importance of green logistics is increasingly evident from recent global and regional trends. Globally, energy-related CO₂ emissions reached a record high of 37.8 Gt in 2024, while freight transportation and logistics activities account for approximately 8% of global greenhouse gas emissions, with freight demand expected to roughly double by 2050. In China, logistics growth has been particularly rapid: total social logistics value reached CNY 360.6 trillion in 2024, up 5.8% year on year, and the express delivery sector handled 174.5 billion parcels, up 21% from the previous year. Guangzhou is a highly relevant context for this issue because Guangzhou Port recorded 680 million tons of cargo throughput and 26.45 million TEUs of container throughput in 2024, ranking among the world's leading ports. These trends show that logistics firms face increasing pressure to balance operational expansion, emission reduction, packaging waste control, and sustainable performance improvement [4].

The change is taking place in a policy context where green transformation is viewed as a strategic necessity rather than an alternative corporate endeavor. The national climate pledges of China and the overall concept of ecological civilization have created a clear goal of low-carbon development in industries, such as transportation and logistics [5]. Simultaneously, the fast growth of e-commerce and express delivery systems has increased the intensity of logistics operations, which has resulted in a steady increase in the volume of cargo, transportation frequency, energy use, and waste production during packaging, thus adding to the environmental impact of logistics operations [6]. Transport is still one of the biggest sources of carbon emissions in the country, where most of the transport-related energy consumption is contributed by the road freight industry because it relies heavily on fossil fuel and is characterized by fragmented operations [7]. In addition, the growth of distribution based on parcels has increased the use of disposable packaging material and put greater pressure on the efficiency of resources and waste management systems [8]. In particular, the national action plan to achieve carbon peaking emphasizes structural adjustment, energy efficiency enhancement, and green technology upgrade, which together impose highly demanding compliance and performance requirements on logistics companies. The policy requirements are further supported by the fact that the efficiency improvements have not completely balanced out the environmental effects caused by increased freight demand. At the same time, the focus of transport modernization plans is on the coordinated evolution of integrated transport systems and green transport capability, which reinforces the view that the efficiency of logistics and the reduction of emissions need to be pursued concurrently, not one after another [9]. Taken together, the convergence of regulatory pressure and sectoral expansion highlights the urgency of the logistics companies to incorporate a green supply chain management approach and build organizational capabilities that allow environmentally sustainable and performance-driven changes.

In such circumstances, logistics companies are faced with a pragmatic dilemma that has both operational and strategic aspects. On the other hand, companies are under pressure to go green through the use of energy-efficient transport and routing optimization, low-emission vehicle usage, energy-saving warehousing processes, ecologically friendly packaging management, and digital monitoring systems that will allow tracking of emissions and resources optimization [10]. Such practices indicate the technological and operational nature of green supply chain management, whereby there is process optimization, clean process execution, and environmentally conscious system and service design in logistic contexts. Conversely, companies compete in extremely competitive service markets, where the customers' demands on speed, reliability, and low cost are still primary, and the subcontracting, fragmented service chains, and short cycle performance indicators can deter the companies from investing in sustainability-related technologies and process redesign

over the long term [11]. Consequently, the implementation of sustainability initiatives can be inconsistent, pilot-driven, or compliance-driven instead of capability-driven. This results in a disconnect between policy aspirations and on-the-ground actions at the firm level, particularly in larger logistics hubs where the volume of operations is significant, and the coordination of organizations is complicated, which points to the need to consider the issue of the translation of both technological and behavioral GSCM practices into organizational capabilities that enable supporting green innovation and performance improvement over time in the logistics context. GSCM is an effective paradigm to resolve this issue since it correlates inner processes and outer supply chain relationships with the environmental goals and results [12]. Nevertheless, the adoption of GSCM in logistics does not happen in one uniform way.

There are normally at least two interrelated layers. Technical GSCM practices mean technology and process-based approaches, including low-carbon transportation systems, route optimization systems, warehouse energy saving management, tracking systems, and green packaging methods [13]. Behavior-based GSCM practices mean measures related to humans and organizations, including the environmental routine of employees, education and motivation, multi-functional cooperation, norm of supplier cooperation, and orderliness in their work activities [14]. Technical updates can be implemented more quickly in most businesses than behavioral changes that could lead to individual investments in equipment with no stable processes and teamwork. On the other hand, without technical support, behavioral commitment may be symbolic and have negligible quantitative outcomes. This implementation tension suggests that technical and behavioral practices need to be studied separately to comprehend the way logistics companies are really shifting their focus on green intentions toward performance enhancement.

Another issue is that the success of GSCM is not only dependent on the selection of certain practices but on whether the organization has a mechanism to promote learning, participation, and continuous improvement. A green innovation culture can be a mechanism. It is a reflection of common values, norms, and management that encourages environmental experimentation, interdepartmental cooperation, and problem-solving oriented towards innovation [15]. If green innovation culture is not robust, it is possible that green initiatives will be fragmented and short-lived, and that the operational teams will not see sustainability as an opportunity but as a burden. With a powerful green innovation culture, companies are able to combine their technical investments with the involvement of employees and supply chain management, which changes the role of GSCM as a compliance activity into an organizational capacity that facilitates not only sustainability but also competitiveness.

Although GSCM has been extensively examined, several gaps remain in the logistics context. First, much of the existing GSCM performance literature focuses on manufacturing firms [16], where green transformation is often associated with cleaner production, material efficiency, process engineering, and production technology. Logistics firms, however, operate under different conditions, including time-sensitive delivery, dispersed service networks, subcontracted capacity, route and warehouse coordination, and frequent interaction with customers and suppliers [17]. These characteristics suggest that manufacturing-based GSCM findings may not fully explain how green practices are implemented and converted into performance outcomes in logistics firms.

Second, prior studies have often treated GSCM as an aggregated construct, which may obscure the distinct roles of different green practice domains [18]. Technical GSCM practices mainly operate through technological upgrading, process control, cleaner operations, eco-design, and measurable resource optimization. Behavioral GSCM practices, by contrast, operate through leadership support, employee involvement, customer–supplier collaboration, shared responsibility, and relational coordination. Separating these two

dimensions is therefore conceptually important because logistics firms may rely on different technological-operational and behavioral-relational mechanisms when pursuing sustainability performance.

Third, although green organizational culture has been recognized as important, fewer studies have examined green innovation culture as a specific mechanism through which GSCM practices are translated into triple-bottom-line performance [19]. Based on these gaps, the central research question of this study is: How do technical and behavioral GSCM practices influence logistics firms' organizational performance, and through what mechanism does green innovation culture mediate this relationship? To answer this question, this study develops and tests a mediation model using data from logistics firms in Guangzhou, China.

The main novelties and contributions of this study are as follows:

It extends GSCM research to the logistics context, where sustainability transformation depends on both operational systems and service-network coordination.

It clarifies why manufacturing-based GSCM findings may be insufficient for explaining green transformation in logistics firms.

It separates technical and behavioral GSCM practices, offering a more fine-grained understanding of how different green practice domains influence organizational outcomes.

It positions green innovation culture as a mediating mechanism that translates GSCM practices into triple-bottom-line performance.

It provides empirical evidence from Guangzhou and offers practical implications for logistics firms pursuing green transformation.

2. Literature Review

2.1. Theoretical Approach

This study draws primarily on the resource-based view (RBV) and is further informed by dynamic capabilities theory to explain how different dimensions of green supply chain management (GSCM) practices shape logistics firms' triple-bottom-line performance. RBV argues that firms achieve sustained performance advantages when they possess and effectively deploy valuable, rare, inimitable, and non-substitutable resource bundles [20]. In the context of green logistics transformation, GSCM practices can be understood as strategic resource configurations that allow firms to reduce environmental burdens while improving operational efficiency and stakeholder legitimacy. However, these resources are not homogeneous. Technical GSCM practices and behavioral GSCM practices represent two analytically distinct but complementary resource domains [21].

Technical GSCM practices refer to technology- and process-oriented resources embedded in cleaner production, green operations, eco-design, environmental monitoring, and efficient logistics processes [22]. These practices operate mainly through process standardization, operational control, pollution prevention, and measurable resource optimization. By contrast, behavioral GSCM practices refer to intangible organizational and relational resources embedded in top management support, employee involvement, customer participation, and supplier collaboration [23]. These practices operate through commitment, coordination, shared responsibility, cross-functional learning, and inter-organizational alignment. This distinction is theoretically important because prior studies have often treated GSCM as an aggregated construct, thereby assuming that green practices work as a unified bundle and produce similar effects on organizational outcomes [24]. Such an approach may obscure whether sustainability performance is driven mainly by technological-operational mechanisms, behavioral-relational mechanisms, or their combined effects.

Although RBV explains why technical and behavioral GSCM practices can be regarded as valuable strategic resources, it does not fully explain how these resources are converted

into sustained organizational outcomes. Dynamic capabilities theory complements RBV by emphasizing a firm's ability to integrate, reconfigure, and renew its resource base in response to environmental demands and competitive pressures [25]. From this perspective, the performance value of GSCM practices does not arise automatically from their adoption. Instead, firms need an internal mechanism that translates green practices into shared routines, innovation-oriented behaviors, and continuous improvement processes. Green innovation culture plays this conversion role because it supports the interpretation, institutionalization, and routinization of environmental priorities within the organization [26].

Green innovation culture is therefore conceptualized as a mediator rather than a moderator in this study. A moderator would imply that green innovation culture merely strengthens or weakens the relationship between GSCM practices and performance. However, the logic of this study is that technical and behavioral GSCM practices actively shape green innovation culture by embedding environmental priorities into operational systems, managerial commitments, employee participation, and supply chain collaboration. In turn, green innovation culture converts these practices into organizational performance by encouraging green experimentation, knowledge sharing, implementation routines, and continuous improvement. Thus, green innovation culture is not merely a background condition, but an internal transformation mechanism through which GSCM practices are translated into economic, environmental, and social outcomes.

This positioning also extends prior mediation-based GSCM research. Recent empirical studies have shown that GSCM, green logistics, and green innovation can improve environmental performance, reputation, and broader sustainability outcomes [22,27]. However, many of these studies examine GSCM as an overall practice bundle or focus on mechanisms such as green innovation, external collaboration, or monitoring. Less attention has been paid to green innovation culture as a culture-based conversion mechanism linking different GSCM practice domains to triple-bottom-line performance. In this study, green innovation culture is reflected through firms' orientation toward green innovation, organizational support for green innovation activities, and the implementation of green innovation in day-to-day operations [28].

Organizational performance is conceptualized through the triple-bottom-line framework, which encompasses economic performance, environmental performance, and social performance. This broader performance lens is especially appropriate in logistics settings, where sustainability outcomes extend beyond financial efficiency to include ecological impact reduction, operational transparency, stakeholder responsibility, and social legitimacy. Taken together, RBV explains why technical and behavioral GSCM practices constitute important strategic resources, while dynamic capabilities theory clarifies how these resources are transformed into performance through green innovation culture. The theoretical contribution of this study lies in moving beyond an aggregated view of GSCM and proposing a mechanism-based explanation of how different green practice domains generate sustainability performance in logistics firms.

2.2. Hypothesis Development

In logistics firms, green supply chain practices may create short-term costs, operational disruptions, and coordination burdens. Technical GSCM practices, such as low-emission transport systems, green warehousing, digital monitoring, and eco-design, may require substantial investment and process redesign. If they are implemented as isolated compliance tools without sufficient employee capability or organizational support, they may fail to generate a green innovation culture or performance gains. Similarly, behavioral GSCM practices, such as employee participation, supplier collaboration, and customer involvement, may increase communication costs, create conflicts between environmental

standards and delivery efficiency, or become symbolic routines when managerial commitment is weak. Therefore, the positive effects of technical and behavioral GSCM practices are not automatic. They depend on whether these practices are effectively embedded into organizational routines and transformed into innovation-oriented capabilities. This makes the proposed hypotheses empirically meaningful rather than merely reflecting a general management assumption.

Technical GSCM practices refer to technology- and process-based green supply chain activities that reorganize operations to reduce environmental impact without undermining efficiency [29]. Green innovation culture, in turn, refers to shared values, norms, and organizational behaviors that make environmental experimentation and continuous improvement legitimate and feasible [19]. It is represented here by green innovation orientation, green innovation enablement, and green innovation implementation.

Technical GSCM practices can contribute to the development of a green innovation culture in several ways. First, the integration of eco-design and cleaner production into routine workflows embeds environmental considerations into daily decision-making and operational standards. As these practices become part of regular organizational processes, they can reinforce a longer-term sustainability orientation and strengthen the strategic direction of green innovation. Second, the adoption of green manufacturing systems and related monitoring mechanisms requires investments in infrastructure, employee skills, and internal knowledge systems. Such investments can strengthen organizational support for green experimentation, inter-functional learning, and the coordination needed to sustain environmentally oriented innovation activities. Third, technical green routines can generate measurable feedback, standardized procedures, and continuous improvement cycles, thereby facilitating the routinization and implementation of green initiatives across the organization.

Although logistics firms often operate under fragmented processes, tight delivery schedules, and extensive coordination demands, these contextual constraints do not negate the potential cultural effects of technical GSCM practices. Rather, they make the institutionalization of technical green routines even more important for building shared understandings, support systems, and implementation mechanisms around environmental innovation. Prior studies have also reported a persistent positive association between GSCM practices and green innovation, suggesting that technical GSCM can provide an important foundation for the development of an innovation-supportive green culture over time [30]. While this relationship should be verified in logistics settings, the theoretical logic suggests that technical GSCM practices are likely to foster a green innovation culture. However, technical GSCM practices may not necessarily foster a green innovation culture when they are implemented as isolated compliance tools or when employees lack the knowledge and autonomy to use them for innovation. In such cases, technical systems may improve monitoring but fail to create a shared cultural commitment to green innovation. Therefore, the following hypothesis is proposed:

H1. *Technical GSCM practices have a positive effect on green innovation culture.*

The behavioral practices of GSCM are described as the human, managerial, and relational behavior of the organization members and supply chain participants to ensure that green priorities are constantly implemented throughout the organization, and as such, they will be manifested in the form of support of the top management, involvement of employees, and participation of customers and suppliers [24]. The green innovation culture is described as the values, norms, and routines that provide legitimacy to and support environmental experimentation and ongoing improvement, and its reflection in this study is in terms of green innovation orientation, green innovation enablement, and

green innovation implementation [15]. The support of top management enhances green innovation orientation by making sustainability a strategic focus, providing an indication of legitimacy in green experimentation, and lessening the internal uncertainty that usually inhibits the innovation process [23]. The participation of employees has a positive effect on green innovation enablement since extensive engagement in green programs enhances collective environmental awareness, enhances problem-solving skills, and strengthens cross-functional cooperation practices, which allow conducting green experimentation in regular job operations. The inclusion of customers and suppliers in green innovation implementation is facilitated by the alignment of green standards and the ability to learn together, develop together, and provide iterative feedback across organizational borders, which makes green innovation a repeatable process instead of a one-off undertaking. A consistent positive association between collaborative green supply chain behaviors and green innovation further supports the expectation that behavioral GSCM practices cultivate a supportive cultural environment in which sustainability-oriented ideas are encouraged, resourced, and executed over time [31]. Nevertheless, behavioral GSCM practices may also produce coordination burdens if participation and collaboration are poorly designed. Excessive meetings, unclear responsibilities, or conflicting stakeholder expectations may weaken rather than strengthen the development of a shared green innovation culture. On this basis, the study advances:

H2. *Behavioral GSCM Practices have a positive effect on green innovation culture.*

Green innovation culture refers to the shared values and routines that support sustainability-oriented innovation, and in this study, it is reflected in green innovation orientation, green innovation enablement, and green innovation implementation [32]. Organizational performance is conceptualized as triple bottom line outcomes, including economic performance, environmental performance, and social performance [33]. When green innovation is embedded as a cultural system, it aligns strategic priorities with day-to-day decision making and encourages cross-functional coordination, which strengthens process efficiency, risk control, and competitiveness as economic outcomes [34]. The same cultural embedding promotes the routinization of green improvements and the effective use of environmental feedback, which supports measurable reductions in emissions, waste, and resource consumption as environmental outcomes [35]. Also, a society that promotes green innovation is more transparent, employee-friendly, and legitimate to stakeholders, hence promoting social performance through better responsibility practices and reputational capital [36]. A sustainability-oriented innovation culture can help support the joint fulfillment of environmental goals and market performance because it provides the ability to scale and commercialize greener services and solutions [37]. Although green innovation culture is expected to enhance performance, its effect may not be immediate or guaranteed. A strong emphasis on green experimentation may increase short-term costs or create uncertainty if it is not aligned with operational efficiency and market demands. Previous mediation studies have commonly examined green innovation, green capability, or supply chain collaboration as mechanisms linking GSCM to performance [38]. In contrast, this study focuses on green innovation culture, which captures the shared values, support systems, and implementation routines that make green innovation continuous and organization wide. Hence, we posit:

H3. *Green innovation culture has a positive effect on organizational performance.*

The adoption of eco-design into the operational decision rules minimizes material intensity and waste at the lifecycle stages, which facilitates economic performance in

terms of cost savings and efficiency gains, and reduces environmental impacts at the same time [39]. The production of cleaner goods enhances environmental performance because it minimizes emissions, energy consumption, and waste of pollutants as a result of process optimization and pollution preventive measures, and such changes may also be converted into financial benefits due to the reduction of compliance risk and operational loss [40]. It also enhances the performance by facilitating more green process innovation, boosting resource productivity, and increasing operational stability, which could help achieve more stable service quality and minimize disruption cost in logistics-related production and service systems [41]. Traceability and technical monitoring tools that are part of technical GSCM also contribute towards social performance by enhancing safety management, transparency, and accountability in all aspects of supply chain operations, which results in increased stakeholder trust and legitimacy. Since technical GSCM practices are capable of producing efficiency, environmental enhancement, and legitimacy benefits simultaneously due to process redesign and quantifiable control systems, it is anticipated that their performance contribution will be positive in the context of the logistics enterprise. Technical GSCM practices may also have negative or insignificant effects on performance when green technologies require high investment, disrupt established logistics routines, or fail to match the firm's operational capacity. This gives rise to the following hypothesis:

H4. *Technical GSCM practices have a positive effect on organizational performance.*

Economic performance is enhanced by top management support through the validation of sustainability as a strategic priority, the stabilization of resource allocation to green projects, and the enhancement of the quality of coordination, which lowers inefficiency and compliance expenses [42]. The involvement of employees enhances environmental performance since compliance with the day-to-day operations, minimization of waste, and behavior of continuous improvement is influenced by frontline involvement, shared responsibility, and a learning-based approach to participation in green programs [43]. Performance is improved by the involvement of customers and suppliers as they align green standards, can solve problems together, and lessen the implementation gaps that may arise when the environmental requirements are not shared among the supply chain partners, thus enhancing environmental performance as well as service reliability. The behavioral practices also enhance social performance by enhancing transparency, safety regulations, and stakeholder legitimacy through participatory governance and accountability through collaboration. Behavioral GSCM practices may not automatically improve organizational performance because employee involvement and supplier/customer collaboration can also increase coordination costs, slow decision-making, or create conflicts between environmental goals and delivery-speed requirements. Thus, this study proposes:

H5. *Behavioral GSCM practices have a positive effect on organizational performance.*

To further specify the research gap, Table 1 presents a summary of representative studies on GSCM, green innovation, green culture, and sustainability performance. The table compares existing studies in terms of research context, factors examined, analytical tools, and remaining gaps. It shows that although prior research has established important links between GSCM and sustainability outcomes, limited attention has been paid to logistics firms, the distinction between technical and behavioral GSCM practices, and the mediating role of green innovation culture in triple-bottom-line performance. These limitations justify the research model proposed in this study.

Table 1. Summary of Prior Studies and Research Gaps.

Study	Context	Factors Examined	Method/Tools	Remaining Gap
Hooker, Seman [28]	Supply chain/environmental performance	GSCM, green innovation, environmental performance	SEM	Did not distinguish technical and behavioral GSCM or examine triple-bottom-line performance in logistics firms
Nureen, Liu [24]	GSCM/environmental sustainability	Technical and behavioral GSCM dimensions	Literature-based analysis	Provided conceptual distinction but limited empirical testing of different pathways
Fang, Shi [19]	Green HRM/environmental performance	Green HRM, green innovation, green culture	Mediation analysis	Did not focus on GSCM or logistics firms
Wiredu, Yang [23]	Corporate environmental performance	GSCM practices, supply chain advantage, environmental performance	SEM	Treated GSCM mainly as a practice bundle and focused on environmental performance
Junejo, Sohu [44]	Emerging market firms	Green supply chain practices, sustainable innovation, reputation	Quantitative analysis	Did not compare technical and behavioral GSCM effects in logistics settings
Rashid and Rasheed [42]	Supply chain collaboration	GSCM, external collaboration, monitoring, performance	Quantitative analysis	Did not examine green innovation culture as a mediating mechanism
Aggarwal and Agarwala [29]	Green organizational culture	Green organizational culture dimensions	Conceptual/scale development	Did not link green innovation culture to GSCM and triple-bottom-line performance
Present study	Logistics firms in Guangzhou	Technical GSCM, behavioral GSCM, green innovation culture, organizational performance	CFA and CB-SEM	Addresses logistics-specific evidence, dual GSCM dimensions, and the mediating role of green innovation culture

3. Methodology

3.1. Data Collection

The target population comprised logistics practitioners working in Guangzhou, China. Guangzhou was selected not merely for convenience, but because it is one of China's major logistics and supply chain hubs, with a high concentration of transportation, warehousing, e-commerce logistics, cold-chain logistics, third-party logistics, and integrated supply chain service providers. Firms in Guangzhou are also increasingly exposed to sustainability regulations, customer environmental expectations, low-carbon transition pressures, and green logistics policy requirements. Therefore, Guangzhou provides a suitable empirical context for examining how logistics firms adopt green supply chain management (GSCM) practices and translate them into organizational outcomes. To ensure informed responses on GSCM-related activities, eligibility was limited to employees whose roles were directly associated with supply chain, operations, or sustainability functions, such as logistics planning, procurement, warehousing, operational coordination, and ESG or sustainability units.

A non-probability purposive sampling strategy was adopted to reach respondents with domain-specific knowledge of green logistics and supply chain practices [45]. This approach was appropriate because the study required respondents who could evaluate organizational GSCM practices rather than general employees with limited exposure to such activities. However, purposive sampling also implies that the findings should be generalized with caution, as the sample was not randomly drawn from the full population of logistics firms. The sampling frame included logistics-related firms located in Guangzhou, such as third-party logistics providers, transportation and distribution firms, warehousing and fulfillment providers, integrated supply chain service providers, and

logistics departments within manufacturing and retail companies. Data were collected through three complementary channels: an online survey platform, targeted email invitations distributed through professional networks and company contacts, and face-to-face administration at industry events such as green logistics forums and supply chain seminars. This sampling strategy may introduce selection bias because firms or individuals with stronger awareness of green logistics may have been more willing to participate. Therefore, the results should be interpreted as evidence from knowledgeable logistics practitioners rather than as statistically representative estimates for all logistics firms in China.

The final sample captured both operational and strategic perspectives by including frontline staff, sustainability officers, middle managers, and top managers from firms of varying sizes, service types, and ownership structures. To enhance data quality and reduce duplication bias, responses were screened using IP addresses, timestamps, and organizational identifiers, and incomplete, duplicate, or suspicious entries were removed. More than one respondent from the same company was allowed only when individuals held different operational or managerial positions, as the unit of analysis was the practitioner's perception of organizational practices rather than audited firm-level records. To assess potential non-response bias, early and late respondents were compared on key demographic characteristics and main study variables, and no significant differences were identified. Data collection was conducted over a one-month period from May to June 2025. Of the 650 questionnaires distributed, 426 valid responses were retained after screening, representing a valid response rate of 65.54%, which was adequate for SEM estimation and mediation testing [46]. Nevertheless, because the sample was restricted to one major logistics center in China, the findings should be interpreted with caution in terms of generalizability to other regions with different regulatory, economic, and GSCM development conditions.

3.2. Measurement

The standardized questionnaire used a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) and was designed in line with the study's conceptual framework. The first section collected respondent and firm profile information, including gender, age group, years of experience, education level, position, company size, logistics operation type, ownership structure, and the level and duration of GSCM adoption. These data were used to describe the sample and to support robustness checks.

Technical GSCM Practices were measured as environmentally oriented technological and operational interventions embedded in logistics processes, facility management, packaging, and distribution systems to reduce resource consumption, emissions, and waste. Consistent with prior GSCM research, three reflective items captured green process optimization in logistics operations, cleaner production-oriented operational control, and eco-design-based service and process design [15]. Behavioral GSCM Practices were measured using three reflective items assessing top management support, employee participation, and customer and supplier involvement, reflecting the behavioral and relational foundations of sustainability implementation in logistics firms [47]. Green Innovation Culture was measured with three reflective items representing green innovation orientation, green innovation enablement, and green innovation implementation, capturing the organization's shared values and support systems for sustainability-oriented innovation [48]. Organizational performance was operationalized through the triple-bottom-line framework, including economic, environmental, and social performance, with three reflective items used for each dimension [49]. In total, the measurement model comprised 18 reflective indicators. All constructs were specified as reflective because the indicators were treated as manifestations of broader underlying organizational orientations rather than as formative components that jointly define the constructs.

Although organizational performance was measured through economic, environmental, and social indicators, it was specified as reflective because these indicators were treated as manifestations of a broader perceived sustainability performance construct rather than as independent formative components. In other words, firms with stronger overall sustainability performance are expected to report higher levels of economic, environmental, and social outcomes simultaneously. The indicators were therefore expected to covary and reflect the same underlying performance orientation, which supports the reflective specification. This approach is consistent with the study's aim of examining perceived triple-bottom-line performance as an overall organizational outcome.

3.3. Data Analysis

Data analysis proceeded in several stages. First, data screening, descriptive statistics, reliability analysis, and preliminary bias tests were conducted using computer software. Frequencies, percentages, means, and standard deviations were computed to summarize the sample characteristics and key study variables. Second, given the cross-sectional and self-reported nature of the data, both procedural and statistical remedies were applied to assess potential common method bias (CMB), including Harman's single-factor test, confirmatory factor analysis (CFA) model comparisons, and the common latent factor (CLF) approach. The results indicated that common method variance did not substantially affect the measurement or structural model. Third, potential non-response bias was assessed by comparing early and late respondents on key demographic characteristics and main study variables. No significant differences were identified, suggesting that non-response bias was unlikely to pose a serious threat to the findings.

Fourth, CFA was conducted to assess factor loadings, construct reliability, convergent validity, and discriminant validity. Confirmatory factor analysis and structural equation modeling were performed using AMOS. This study adopted covariance-based SEM (CB-SEM) rather than PLS-SEM because the research model was theory-driven and confirmatory in nature. The purpose was to test a theoretically specified mediation model and evaluate both the measurement model and structural model using overall model fit indices. SEM was appropriate for this study because the model included multiple latent constructs, simultaneous direct and indirect paths, and a theoretically specified mediation mechanism. It also allowed the measurement model and structural model to be evaluated within an integrated analytical framework. To account for potential confounding influences, a set of respondent- and firm-level characteristics was included as control variables, including gender, age group, years of industry experience, educational level, current position, company size, logistics operation type, ownership structure, level of GSCM adoption, and years of GSCM implementation. Finally, mediation effects through Green Innovation Culture were examined using bootstrapping with 5000 resamples and bias-corrected 95% confidence intervals. Because the data were cross-sectional, the results should be interpreted as theoretically grounded associations rather than definitive causal evidence. Future studies using longitudinal or multi-source designs could further strengthen causal inference.

Self-reported data were appropriate because the constructs examined in this study, such as perceived GSCM practices, green innovation culture, and perceived organizational performance, reflect organizational practices and cultural conditions that are often evaluated through managerial and employee perceptions. To reduce common method bias, several procedural remedies were adopted during questionnaire design and data collection, including assuring anonymity, emphasizing that there were no right or wrong answers, using clear and neutral item wording, and separating predictor and outcome constructs in the questionnaire.

3.4. Pilot Study

During pilot testing, 30 logistics practitioners in Guangzhou were selected based on the same screening requirements as the formal sample via professional networks, and no pilot respondents were included in the final sample. Pilot test sample size is 30 respondents, which is the smallest suggested sample size in a pilot study to achieve the initial reliability and refine the instrument [50]. Initial measurements of reliability and validity using the pilot data showed satisfactory results of measurement in the context of further large-scale evaluation of SEM. As shown in Figure 1, the internal consistency was good, and the results obtained were Technical GSCM Practices 0.82, Behavioral GSCM Practices 0.85, Green Innovation Culture 0.88, and Organizational Performance 0.86 (overall scale 0.93). The corrected item-total correlations were between 0.45 and 0.78, which implies that all indicators have made a meaningful contribution to the construct they were supposed to measure, and none of them should be deleted. Factor analysis also validated the dimensionality: the Kaiser–Meyer–Olkin index was 0.80, and the test of sphericity by Bartlett was statistically significant ($p < 0.001$), meaning that the correlation matrix could be subject to factor extraction. With principal axis factoring using oblique rotation, items loaded neatly on their hypothesized factors, with standardized loadings ranging between 0.62 and 0.84 and minimal cross-loadings (all secondary loadings < 0.30); the four-factor model accounted for 73.1 percent of the overall variance. After these pilot findings and advised measurement values [50], it was assumed that the instrument was reliable and conceptually consistent and could be moved to the next stage of full-scale data collection and confirmatory measurement assessment in the main study.

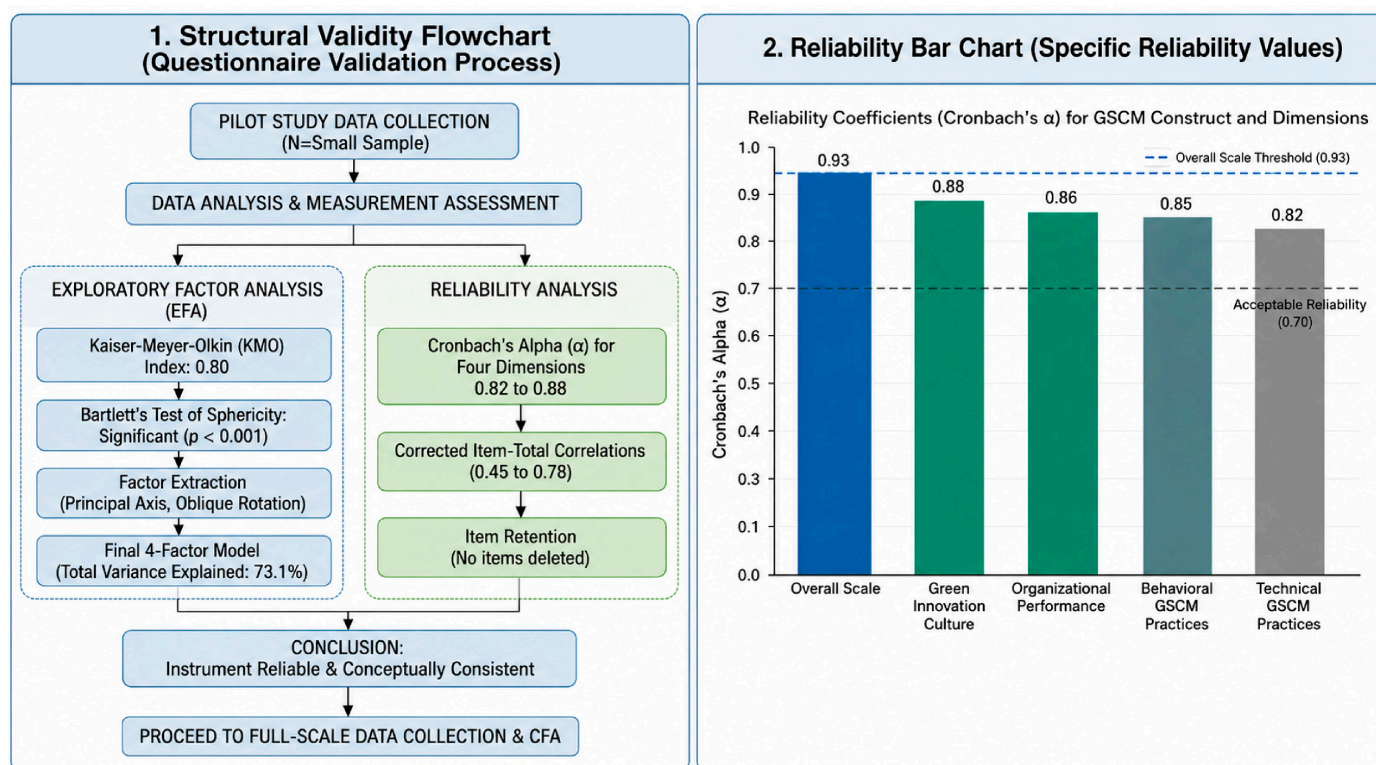


Figure 1. Summary of the pilot study and preliminary measurement assessment.

4. Results

4.1. Descriptive Statistical Analysis

Table 2 is a summary of the sample structure, which shows that the majority of the respondents are mid-career logistics professionals who have significant experience in the

industry and can be considered to have a fairly sound educational background, which makes the respondents' assessments of GSCM-related practices credible. The distribution of positions covers both frontline implementation as well as managerial supervision, and the characteristics of the firms indicate sufficient diversity across firm size, form of ownership, and logistic business operation areas, enhancing the representativeness of the data as per the context of logistics in Guangzhou. Crucially, the sample represents overall high involvement in green supply chain programs and involves companies that are at various stages of implementation, which will serve as an appropriate empirical foundation to further measure validation and hypothesis testing concerning the interrelationships between technical and behavioral GSCM practices, green innovation culture, and multidimensional organizational performance.

Table 2. Sample Information.

Information and Options		Frequency	Percent
Gender	Male	278	65.3
	Female	148	34.7
Age group (years)	18–30	96	22.5
	31–40	184	43.2
	41–50	103	24.2
	Above 50	43	10.1
Years of logistics industry experience	3–5 years	124	29.1
	6–10 years	156	36.6
	More than 10 years	146	34.3
Highest educational level completed	High school or below	52	12.2
	Vocational or technical diploma	139	32.6
	Bachelor's degree	171	40.1
	Master's degree or above	64	15
Current Position	Operational staff	140	32.9
	Sustainability officer	124	29.1
	Middle management	115	27.0
	Top management	47	11.0
Company Size (by Number of Employees)	Large enterprise (250 and above)	170	39.9
	Medium enterprise (50–249)	156	36.6
	Small enterprise (1–49)	100	23.5
Type of Logistics Operations	Warehousing	71	16.7
	Transportation	66	15.5
	State-owned	107	25.1
	Other	78	18.3
	E-commerce logistics	74	17.4
	Integrated services	74	17.4
Company Ownership Structure	Cold-chain logistics	63	14.8
	Privately-owned	111	26.1
	Foreign-invested	105	24.6
	Joint venture	103	24.2
Level of Adoption of Green Supply Chain Practices	Very high	140	32.9
	High	132	31.0
	Moderate	128	30.0
	Low	26	6.1
Years of Green Supply Chain Management Practice Implementation	Less than 1 year	121	28.4
	More than 6 years	110	25.8
	1–3 years	98	23.0
	4–6 years	97	22.8

Table 3 reports the descriptive statistics of all observed variables, including their means and standard deviations. The item means ranged from 3.520 to 3.620, suggesting that respondents generally perceived technical GSCM practices, behavioral GSCM practices, green innovation culture, and organizational performance at a moderate to moderately positive level. Although the mean values were relatively close across items, this pattern should not be interpreted as indicating that the constructs were conceptually or empirically indistinguishable. Instead, it may reflect that the sampled logistics firms were operating at a broadly similar stage of green management implementation and sustainability performance development. The standard deviations ranged from 0.956 to 1.049, showing adequate variation in responses across firms, positions, and operational contexts. Therefore, the descriptive results provide a useful overview of the sample, while the distinctiveness of the constructs is further evaluated through the measurement model, including CFA, composite reliability, AVE, the Fornell–Larcker criterion, and HTMT.

Table 3. Descriptive Statistics Results $n = 426$.

Study Variables	Items	Mean	SD	Construct Mean
Technical GSCM Practices	GM	3.58	0.977	3.59
	CP	3.62	1.034	
	ED	3.57	0.956	
Behavioral GSCM Practices	TM	3.56	0.99	3.577
	EMP	3.59	1.009	
	CS	3.58	1.017	
Green Innovation Culture	IO	3.58	1.012	3.58
	IE	3.57	1.029	
	II	3.59	1.009	
Organizational Performance	EP1	3.56	0.981	3.563
	EP2	3.55	1.049	
	EP3	3.62	1.046	
	NP1	3.56	1.007	
	NP2	3.56	0.976	
	NP3	3.58	1.019	
	SP1	3.59	1.005	
	SP2	3.52	1.02	
	SP3	3.53	1.004	

4.2. Reliability and Construct Validity Assessment

Table 4 provides the internal consistency reliability of each construct. All of the constructed Cronbach alpha coefficients are above the widely used cut-off score of 0.70, indicating that the internal consistency of the measurement items is acceptable. Technical GSCM practices and behavioral GSCM practices are consistently reliable with three items each, and this shows that the indicators are consistent in assessing the intended operational and managerial elements of GSCM implementation. Internal consistency of green innovation culture is also very high, and it is possible to measure orientation, enablement, and implementation components of green innovation culture as one cultural competence. The organizational performance has the highest alpha value, and this indicates that the nine indicators are good representatives of the economic, environmental, and social performance outcomes of the organization.

Table 4. Reliability Statistics.

Scheme	Number of Questions	Cronbach's α
Technical GSCM Practices	3	0.805
Behavioral GSCM Practices	3	0.817
Green Innovation Culture	3	0.821
Organizational Performance	9	0.857

Table 5 shows that the data can be used in factor analysis. The KMO value of 0.884 is a high indicator of the sampling adequacy, implying that the correlation structure between the items is sufficiently tight to produce trustworthy latent factors. The test of sphericity conducted by Bartlett is statistically significant ($p < 0.001$), and it refutes the null hypothesis that the correlation matrix is an identity matrix, and supports the fact that the items have enough similar variance. All these findings indicate the factorability of the data and give reasons why the measurement model evaluation should continue in further analyses.

Table 5. KMO and Bartlett's Test.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy.		0.884
Bartlett's Test of Sphericity	Approx. Chi-Square	3229.354
	df	153
	Sig.	0.000

4.3. Measurement Model

The measurement model is applied to measure the reliability and validity of the constructs through assessing the relationships among observed indicators and their underlying latent variables [51]. Table 6 indicates that the measurement model is well-fitted to the overall data. The ratio of chi-square to degrees of freedom is significantly lower than the suggested limit, which means that the misfit of the model is relatively low compared to the complexity of the model. The RMSEA value is much less than the traditional cut-off point, indicating extremely low approximation error. Moreover, incremental and absolute fit indices (GFI, AGFI, NFI, TLI, and CFI) all have values higher than the required ones, thus validating the fact that the defined factor structure fits the observed covariance patterns well and can serve as a solid foundation for further structural path testing.

Table 6. Model Fit Criteria.

Fit Index	χ^2/df	RMSEA	GFI	AGFI	NFI	TLI	CFI
Reference standards	<3	<0.08	>0.9	>0.9	>0.9	>0.9	>0.9
Result	1.150	0.019	0.964	0.951	0.956	0.993	0.994

Convergent validity refers to how closely different indicators of the same construct are related to each other and also consistently indicate the desired concept [52]. According to commonly used SEM assessment criteria, standardized factor loadings should preferably be higher than 0.70, CR values should exceed 0.70, and AVE values should be greater than 0.50 [53]. As reported in Table 7, the standardized factor loadings of all indicators ranged from 0.722 to 0.806, suggesting that each item was adequately associated with its intended latent construct. The CR values ranged from 0.806 to 0.924, indicating satisfactory construct reliability. Moreover, all AVE values ranged from 0.575 to 0.604, exceeding the recommended threshold of 0.50. These findings indicate that the indicators of each construct shared sufficient common variance and that the measurement model demonstrated acceptable convergent validity.

Table 7. Convergence Validity.

Latent Variables	Observation Indicators	Factor Loading	CR	AVE
Technical GSCM Practices	GM	0.759	0.806	0.581
	CP	0.756		
	ED	0.771		
Behavioral GSCM Practices	TM	0.806	0.816	0.597
	EMP	0.752		
	CS	0.759		
Green Innovation Culture	IO	0.784	0.821	0.604
	IE	0.763		
	II	0.785		
Organizational Performance	EP1	0.725	0.924	0.575
	EP2	0.722		
	EP3	0.778		
	NP1	0.757		
	NP2	0.778		
	NP3	0.756		
	SP1	0.741		
	SP2	0.79		
	SP3	0.775		

4.4. Discriminant Validity

Discriminant validity refers to the extent to which a latent construct is empirically distinct from other constructs in the same model [54]. In this study, discriminant validity was assessed using both the Fornell–Larcker criterion and the heterotrait–monotrait ratio of correlations (HTMT). The Fornell–Larcker criterion requires that the square root of each construct’s AVE should be greater than its correlations with other constructs. As shown in Table 8, the diagonal values, which represent the square roots of AVE, were higher than the corresponding inter-construct correlations in the same rows and columns. This result indicates that each construct shared more variance with its own indicators than with other latent constructs.

Table 8. Discriminant Validity Test.

Latent Variables	TG	GI	BG	OP
TG	0.762			
BG	0.415	0.773		
GI	0.514	0.509	0.777	
OP	0.532	0.641	0.566	0.758

Note: The diagonal is the square root of the corresponding dimension AVE. TG: Technical GSCM Practices; BG: Behavioral GSCM Practices; GI: Green Innovation Culture; OP: Organizational Performance; $p < 0.001$.

To further strengthen the assessment of discriminant validity, HTMT was also calculated. HTMT is considered a more sensitive criterion for detecting potential overlap between latent constructs. Following commonly accepted methodological standards, HTMT values below 0.85 indicate satisfactory discriminant validity, while values below 0.90 may still be acceptable for conceptually related constructs. As shown in Table 9, all HTMT values

were below the recommended threshold, further confirming that Technical GSCM Practices, Behavioral GSCM Practices, Green Innovation Culture, and Organizational Performance were empirically distinguishable. Taken together, the Fornell–Larcker and HTMT results provide sufficient evidence that the measurement model achieved acceptable discriminant validity and could be used for subsequent structural path testing.

Table 9. HTMT Results.

Latent Variables	TG	BG	GI	OP
Technical GSCM Practices	—			
Behavioral GSCM Practices	0.486	—		
Green Innovation Culture	0.596	0.587	—	
Organizational Performance	0.613	0.652	0.734	—

Note: TG = Technical GSCM Practices; BG = Behavioral GSCM Practices; GI = Green Innovation Culture; OP = Organizational Performance. HTMT values below 0.85 indicate satisfactory discriminant validity.

4.5. Structural Model Results and Hypothesis Testing

The direct path results shown in Table 10 are broadly consistent with prior studies reporting positive relationships between GSCM practices, green innovation, green culture, and sustainability performance. However, the contribution of this analysis lies not merely in confirming positive associations, but in comparing the relative strengths of different GSCM pathways in logistics firms. In terms of effect magnitude, the strongest direct path was from Green Innovation Culture to Organizational Performance ($\beta = 0.427$), followed by Behavioral GSCM Practices to Green Innovation Culture ($\beta = 0.402$). This indicates that Green Innovation Culture was the most immediate predictor of performance, while behavioral practices were particularly important for shaping such a culture. Behavioral GSCM Practices had a stronger effect on Green Innovation Culture than Technical GSCM Practices did ($\beta = 0.402$ vs. $\beta = 0.208$), suggesting that leadership support, employee involvement, and customer–supplier collaboration are more influential in building an innovation-oriented green culture than technical practices alone. By contrast, the direct effects of Technical GSCM Practices and Behavioral GSCM Practices on Organizational Performance were relatively close ($\beta = 0.238$ vs. $\beta = 0.226$), indicating that both operational-technological systems and behavioral-relational mechanisms contribute to performance outcomes. This comparative pattern is meaningful because prior studies have often examined GSCM as an overall construct or focused mainly on environmental performance, whereas the present results show that technical and behavioral practices do not operate identically in logistics firms.

Table 10. Direct Path Effects.

Hypothesis	Path	β	S.E.	p	Results
H1	TG→GI	0.208	0.072	0.002	Accepted
H2	BG→GI	0.402	0.070	***	Accepted
H3	GI→OP	0.427	0.050	***	Accepted
H4	TG→OP	0.238	0.050	***	Accepted
H5	BG→OP	0.226	0.049	0.002	Accepted

Note: TG: Technical GSCM Practices; BG: Behavioral GSCM Practices; GI: Green Innovation Culture; OP: Organizational Performance. ***: $p < 0.001$.

The bootstrap-based indirect effects are reported in Table 11, and it is indicated that the Green Innovation Culture is a highly significant mediator when changing the two types of GSCM practices into better Organizational Performance. Green innovation culture significantly mediated the relationships between both Technical GSCM practices and orga-

nizational performance, and behavioral GSCM Practices and organizational performance. The indirect effect of Technical GSCM Practices on Organizational Performance through Green Innovation Culture was significant (effect = 0.065, SE = 0.029, 95% BC CI [0.020, 0.142]), while the indirect effect of Behavioral GSCM Practices was also significant and comparatively stronger (effect = 0.117, SE = 0.035, 95% BC CI [0.067, 0.206]). Since neither confidence interval included zero, both mediation effects were supported. These findings indicate that green innovation culture serves as an important explanatory mechanism linking GSCM practices to organizational performance, with behavioral GSCM practices showing a stronger indirect influence than technical GSCM practices.

Table 11. Indirect Effect Bootstrap Analysis.

Mediation Path	Effect Value	SE	Bias-Corrected Lower	95%CI Upper	Results
TG→GIC→OP	0.065	0.029	0.020	0.142	Accepted
BG→GIC→OP	0.117	0.035	0.067	0.206	Accepted

Note: TG: Technical GSCM Practices; BG: Behavioral GSCM Practices; GIC: Green Innovation Culture; OP: Organizational Performance.

Table 12 summarizes the direct, indirect, and total effects in the structural model. Technical GSCM Practices and Behavioral GSCM Practices both had positive direct effects on Green Innovation Culture, with Behavioral GSCM Practices showing the stronger effect ($\beta = 0.401$ vs. $\beta = 0.208$). Together, these two predictors explained 70.9% of the variance in Green Innovation Culture, indicating strong explanatory power. For Organizational Performance, Green Innovation Culture had the strongest direct effect ($\beta = 0.427$), followed by Technical GSCM Practices ($\beta = 0.238$) and Behavioral GSCM Practices ($\beta = 0.226$). The indirect effect of Behavioral GSCM Practices through Green Innovation Culture was also stronger than that of Technical GSCM Practices (0.171 vs. 0.089), resulting in a higher total effect on Organizational Performance (0.397 vs. 0.327). The model explained 47.2% of the variance in Organizational Performance, indicating moderate to substantial explanatory power. Given that organizational performance is shaped by multiple internal and external factors, such as market competition, firm size, customer demand, regulatory pressure, and resource availability, explaining nearly half of its variance represents a meaningful level of explanatory capability in the logistics context.

Table 12. Direct, Indirect, and Total Effects in the Structural Model.

Dependent Variable	Effect	Technical GSCM Practices	Behavioral GSCM Practices	Green Innovation Culture	R ²
Green Innovation Culture	DE	0.208	0.401	–	0.709
	IE	–	–	–	
	TE	0.208	0.401	–	
Organizational Performance	DE	0.238	0.226	0.427	0.472
	IE	0.089 (via GIC)	0.171 (via GIC)	–	
	TE	0.327	0.397	0.427	

All in all, Figure 2 presents the final structural equation model with standardized path coefficients.

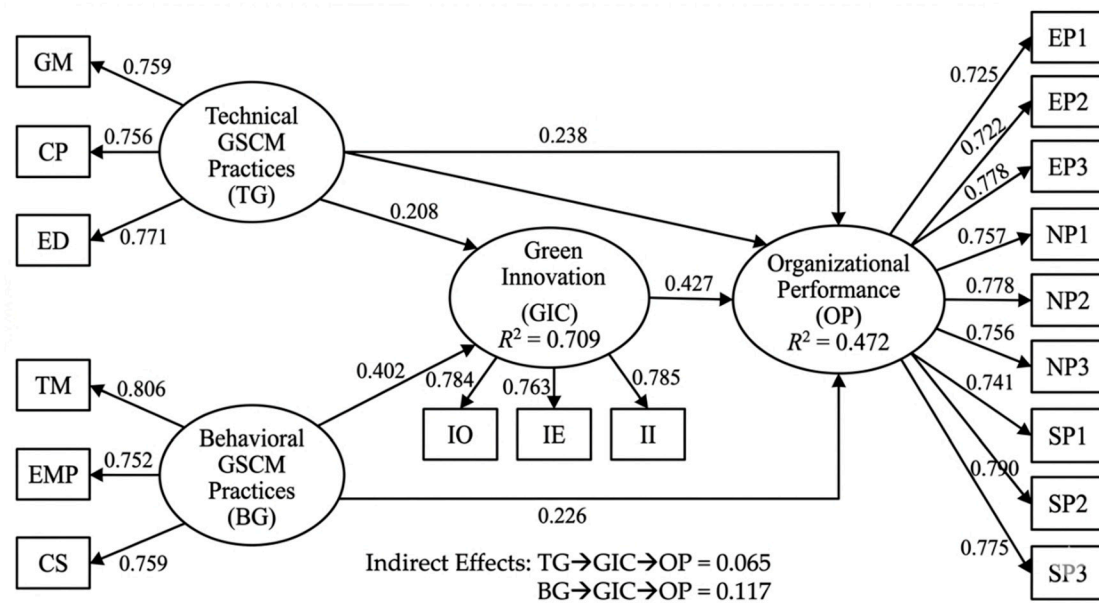


Figure 2. Structural equation model. Note: TG = Technical GSCM Practices, BG = Behavioral GSCM Practices, GIC = Green Innovation Culture, OP = Organizational Performance. Direct and indirect effects through GIC are significant ($p < 0.05$ or specific p -value).

5. Discussion

5.1. Key Findings

The findings can be interpreted more clearly through RBV and the dynamic capabilities theory. From the RBV perspective, Technical GSCM Practices and Behavioral GSCM Practices represent two complementary strategic resource domains. Technical practices provide operational resources such as cleaner processes, eco-design, monitoring systems, and resource-efficient logistics routines, which may generate relatively direct benefits through process control, waste reduction, compliance improvement, and environmental efficiency. Behavioral practices, by contrast, represent intangible and relational resources, including leadership commitment, employee participation, customer involvement, and supplier collaboration. The stronger effect of Behavioral GSCM Practices on Green Innovation Culture suggests that these intangible and relational resources are especially important in logistics firms, where green transformation depends heavily on coordination across dispersed service networks, subcontracted capacity, frontline execution, and customer–supplier interfaces. Under such conditions, technical systems alone are unlikely to create a shared green innovation culture unless they are supported by behavioral governance and relational alignment.

More importantly, the findings should be understood in relation to the continuing relevance of the green concept in logistics management. Although the positive directions of the hypotheses may appear intuitive, their empirical validation remains meaningful because logistics firms operate under strong tensions between delivery speed, cost efficiency, service reliability, and environmental responsibility. In this context, green logistics is not simply a normative environmental slogan, but a managerial approach that requires the redesign of transportation, warehousing, packaging, monitoring, and inter-organizational coordination. The results show that green concepts become performance-relevant only when they are translated into concrete technical practices and behavioral routines. This is particularly important for logistics firms because their environmental impact is embedded in daily operational decisions, such as route planning, energy use, packaging selection, warehouse management, and supplier–customer coordination. Therefore, the study confirms that

the value of green logistics management lies not only in reducing environmental burdens but also in building organizational routines and innovation-oriented cultures that support sustainable economic, environmental, and social outcomes.

From the dynamic capabilities perspective, Green Innovation Culture acts as the mechanism through which technical and behavioral resources are integrated, reconfigured, and institutionalized over time. This interpretation helps explain the partial mediation pattern observed in the results. The direct effects of GSCM practices on Organizational Performance reflect more immediate operational impacts, such as efficiency improvement, waste reduction, compliance enhancement, and better coordination. By contrast, the indirect effects through Green Innovation Culture reflect longer-term capability-building implications, because green practices become embedded in shared values, learning routines, experimentation, and continuous improvement processes. These findings are consistent with prior studies showing that GSCM practices, green innovation, and green culture can improve sustainability outcomes [55,56], but they extend prior work by showing that GSCM in logistics is not a uniform practice bundle. Instead, it operates as a dual system in which technical practices provide the operational foundation, while behavioral practices are particularly important for building the innovation-oriented culture needed for sustained triple-bottom-line performance.

5.2. Theoretical Implications

This study makes several theoretical contributions to the GSCM and sustainability performance literature. First, whereas much of the prior literature has treated GSCM as an aggregated construct and examined its overall effect on firm performance, the present study shows that, in logistics settings, GSCM is better understood as comprising two analytically distinct yet complementary dimensions: technical practices and behavioral practices. This distinction generates new knowledge by demonstrating that green transformation in logistics does not unfold through a single, homogeneous practice bundle, but through different practice streams that rely on different implementation logics. In service-oriented and time-sensitive logistics networks, this distinction is particularly important because execution quality, coordination, and relational alignment are as critical as technological upgrading itself.

Second, this study extends the literature on organizational culture in sustainability research. Prior studies have often positioned green organizational culture as a relatively stable contextual condition that shapes the effectiveness of green practices [57]. In contrast, the present findings suggest that green innovation culture can also be understood as an endogenous organizational mechanism that develops through managerial and operational practices. More specifically, technical GSCM practices appear to contribute routinized systems and process discipline, while behavioral GSCM practices provide legitimacy, participation, and coordination support. This shifts the theoretical role of culture from a passive background factor to an active conversion mechanism through which green practices are translated into organizational performance. In doing so, the study offers a more process-based understanding of how sustainability-oriented culture emerges and functions in logistics firms.

Third, the findings refine resource-based and capability-based explanations of sustainability transformation in logistics. Existing research has often emphasized technological and physical resources as the primary sources of environmental advantage, while behavioral resources have frequently been treated as secondary enablers [58]. The present study challenges that hierarchy by showing that behavioral GSCM practices exert a stronger effect on green innovation culture than technical practices. This provides new evidence that, in logistics firms, intangible and relational resources such as leadership commitment, employee

participation, and stakeholder involvement are not merely supportive but strategically important in shaping capability development. This contribution is especially relevant in logistics contexts, where performance outcomes depend heavily on coordination across organizational boundaries, distributed operations, and service interfaces.

Finally, the study contributes to the triple-bottom-line literature by showing that logistics sustainability performance should not be interpreted only in terms of isolated economic or environmental gains. Instead, the results support a broader view in which economic, environmental, and social performance are jointly influenced by the interaction between practice adoption and green innovation culture. This adds to the literature by moving beyond compliance-oriented accounts of GSCM and toward a capability-based perspective, in which sustainability performance is achieved through the combined effects of technical upgrading, behavioral governance, and the institutionalization of green innovation over time. By doing so, the study also clarifies why apparently predictable green-management relationships remain theoretically relevant in logistics research: the key issue is not whether green practices are beneficial in general, but how different forms of green logistics practices generate performance through different operational and cultural mechanisms.

5.3. Practical Implications

First, managers should avoid treating green supply chain management as a purely technical issue. Although technical GSCM practices such as eco-design, cleaner production, and green process optimization directly improve organizational performance, their impact becomes more sustainable when they are accompanied by supportive behavioral mechanisms. In practice, this means that investments in green equipment, cleaner operational systems, or environmentally oriented process redesign should be aligned with managerial commitment, employee engagement, and clear implementation responsibilities. For logistics managers, this means that the green concept should be embedded into routine logistics management rather than treated as a separate environmental program. Green route optimization, low-carbon warehousing, recyclable packaging, supplier coordination, and employee participation should be managed as interconnected components of everyday logistics operations.

Second, Senior managers need to embed sustainability goals into performance evaluation, budgeting, and daily supervision rather than treating them as symbolic commitments. Firms can also strengthen employee participation through green suggestion systems, cross-functional project teams, and routine training programs that connect sustainability objectives with operational tasks. In addition, collaboration with customers, suppliers, and third-party service providers should move beyond transactional compliance toward shared environmental standards, joint problem-solving, and information exchange. Such actions can help green practices become coordinated routines rather than isolated initiatives.

Third, logistics companies should therefore not only introduce green practices but also institutionalize the values, support systems, and operational routines that allow these practices to be maintained over time. This may include creating internal green innovation teams, establishing feedback systems for environmental improvement, rewarding sustainability-related initiatives, and encouraging departments to translate environmental goals into practical process changes. By doing so, firms are more likely to achieve not only short-term operational gains, but also broader economic, environmental, and social benefits.

Finally, the results also offer implications for policymakers, industry associations, and training institutions. Policies aimed at promoting green logistics should extend beyond technical compliance requirements and support the development of organizational capabilities. For example, regulators and industry bodies may encourage firms to adopt integrated programs that combine green technologies, employee training, and collaborative standards

across supply chain partners. Training institutions can also play a role by developing professional programs that build both technical competence and behavioral governance skills related to sustainable logistics. In this way, the green transformation of logistics hubs such as Guangzhou can become more scalable, coordinated, and durable.

6. Conclusions

This study examined how technical and behavioral green supply chain management (GSCM) practices influence organizational performance in logistics firms, and whether green innovation culture functions as a mediating mechanism in this relationship. Based on survey data from 426 logistics practitioners in Guangzhou, China, the findings show that both technical and behavioral GSCM practices positively affect green innovation culture and organizational performance. Green innovation culture also has a significant positive effect on organizational performance, confirming its role as an important mechanism through which GSCM practices are translated into triple-bottom-line outcomes.

The study offers two main theoretical contributions. First, it advances GSCM research by proposing a dual-structure perspective. Rather than treating GSCM as a single aggregated construct, the study distinguishes between technical practices and behavioral practices. Technical GSCM practices provide the operational foundation for cleaner logistics processes, resource efficiency, monitoring, and environmental improvement, whereas behavioral GSCM practices provide the leadership commitment, employee involvement, and stakeholder collaboration needed to embed sustainability into organizational routines. Second, the study extends green innovation and capability-based research by showing that green innovation culture is not merely a contextual factor, but a mediating mechanism that converts green practices into economic, environmental, and social performance. This finding highlights that sustainable logistics performance depends not only on adopting green practices but also on developing an innovation-oriented culture that supports learning, experimentation, and continuous improvement.

The findings also provide several practical implications. Logistics managers should avoid treating green transformation as a purely technical upgrading project. Investments in low-emission transport, route optimization, green warehousing, environmental monitoring, and eco-friendly packaging should be combined with behavioral governance mechanisms such as top management support, employee training, cross-functional teams, green suggestion systems, and supplier–customer collaboration. Firms should also institutionalize green innovation culture by setting clear sustainability goals, rewarding green improvement initiatives, sharing environmental performance feedback, and encouraging departments to translate green objectives into operational routines. For policymakers and industry associations, the findings suggest that green logistics policies should not focus only on technical compliance or equipment upgrading. Policy support should also encourage professional training, collaborative green standards, green innovation platforms, and knowledge-sharing mechanisms among logistics firms, suppliers, customers, and local government agencies.

This study has several limitations that provide opportunities for future research. First, the cross-sectional design limits causal inference. Future studies could use longitudinal data to examine how GSCM practices and green innovation culture evolve over time and how their performance effects accumulate. Second, the study focuses on logistics firms in Guangzhou, China, which may limit external validity. Future research could conduct cross-regional, cross-country, or multi-industry comparative studies to test whether the relative effects of technical and behavioral GSCM practices differ across institutional and market contexts. Third, the study relies on self-reported data from logistics practitioners. Future

research could combine survey data with objective indicators, such as carbon emissions, energy use, delivery efficiency, waste reduction, or third-party sustainability assessments.

Future research could also extend this model by integrating Industry 5.0 principles. Industry 5.0 emphasizes human-centric innovation, sustainability, resilience, and human–technology collaboration. In green logistics, this perspective may help explain how artificial intelligence, digital monitoring, collaborative robots, and human expertise can jointly enhance green supply chain practices and innovation culture. Recent research also suggests that the synergy between Industry 5.0 and GSCM can support more sustainable supply chain transformation by combining digitalized decision-making, human–machine interaction, and green management practices. Future studies could therefore examine how AI–human collaboration, employee digital capability, and human-centric innovation culture strengthen the effectiveness of technical and behavioral GSCM practices. This direction would help explain how logistics firms can move toward more resilient, sustainable, and human-centered logistics systems.

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