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Technological Capabilities and Institutional Pressures in Green Logistics Adoption: Evidence from an Emerging Economy's Freight Forwarding Sector

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Abstract

Purpose: This study examines how access to green technologies, institutional pressures, and supply chain collaboration influence green logistics adoption and organizational performance in Vietnam's logistics industry. Motivated by inconsistent findings in prior sustainability research and concerns about model validity in emerging-market studies, the paper integrates the Resource-Based View and Institutional Theory to explain how internal capabilities and external constraints jointly shape sustainability outcomes.

Design/methodology/approach: Data were collected through a structured questionnaire survey, yielding 334 valid responses from logistics firms operating in Vietnam. Partial least squares structural equation modeling (PLS-SEM) using SmartPLS was employed to test direct, moderating, and mediating relationships, supported by bootstrapping. To enhance robustness and address spurious inference concerns, extensive diagnostic tests were conducted, and key results were cross-validated using covariance-based SEM (CB-SEM).

Findings: The results indicate that access to green technologies has a limited direct effect on green logistics adoption, whereas supply chain collaboration significantly enhances adoption and environmental awareness. Institutional pressures primarily influence organizational performance rather than operational adoption decisions. Moderation and mediation analyses show that organizational size and environmental awareness condition and partially transmit the effects of technological access and collaboration. By clarifying how organizational and institutional factors shape sustainability adoption under uncertainty, these findings provide evidence-based insights that support managerial and policy decision-making in Decision Sciences.

Theoretical implications: The study challenges technology-centric explanations of green logistics adoption by demonstrating that organizational and institutional mechanisms play a more decisive role in emerging markets, thereby extending sustainability and logistics theory through a combined moderation–mediation framework.

Practical implications: Logistics firms should complement green technology investments with organizational capability development and supply chain collaboration. Policymakers should strengthen institutional frameworks and support collaborative sustainability initiatives, particularly for small and medium-sized firms.

Originality/value: This study is among the first to integrate extended survey data, dual SEM estimation, comprehensive diagnostics, and moderation–mediation analysis to examine green logistics adoption in an emerging economy, offering robust empirical and methodological contributions to sustainability and decision sciences research.

Keywords: Green logistics adoption; Institutional pressures; Supply chain collaboration; Organizational size; Emerging markets; Structural equation modeling
JEL Classifications: L14, L91, M11, O33, Q56

1. Introduction

The global logistics industry is currently undergoing a profound transformation, as environmental sustainability has become a central concern shaping its long-term development (Tetteh et al., 2024). Logistics activities, which underpin international supply chains, are responsible for a substantial share of global greenhouse gas emissions, accounting for approximately 8–10% of total annual emissions worldwide (Ouni & Abdallah, 2024). In particular, the transport sector contributes nearly 24% of global CO_2 emissions, with freight transportation representing a significant proportion of this figure (Jayarathna et al., 2022). These statistics underscore the urgent need for environmentally responsible logistics practices, especially in contexts where rapid economic growth intensifies environmental pressures. Consequently, green logistics has emerged as a critical strategic response to mitigate the environmental impacts of logistics operations (Varghese & Pradhan, 2025).

Green logistics refers to the systematic integration of environmental considerations into logistics and supply chain activities, with the aim of reducing carbon emissions, minimising waste, and enhancing operational efficiency through cleaner technologies and sustainable process design (Samper et al., 2022). Empirical evidence suggests that the adoption of sustainable packaging, energy-efficient transportation, and green supply chain technologies can reduce logistics-related emissions by up to 20% in developing economies (Boutabba et al., 2024; Roy & Mohanty, 2023). However, the effectiveness of these practices varies considerably across countries, largely due to differences in institutional environments, resource availability, and organisational capabilities. These variations are particularly pronounced in emerging economies, where rapid industrialisation and expanding transport networks often outpace the implementation of environmental safeguards.

In recent years, green logistics has attracted increasing scholarly and managerial attention, driven by stricter environmental regulations, growing stakeholder pressure, and the recognition that sustainable logistics practices may generate both cost efficiencies and competitive advantages (Gerlitz & Meyer, 2021; Li et al., 2021). Despite these incentives, the diffusion of green logistics practices remains uneven across regions and industries (Yan et al., 2022). While firms in developed economies have made substantial progress in integrating sustainability into logistics operations, adoption levels in emerging markets—such as Vietnam—remain relatively low, notwithstanding a growing awareness of environmental responsibilities.

Vietnam's logistics sector plays a pivotal role in linking Southeast Asia to global trade networks and has experienced rapid growth alongside the country's economic development. This expansion, however, has intensified environmental challenges, particularly in freight forwarding and transportation activities (Phung et al., 2022). Although the Vietnamese government has articulated ambitious sustainability goals, the practical implementation of green logistics practices within the freight forwarding industry remains limited and fragmented (Thi Binh An et al., 2024). This gap between policy intent and operational practice

highlights the need for empirical research that identifies the key factors influencing firms' decisions to adopt green logistics in this context.

The adoption of green logistics practices is shaped by a complex interplay of internal organisational resources and external institutional pressures. On the one hand, internal factors such as financial capacity, technological expertise, and managerial capabilities influence a firm's ability to implement environmentally sustainable logistics solutions (Li et al., 2021). These internal drivers are well explained by the Resource-Based View (RBV), which posits that firms achieve sustainable competitive advantage by effectively deploying valuable, rare, and inimitable resources, including green technologies and environmentally oriented managerial knowledge (Barney, 2021). On the other hand, Institutional Theory emphasises the role of external forces—such as regulatory requirements, industry norms, and market expectations—in compelling organisations to conform to environmentally responsible practices (Chen et al., 2022). While both theoretical perspectives have been applied independently in prior studies, their combined empirical examination within the context of freight forwarding in emerging economies remains limited.

Existing research identifies cost reduction, operational efficiency, and regulatory compliance as primary motivations for adopting green logistics practices (Sharma et al., 2022). Conversely, high initial investment costs, limited technological know-how, and insufficient governmental incentives are frequently cited as major barriers, particularly in developing countries. In the Vietnamese context, however, there is still insufficient empirical evidence on how freight forwarding firms balance these perceived opportunities and constraints, and how internal organisational capabilities interact with external institutional pressures to shape adoption decisions.

Addressing this gap, the present study investigates the key drivers and barriers influencing the adoption of green logistics practices within Vietnam's freight forwarding industry by integrating the Resource-Based View and Institutional Theory into a unified analytical framework. This integrated perspective explicitly supports managerial and policy decision-making under institutional and resource constraints.

Specifically, this research seeks to answer the following questions:

(1) What are the principal motivations and deterrents affecting green logistics adoption in Vietnam's freight forwarding sector?
(2) To what extent do external institutional pressures, such as regulatory policies and customer demand, influence firms' adoption of green logistics practices?
(3) How do organisational capabilities, including financial resources and technological expertise, shape firms' ability to implement green logistics initiatives?

This study is original in three important respects. First, it provides one of the few large-scale empirical examinations of green logistics adoption specifically within Vietnam's freight forwarding industry, a context that has received limited attention in the existing literature. Second, it offers a comparative assessment of internal organisational capabilities and external institutional pressures within a single

integrated framework, thereby extending prior studies that have examined these factors in isolation. Third, by applying RBV and Institutional Theory jointly, this study advances decision-making research by explaining how logistics firms in emerging markets navigate sustainability-related decisions under institutional uncertainty. Methodologically, this study contributes by empirically testing the integrated theoretical framework using firm-level data from an emerging market logistics context, thereby providing robust evidence to support sustainability-related decision-making in environments characterised by institutional constraints.

By focusing on a specific and underexplored emerging market context, this research contributes both theoretically and practically to the green logistics literature. The findings enhance theoretical understanding of sustainability adoption by clarifying the mechanisms through which internal and external forces jointly influence organisational behaviour in logistics. From a practical perspective, the results provide valuable insights for policymakers, logistics managers, and industry stakeholders seeking to promote environmentally sustainable practices in Vietnam and similar emerging economies.

Given the increasing global urgency to address climate change and the logistics sector's substantial contribution to carbon emissions, this study is both timely and policy relevant. Shifts in consumer behaviour towards environmentally responsible products and services further intensify the pressure on logistics firms to adopt green practices (Stefanelli et al., 2021). Understanding the specific barriers and enablers of green logistics adoption in emerging markets such as Vietnam is therefore essential for designing sustainability strategies that are both locally applicable and globally impactful.

2. Literature Review

2.1 Green Logistics and Freight Forwarding

Green logistics has emerged as a central concept in contemporary supply chain management, reflecting growing concerns regarding the environmental impacts of logistics activities. Green logistics is commonly defined as the systematic integration of environmentally responsible practices into logistics operations with the objective of reducing carbon emissions, minimising resource consumption, and improving overall supply chain efficiency through technological innovation and sustainable process design (Centobelli et al., 2020a; Moslehpour et al., 2017). The logistics sector—particularly freight transportation—remains a major contributor to global greenhouse gas emissions, accounting for approximately 24% of total CO_2 emissions from fuel combustion (International Energy Agency, 2024). These figures underscore the necessity of adopting environmentally sustainable logistics solutions, especially in freight-intensive activities such as freight forwarding.

The implementation of green logistics practices, including route optimisation, eco-friendly packaging, and the use of alternative and low-emission fuels, has been shown to significantly reduce environmental externalities while simultaneously enhancing operational efficiency (Allen et al., 2021; Moslehpour et al., 2018). Prior empirical studies further indicate that such practices can generate economic benefits by

lowering fuel consumption, reducing operational waste, and improving service reliability, thereby aligning environmental objectives with firm performance (Centobelli et al., 2020b; Chen et al., 2022).

Freight forwarding represents a critical segment of the logistics industry, responsible for coordinating and managing cross-border transportation and documentation activities. Due to its heavy reliance on transportation infrastructure and multimodal logistics networks, freight forwarding operations are particularly exposed to environmental challenges. Nguyen & Le (2020) demonstrate that the adoption of digital tracking systems, electric vehicles, and energy-efficient warehousing technologies can substantially reduce emissions and operating costs within freight forwarding firms. These technologies are increasingly viewed as strategic resources that enable firms to respond to environmental pressures while maintaining competitiveness, consistent with prior decision-making and adoption studies (Liao & Wong, 2008; Moslehpour et al., 2018).

Despite the demonstrated benefits, the adoption of green logistics technologies within freight forwarding remains uneven, particularly in developing economies such as Vietnam. Empirical evidence suggests that limited financial resources, high initial investment costs, inadequate technological infrastructure, and insufficient regulatory support continue to constrain adoption efforts (Do et al., 2024; Liao et al., 2014). Moreover, Lee (2021) highlights that a shortage of skilled human capital and limited organisational expertise further impede the effective implementation of green logistics initiatives. These constraints indicate that green logistics adoption is not solely a technological issue but is also shaped by organisational capabilities and external institutional conditions, a theme widely discussed in sustainability and behavioural decision-making research (Liao et al., 2012; Moslehpour et al., 2017).

Although prior studies document the advantages of green logistics adoption, there remains limited empirical evidence on how freight forwarding firms in emerging markets simultaneously perceive and respond to both the drivers and barriers of green logistics implementation. This gap highlights the need for context-specific research that examines the determinants of green logistics adoption in Vietnam's freight forwarding industry.

From a behavioural and decision-science perspective, prior studies emphasise that firms' adoption of innovative and sustainability-oriented practices is shaped not only by technological feasibility but also by managerial perceptions, organisational climate, and institutional context. Liao and Wong (2008) and Liao et al. (2012) demonstrate that perceived usefulness, ease of implementation, and external pressures play critical roles in technology adoption decisions. Similarly, Moslehpour et al. (2018) highlight the importance of organisational climate, leadership support, and work style in facilitating sustainable practices within firms. These insights suggest that green logistics adoption in freight forwarding should be examined through an integrated lens that captures both organisational decision-making processes and environmental constraints Moslehpour et al. (2017).

2.2 Sustainable Supply Chain Management (SSCM)

Sustainable Supply Chain Management (SSCM) has attracted substantial academic and managerial attention over the past two decades due to its emphasis on balancing the three dimensions of the triple bottom line—economic, environmental, and social sustainability. SSCM is broadly defined as the strategic integration of sustainability objectives into supply chain operations to enhance resource efficiency, reduce environmental degradation, and ensure long-term organisational performance (Razzak, 2022). Common SSCM practices include the adoption of renewable energy sources, digital technologies for route and inventory optimisation, and collaborative initiatives among supply chain partners to achieve shared sustainability goals (An et al., 2021).

Within the freight forwarding context, the implementation of SSCM practices has been associated with notable environmental and operational improvements. Duzgun and Atay (2025) report that freight forwarding firms adopting SSCM practices experience improved logistics efficiency, reduced emissions, and enhanced service quality. Digital technologies—such as Internet of Things (IoT)-enabled tracking systems—play a particularly important role by improving visibility, reducing uncertainty, and minimising resource wastage across logistics operations (Centobelli et al., 2020b). These findings are consistent with prior studies emphasising the role of technological and organisational factors in shaping sustainable decision-making (Liao et al., 2014; Pham et al., 2018).

Empirical evidence further supports the relevance of integrated decision-making frameworks in sustainability research. Moslehpour et al. (2018) show that sustainability-related intentions and behaviours are often mediated by perceived usefulness and organisational support, while Pham et al. (2018) demonstrate that multi-criteria decision-making approaches are essential for evaluating complex sustainability trade-offs in logistics and supply chain contexts. These studies reinforce the need to analyse SSCM adoption by jointly considering internal organisational capabilities and external institutional pressures, particularly in emerging market environments (Wong et al., 2024).

The adoption of SSCM practices is also strongly influenced by external stakeholders, including regulatory authorities, customers, and industry associations. Regulatory pressure and growing consumer awareness of environmental issues increasingly compel logistics firms to adopt sustainable practices in order to maintain legitimacy and market competitiveness (Chen et al., 2022; Vo & Nguyen, 2023). Empirical studies indicate that firms aligning their logistics operations with environmental objectives often benefit from enhanced customer trust, improved brand reputation, and stronger competitive positioning (Nguyen & Le, 2020).

However, despite these potential benefits, the implementation of SSCM practices in developing economies such as Vietnam remains fragmented and inconsistent. Nazir et al. (2024) identify key challenges, including insufficient government incentives, limited access to advanced technologies, and a lack of managerial awareness regarding the long-term benefits of sustainability initiatives. These challenges suggest that SSCM adoption is contingent upon both internal organisational capabilities and external institutional pressures, rather than being driven by environmental awareness alone (Hui et al., 2017).

Taken together, the existing literature highlights the importance of integrating organisational resource-based perspectives with institutional explanations to better understand sustainability adoption in logistics. Nevertheless, empirical studies that jointly examine green logistics and SSCM within the freight forwarding sector—particularly in emerging markets—remain scarce. This unresolved gap motivates the present study and provides the foundation for the theoretical framework and hypothesis development presented in the following section.

3. Theoretical Framework and Hypotheses Development

3.1. Theoretical Framework

This study integrates the Resource-Based View (RBV) and Institutional Theory to examine green logistics adoption within Vietnam's freight forwarding industry. The integration of these two perspectives enables a comprehensive understanding of how internal organisational resources and external institutional pressures jointly shape sustainability-related decision-making and behavioural outcomes. This combined theoretical lens has been widely applied in prior adoption and decision-science research to explain complex organisational responses to sustainability and technological innovation (Liao et al., 2012; Liao & Wong, 2008; Moslehpour et al., 2018).

3.1.1 Resource-Based View (RBV)

The Resource-Based View (RBV) argues that firms achieve sustained competitive advantage through the possession and effective deployment of valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney, 2021). Within the context of green logistics, resources such as advanced routing systems, eco-friendly vehicle fleets, energy-efficient warehousing, and digital logistics platforms represent critical strategic assets that support environmentally sustainable operations (Chen et al., 2022).

However, RBV emphasises that the mere possession of green resources is insufficient to generate superior outcomes. Firms must also develop organisational capabilities, including managerial expertise, employee competencies, and internal routines, to effectively deploy and integrate these resources into daily operations (Centobelli et al., 2020a). Prior empirical studies demonstrate that firms with stronger organisational capabilities are more likely to translate sustainability-related investments into operational efficiency and environmental performance improvements (Nguyen et al., 2023).

From a behavioural and decision-making perspective, RBV-based adoption is further influenced by managerial perceptions of usefulness, feasibility, and expected performance outcomes. Liao and Wong (2008) and Liao et al. (2012, 2014) show that perceived usefulness and ease of implementation significantly affect organisational adoption decisions related to technology-enabled systems. Similarly, Moslehpour et al. (2017, 2019) highlight the role of organisational climate, leadership support, and work style in shaping sustainability-oriented behaviours within firms.

Accordingly, RBV suggests that freight forwarding firms with stronger green resources and organisational capabilities are more likely to adopt and successfully implement green logistics practices, thereby improving both environmental and operational performance. These theoretical insights provide a foundation for developing hypotheses related to internal organisational drivers of green logistics adoption.

3.1.2 Institutional Theory

Institutional Theory focuses on how external pressures influence organisational behaviour through coercive, normative, and mimetic mechanisms (Zhu & Liu, 2025). Coercive pressures arise from government regulations and environmental policies, normative pressures stem from industry standards and professional norms, and mimetic pressures emerge when firms imitate successful competitors under conditions of uncertainty (Chen et al., 2022).

In the logistics sector, growing regulatory scrutiny, stakeholder expectations, and societal concerns regarding environmental responsibility increasingly compel firms to adopt green logistics practices (Duzgun & Atay, 2025). Empirical evidence indicates that institutional pressures not only encourage compliance-based adoption but also shape strategic sustainability decisions aimed at maintaining legitimacy and competitiveness (Liao et al., 2012; Moslehpour et al., 2018).

In emerging economies such as Vietnam, however, institutional environments are often characterised by regulatory inconsistencies and limited enforcement, resulting in institutional voids that weaken formal sustainability incentives (Do et al., 2024). Under such conditions, firms may respond heterogeneously to institutional pressures depending on their internal resources and strategic orientation. Some firms adopt proactive sustainability strategies, while others engage in symbolic or minimal compliance (Duzgun et al., 2024).

Institutional Theory, therefore, suggests that external pressures alone may be insufficient to drive green logistics adoption unless firms possess adequate internal capabilities to respond effectively. This perspective highlights the importance of examining how institutional forces interact with organisational resources in shaping sustainability adoption decisions.

3.1.3 Integration of RBV and Institutional Theory

Integrating RBV and Institutional Theory provides a more nuanced explanation of green logistics adoption by recognising that sustainability decisions are jointly determined by internal organisational capabilities and external institutional pressures. Prior studies emphasise that organisational responses to sustainability initiatives depend on both decision-makers' perceptions and the broader institutional environment (Liao et al., 2014; Moslehpour et al., 2019).

Furthermore, multi-criteria decision-making approaches have been shown to be essential for evaluating sustainability trade-offs in logistics and supply chain contexts, where firms must balance cost efficiency, environmental impact, and stakeholder expectations (Pham et al., 2018). These insights reinforce the

argument that green logistics adoption is a complex strategic decision shaped by interacting internal and external factors rather than a single determinant.

Accordingly, this integrated framework provides a strong theoretical basis for developing multiple hypotheses that capture the direct and interactive effects of organisational resources and institutional pressures on green logistics adoption and performance outcomes. This framework directly informs the hypotheses developed in Section 3.2.

3.2. Hypotheses Development

Building on the integrated Resource-Based View (RBV) and Institutional Theory framework developed in Section 3.1, this study proposes a comprehensive set of hypotheses to explain the drivers, mechanisms, and performance consequences of green logistics adoption in Vietnam's freight forwarding sector. By expanding the hypothesis structure, this study responds directly to calls in the literature for more nuanced and theoretically grounded models that jointly consider organisational capabilities, institutional pressures, and behavioural factors in sustainability adoption, particularly in emerging market contexts (Liao & Wong, 2008; Moslehpour et al., 2019).

Access to Green Technology and Organisational Capabilities: From an RBV perspective, access to green technologies such as energy-efficient transportation systems, routing optimisation software, and low-emission logistics infrastructure represents strategic resources that enhance firms' growth potential. Firms possessing such technologies are better positioned to improve operational scalability, expand service capacity, and strengthen internal coordination mechanisms. In emerging markets, technological access often differentiates firms that are able to grow and formalise operations from those that remain resource-constrained, suggesting a positive relationship between access to green technology and organisational size.

H1: Access to green technology positively influences organisational size.

Beyond its effect on firm size, access to green technology directly facilitates the adoption of green logistics practices (Duzgun et al., 2024). Firms equipped with advanced technologies can more easily implement environmentally friendly processes, reduce emissions, and optimise logistics operations. Prior studies emphasise that technological readiness significantly lowers adoption barriers and enhances the feasibility of sustainability initiatives (Centobelli et al., 2020a; Chen et al., 2022). In the Vietnamese logistics sector, where technological heterogeneity remains substantial, access to green technology is expected to be a critical determinant of green logistics adoption (Chen & Kitsis, 2017).

H2: Access to green technology positively influences green logistics adoption.

Institutional Pressures and Sustainability Outcomes: Institutional Theory posits that organisational behaviour is shaped by coercive, normative, and mimetic pressures arising from regulatory frameworks, industry standards, and societal expectations (Zhu & Liu, 2025). In the context of sustainability, such pressures increasingly compel firms to align their operations with environmental objectives. Firms

operating under stronger institutional pressures may experience performance benefits through enhanced legitimacy, reputational gains, and improved stakeholder relationships.

H3: Institutional pressures positively influence organisational performance.

In addition to performance effects, institutional pressures directly motivate firms to adopt green logistics practices. Regulatory requirements, customer expectations, and competitive imitation create incentives for firms to integrate sustainability into logistics operations. However, in emerging economies such as Vietnam, the effectiveness of these pressures may depend on enforcement strength and organisational readiness (Do et al., 2024). Nevertheless, institutional forces are expected to exert a positive influence on green logistics adoption.

H4: Institutional pressures positively influence green logistics adoption.

Supply Chain Collaboration and Environmental Awareness: Supply chain collaboration enables firms to share resources, knowledge, and best practices, thereby reducing the cost and complexity of implementing green logistics initiatives. Collaborative relationships with suppliers, customers, and logistics partners facilitate joint problem-solving and collective sustainability efforts (An et al., 2021). In freight forwarding networks, where interdependence among actors is high, collaboration is expected to play a pivotal role in advancing green logistics adoption.

H5: Supply chain collaboration positively influences green logistics adoption.

Beyond its direct operational effects, supply chain collaboration can enhance firms' environmental awareness by exposing managers to sustainability norms, shared environmental goals, and collective responsibility within the supply chain. Through repeated interactions and information exchange, collaborative networks foster greater awareness of environmental impacts and regulatory expectations (Lee et al., 2025).

H6: Supply chain collaboration positively influences environmental awareness.

Moderating Effects of Organisational Size and Environmental Awareness: Organisational size may condition the effectiveness of green technology in driving green logistics adoption. Larger firms typically possess greater financial resources, managerial capacity, and absorptive capability, enabling them to more effectively leverage green technologies (Wang et al., 2022). Conversely, smaller firms may face constraints that limit the translation of technological access into actual adoption. Thus, organisational size is expected to moderate the relationship between access to green technology and green logistics adoption.

H7: Organisational size moderates the relationship between access to green technology and green logistics adoption, such that the relationship is stronger for larger firms.

Similarly, environmental awareness may strengthen the impact of supply chain collaboration on green logistics adoption. Firms with higher levels of environmental awareness are more likely to internalise

sustainability norms transmitted through collaborative networks and translate them into concrete operational practices. In contrast, low awareness may weaken the effectiveness of collaboration as a driver of adoption (Wang et al., 2023).

H8: Environmental awareness moderates the relationship between supply chain collaboration and green logistics adoption, such that the relationship is stronger when environmental awareness is higher.

Direct Effects of Organisational Characteristics: Organisational size itself may directly influence green logistics adoption. Larger firms often face greater public scrutiny, regulatory attention, and stakeholder pressure, which increase incentives to adopt sustainable practices. Additionally, scale advantages may reduce the relative cost of green investments.

H9: Organisational size positively influences green logistics adoption.

Environmental awareness reflects managerial understanding of environmental issues and commitment to sustainability. Firms with higher environmental awareness are more likely to proactively adopt green logistics practices, even in the absence of strong regulatory enforcement.

H10: Environmental awareness positively influences green logistics adoption.

Performance Implications of Green Logistics Adoption: Organisational size may also directly affect performance outcomes. Larger firms may benefit from economies of scale, diversified service offerings, and enhanced bargaining power, which contribute to superior organisational performance.

H11: Organisational size positively influences organisational performance.

Green logistics adoption is expected to enhance organisational performance through cost savings, operational efficiency, improved service quality, and reputational benefits. While short-term implementation costs may exist, prior research suggests that sustainability-oriented logistics practices generate long-term performance advantages (Do et al., 2024; El-Garaihy et al., 2022).

H12: Green logistics adoption positively influences organisational performance.

Finally, environmental awareness may directly contribute to organisational performance by shaping strategic orientation, enhancing stakeholder trust, and supporting long-term value creation. Firms that embed environmental considerations into decision-making processes are better positioned to achieve sustainable competitive advantages.

H13: Environmental awareness positively influences organisational performance.

Collectively, the proposed hypotheses constitute an integrated conceptual framework that captures the complex and interrelated influences of technological resources, institutional pressures, organisational

characteristics, behavioural factors, and performance outcomes within the freight forwarding sector. Grounded in the Resource-Based View and Institutional Theory, the framework explains how access to green technologies (AGT), institutional pressures (IP), and supply chain collaboration (SCC) drive green logistics adoption (GLA), while organisational size (OS) and environmental awareness (EA) function both as direct antecedents and as moderating mechanisms that condition these relationships. Green logistics adoption is further theorised to translate into superior organisational performance (OP), reflecting the strategic value of sustainability-oriented capabilities. By modelling both direct and moderating effects, the framework acknowledges the heterogeneity of firm responses to sustainability pressures, particularly in emerging market contexts such as Vietnam. Overall, this comprehensive structure advances existing logistics and sustainability research by offering a multi-dimensional and theoretically grounded explanation of green logistics adoption and its performance implications in freight forwarding firms.

Figure 1: Research Model.
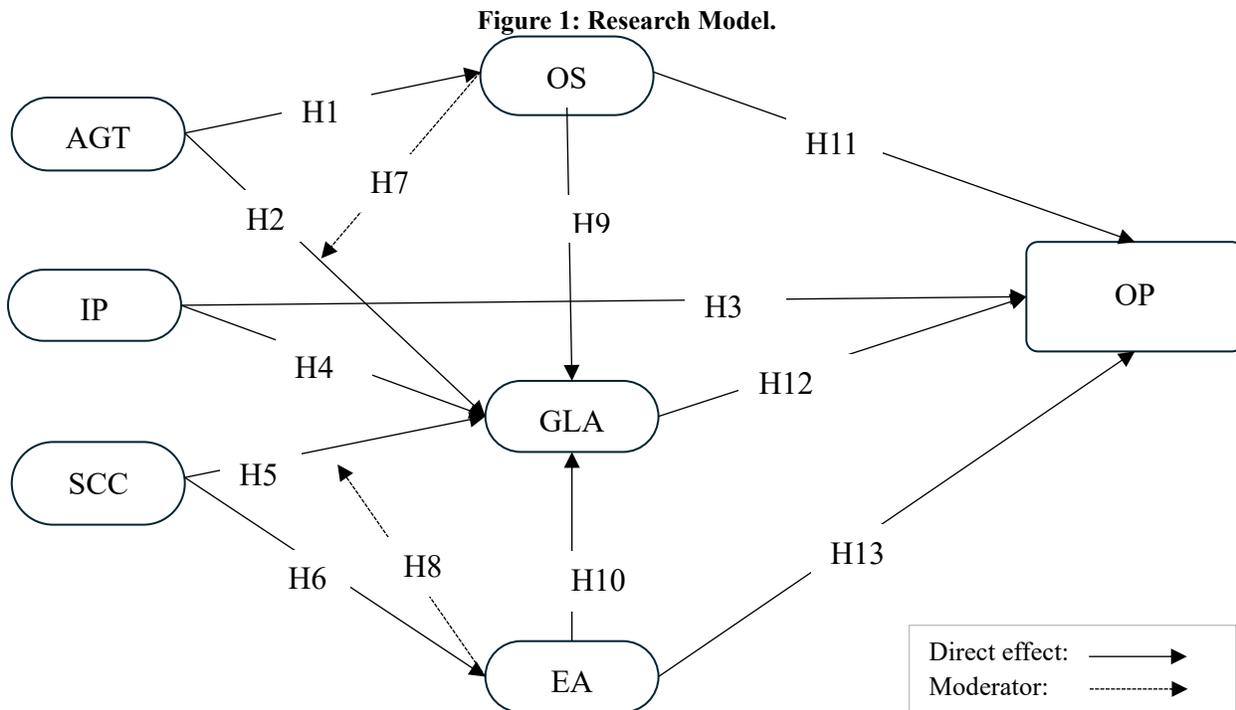
4. Methodology

4.1 Research Design

This study adopts a quantitative research design to examine the direct, moderating, and outcome relationships among access to green technologies, institutional pressures, supply chain collaboration, environmental awareness, green logistics adoption, and organizational performance within the Vietnamese logistics industry. The quantitative approach is appropriate because it enables systematic hypothesis testing, parameter estimation, and statistical inference across a relatively large sample of firms, which is consistent with prior logistics and sustainability research (Hair et al., 2019; Liao & Wong, 2008; Moslehpour et al., 2017).

The research design integrates direct effects, moderation mechanisms, and outcome relationships within a unified structural framework, allowing a more comprehensive explanation of green logistics adoption behaviour beyond simple bivariate associations. By simultaneously modeling technological, institutional, organizational, and behavioural factors, the study advances existing logistics literature, which has often examined these drivers in isolation (Do et al., 2024; Nguyen & Le, 2020).

A structured questionnaire survey was employed to capture firm-level perceptions and practices related to green logistics. All perceptual measures were assessed using a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"), which is widely accepted in logistics, sustainability, and organizational research (Carifio & Perla, 2008; Norman, 2010). Although Likert-scale data are ordinal by nature, they are treated as continuous variables in this study, a practice commonly adopted in multivariate analysis and PLS-SEM when sample sizes are sufficiently large and distributions approximate normality (Bag et al., 2022; Zhu & Liu, 2025).

4.2 Data Collection and Sampling Procedure

Data collection was conducted in two stages to strengthen sample adequacy and measurement robustness. The initial survey was administered between August and November 2024, targeting logistics firms operating in Vietnam. Following reviewer feedback and to enhance statistical power and construct stability, an extended data collection phase was conducted between November and mid-December 2024, during which additional logistics firms were contacted, and new responses were obtained.

A snowball sampling technique was employed, whereby initial respondents were asked to forward the survey to other qualified professionals within the logistics sector. This approach is appropriate when targeting knowledgeable respondents in specialized industries and has been widely applied in logistics and sustainability research (Moslehpour et al., 2019; Pham et al., 2018). Participation criteria required respondents to be employed in logistics-related functions and to possess familiarity with their firm's environmental or operational practices.

The survey was distributed via company emails, professional networks (e.g., LinkedIn), and direct organizational contacts. After removing incomplete and inconsistent responses, a total of 334 valid questionnaires were retained for analysis. This sample size exceeds minimum requirements for multivariate analysis and PLS-SEM, supporting reliable estimation of path coefficients and interaction effects (Hair et al., 2019).

4.3 Sample Characteristics

To provide transparency regarding respondent composition and to support the validity of subsequent empirical analyses, demographic characteristics were analyzed using SPSS 27. Table 1 presents the demographic profile of the respondents, including gender, work experience, organizational position, and education level, thereby offering a comprehensive overview of the sample structure.

Table 1: Sample Demographic Characteristics (N = 334)

Characteristic	Category	Frequency	Percentage (%)
Gender	Female	104	31.1
	Male	230	68.9
Work Experience	0–2 years	133	39.8
	3–5 years	162	48.5
	6–10 years	11	3.3
	More than 10 years	28	8.4
Position	Junior staff	112	33.5
	Mid-level management	157	47.0
	Senior management	44	13.2
	Executive	21	6.3
Education Level	Bachelor's degree	298	89.2
	Master's degree	27	8.1
	PhD	9	2.7

Note(s): This table summarizes the demographic composition of the respondents, providing evidence of sample diversity and representativeness across gender, experience, organizational position, and education level. Source(s): Authors' own work.

The sample comprises respondents spanning junior staff, mid-level management, senior management, and executive-level positions, ensuring representation across multiple organizational hierarchies within the logistics sector. Although junior staff account for 33.5% of the respondents, their inclusion is appropriate given the operationally intensive nature of logistics activities. Junior employees are often directly involved in the implementation of green logistics practices, including the use of environmentally friendly technologies, compliance with sustainability procedures, and coordination with supply chain partners. As such, they possess detailed and context-specific knowledge relevant to green logistics adoption.

Importantly, 66.5% of the respondents occupy mid-level management positions or higher, which are directly responsible for planning, coordinating, and supervising logistics operations and sustainability-related initiatives. This distribution strengthens the strategic reliability of the data and ensures that the findings reflect both operational execution and organizational decision-making perspectives.

With respect to work experience, the majority of respondents report between 0–5 years of experience, reflecting the relatively young and rapidly expanding nature of Vietnam's logistics sector. This experience profile is consistent with the structural characteristics of emerging-market logistics industries and supports the relevance of the data for capturing contemporary sustainability practices and adoption dynamics.

The gender distribution of the sample (68.9% male and 31.1% female) aligns with the male-dominated composition commonly observed in the logistics and transportation industry, particularly in emerging economies. This alignment suggests that the sample reasonably reflects industry norms and does not introduce systematic gender bias into the analysis.

In terms of educational attainment, the vast majority of respondents hold at least a bachelor's degree, indicating a strong capacity to understand organizational strategies, regulatory requirements, and sustainability-related concepts. This educational profile enhances confidence in the respondents' ability to provide informed and reliable assessments of green logistics adoption and organizational performance.

Overall, the sample composition is well aligned with the study's unit of analysis—the firm—and follows the key-informant approach widely adopted in decision sciences, logistics, and sustainability research. The diversity of roles, experience levels, and educational backgrounds supports the robustness of the empirical findings and justifies the use of the sample for drawing conclusions about organizational-level sustainability decisions.

4.4 Measurement of Variables

All constructs were operationalized using multi-item reflective scales adapted from well-established literature and contextually adjusted to the Vietnamese logistics sector. Definitions and sources for each construct are provided to ensure conceptual clarity and theoretical grounding.

Access to Green Technologies (AGT) reflects the extent to which firms can access, invest in, and effectively utilize environmentally friendly logistics technologies (Duzgun & Atay, 2025; Wang et al., 2023). Institutional Pressures (IP) capture regulatory and stakeholder-driven forces influencing firms' environmental practices (Ko et al., 2021). Supply Chain Collaboration (SCC) measures the degree of coordination and joint sustainability initiatives with supply chain partners (Patel & Desai, 2018). Environmental Awareness (EA) reflects organizational culture and employee awareness regarding environmental impacts (Bouzari et al., 2022). Organizational Size (OS) is measured using firm size indicators related to employment scale and revenue (Sanusi & Johl, 2022). Green Logistics Adoption (GLA) captures the extent to which sustainable logistics practices are integrated into daily operations (Liu et al., 2021; Wang et al., 2022). Organizational Performance (OP) includes operational efficiency, financial performance, and reputational outcomes (Singh et al., 2023.

The full questionnaire items corresponding to each construct are provided in Appendix A to ensure transparency and replicability, while the measurement model table reports item codes and psychometric properties only.

4.5 Measurement Model Assessment

Measurement model evaluation was conducted using SmartPLS 3 to assess internal consistency reliability, convergent validity, and construct validity. Table 2 reports the measurement model results, including outer loadings, Cronbach's alpha, rho_A, Composite Reliability (CR), and Average Variance Extracted (AVE) for all constructs.

Table 2: Measurement Model Evaluation

Variables Threshold	Outer Loadings ≥0.6	Cronbach's Alpha ≥0.7	rho_A ≥0.7	CR ≥0.7	AVE ≥0.5
Access to Green Technologies (AGT)		0.817	0.818	0.879	0.646
AGT1	0.766				
AGT2	0.813				
AGT3	0.797				
AGT4	0.838				
Institutional Pressures (IP)		0.711	0.715	0.839	0.636
IP1	0.852				
IP2	0.790				
IP3	0.746				
Supply Chain Collaboration (SCC)		0.827	0.831	0.885	0.658
SCC1	0.814				
SCC2	0.798				
SCC3	0.797				
SCC4	0.835				
Green Logistics Adoption (GLA)		0.703	0.704	0.818	0.529
GLA1	0.688				
GLA2	0.743				
GLA3	0.746				
GLA4.	0.730				
Organizational Performance (OP)		0.803	0.880	0.864	0.618
OP1	0.869				
OP2	0.888				
OP3	0.745				
OP4	0.612				
Organizational Size (OS)		0.807	0.814	0.886	0.722
OS1	0.814				
OS2	0.853				
OS3	0.881				
Environmental Awareness (EA)		0.809	0.814	0.887	0.723
EA1	0.847				
EA2	0.846				
EA3	0.858				

Note(s): All outer loadings exceed 0.60, Cronbach's alpha and Composite Reliability exceed 0.70, and AVE values exceed 0.50, indicating satisfactory reliability and convergent validity. Source(s): Authors' own work.

All indicator loadings exceed the recommended threshold of 0.60, while Cronbach's alpha, rho_A, and CR values are above 0.70, indicating satisfactory internal consistency. AVE values exceed 0.50 for all constructs, confirming convergent validity (Hair et al., 2019). These results demonstrate that the measurement model is statistically sound and suitable for subsequent structural analysis. Table 2 is placed

in Section 4.5 because it directly reports measurement reliability and validity, as explicitly requested by the editor.

4.6 Data Analysis and Model Specification

Data analysis followed a multi-software analytical strategy to enhance robustness and methodological rigor. SPSS 27 was used to compute descriptive statistics and summarize the demographic characteristics of the sample. SmartPLS 3 was employed to estimate the partial least squares structural equation model (PLS-SEM), including the assessment of the measurement model, structural paths, bootstrapped standard errors, coefficients of determination (R^2), and effect sizes (f^2). Stata 17 was additionally used to estimate complementary covariance-based SEM (CB-SEM) global model fit indices and to conduct formal diagnostic checks on model residuals and structural specifications corresponding to Equation 1.

To examine the hypothesized relationships, the following structural equations were specified:

$$GLA = \beta_0 + \beta_1 AGT + \beta_2 IP + \beta_3 SCC + \beta_4 OS + \beta_5 EA + \varepsilon, \tag{1}$$

$$GLA = \beta_0 + \beta_1 AGT + \beta_2 IP + \beta_3 SCC + \beta_4 (AGT \times OS) + \beta_5 (SCC \times EA) + \varepsilon, \tag{2}$$

$$OP = \beta_0 + \beta_1 GLA + \beta_2 AGT + \beta_3 IP + \beta_4 OS + \beta_5 EA + \varepsilon, \tag{3}$$

where β_0 represents the intercept, β_1–β_5 denote the estimated structural path coefficients, and ε represents the stochastic error term. AGT denotes Access to Green Technologies, IP denotes Institutional Pressures, SCC denotes Supply Chain Collaboration, OS denotes Organizational Size, EA denotes Environmental Awareness, GLA denotes Green Logistics Adoption, and OP denotes Organizational Performance. The interaction terms (AGT×OS) and (SCC×EA) represent multiplicative moderation effects and were constructed using mean-centered variables to mitigate potential multicollinearity.

Bootstrapping with 5,000 resamples was applied to assess the statistical significance of direct, moderating, and indirect effects, consistent with established methodological recommendations in sustainability and logistics research (Leung et al., 2023; Moslehpour et al., 2019). Global model fit was further evaluated using CB-SEM in Stata 17, with results indicating acceptable to good model fit based on χ^2/df, RMSEA, CFI, TLI, and SRMR thresholds, in line with widely accepted criteria (Hair et al., 2019; Hu & Bentler, 1999).

To ensure the statistical validity of the estimated relationships and to address potential spurious regression concerns, a comprehensive set of diagnostic checks was undertaken. Residual normality was assessed using the Shapiro–Wilk and skewness–kurtosis tests, model linearity was examined using the Ramsey RESET test and further justified using the nonlinearity testing framework proposed by Hui et al. (2017), and multicollinearity was evaluated using variance inflation factors (VIF). Heteroskedasticity was assessed using the Breusch–Pagan test. As the data are cross-sectional, Durbin–Watson and unit root tests—which require a time-series structure—are not mechanically applicable; instead, spurious regression concerns were mitigated through theory-driven model specification, latent-variable modeling,

and bootstrapped estimation, following recent Decision Sciences guidance. The numerical results of all diagnostic tests and related justifications are reported in Section 5.4 and summarized in Table 7A.

5. Results

5.1 Discriminant Validity Assessment

Discriminant validity was examined to ensure that each construct represents a conceptually distinct phenomenon and that the estimated relationships are not affected by construct overlap. Following established guidelines in structural equation modeling, discriminant validity was assessed using both the Fornell–Larcker criterion and the heterotrait–monotrait ratio (HTMT) (Fornell & Larcker, 1981; Henseler et al., 2015).

Table 3: Discriminant validity (Fornell–Larcker)

	AGT	EA	GLA	IP	OP	OS	SCC
AGT	*0.804*						
EA	0.400	*0.850*					
GLA	0.447	0.402	*0.727*				
IP	0.182	0.131	0.204	*0.797*			
OP	0.216	0.244	0.264	0.279	*0.786*		
OS	0.447	0.473	0.389	0.126	0.288	*0.850*	
SCC	0.328	0.166	0.322	0.143	0.127	0.156	*0.811*

Note(s): Diagonal elements represent the square roots of AVE, and off-diagonal elements represent inter-construct correlations. Discriminant validity is established as the square root of AVE for each construct exceeds its correlations with other constructs (Fornell & Larcker, 1981; Hair et al., 2019). Source(s): Authors' own work.

The Fornell–Larcker results indicate that the square root of the average variance extracted (AVE) for each construct exceeds its correlations with all other constructs. This provides evidence that each construct shares more variance with its own indicators than with other constructs in the model.

Table 4: Heterotrait-Monotrait Ratio (HTMT)

	AGT	EA	GLA	IP	OP	OS	SCC
AGT							
EA	0.489						
GLA	0.590	0.528					
IP	0.264	0.172	0.285				
OP	0.234	0.254	0.321	0.344			
OS	0.548	0.580	0.514	0.164	0.317		
SCC	0.397	0.199	0.420	0.183	0.145	0.191	

Note(s): HTMT values below 0.85 indicate adequate discriminant validity between constructs (Hair et al., 2019; Henseler et al., 2015). Source(s): Authors' own work.

In addition, all HTMT values are below the conservative threshold of 0.85, further confirming satisfactory discriminant validity. Taken together, these results demonstrate that access to green technologies, institutional pressures, supply chain collaboration, environmental awareness, organizational size, green

logistics adoption, and organizational performance are empirically distinct constructs, supporting the adequacy of the measurement model (Benitez et al., 2020; Hair et al., 2019).

5.2 Structural Model Evaluation and Explained Variance

After establishing discriminant validity, the structural model was evaluated. The assessment focused on the coefficient of determination (R^2), which indicates the proportion of variance explained in each endogenous construct by its predictors.

Table 5: Coefficient of Determination (R^2)

	R Square	R Square Adjusted
Environmental Awareness (EA)	0.027	0.024
Green Logistics Adoption (GLA)	0.374	0.361
Organizational Performance (OP)	0.164	0.154
Organizational Size (OS)	0.200	0.198
Note(s): R^2 represents the proportion of variance explained by the exogenous constructs in the structural model. R^2 values of 0.25, 0.50, and 0.75 are commonly interpreted as weak, moderate, and substantial explanatory power, respectively (Hair et al., 2019). Adjusted R^2 accounts for model complexity and sample size. Results are based on the estimation of Equations 1 and 3. Source(s): Authors' own work.		

The results show that the model explains a moderate proportion of variance in green logistics adoption, suggesting that technological, institutional, organizational, and collaborative factors jointly contribute to adoption decisions. Organizational performance also demonstrates meaningful explanatory power, indicating that green logistics adoption and related organizational factors play an important role in shaping performance outcomes. These levels of explained variance are consistent with prior sustainability and logistics studies employing PLS-SEM (Hair et al., 2019).

5.3 Effect Size (f²) Analysis

Beyond statistical significance, effect sizes (f^2) were examined to assess the substantive impact of each predictor on the endogenous constructs. Effect size analysis is essential in PLS-SEM, as statistically significant paths may still have limited practical relevance (Cohen, 1988).

Table 6: Effect Size (f^2) of Structural Model Relationships

Predictor	Endogenous Construct	f²	Effect Size
Access to Green Technologies (AGT)	Green Logistics Adoption (GLA)	0.025	Small
Access to Green Technologies (AGT)	Organizational Size (OS)	0.250	Medium
Environmental Awareness (EA)	Green Logistics Adoption (GLA)	0.029	Small
Environmental Awareness (EA)	Organizational Performance (OP)	0.006	Small
Green Logistics Adoption (GLA)	Organizational Performance (OP)	0.013	Small
Institutional Pressures (IP)	Green Logistics Adoption (GLA)	0.006	Small
Institutional Pressures (IP)	Organizational Performance (OP)	0.056	Small–Medium
Organizational Size (OS)	Green Logistics Adoption (GLA)	0.007	Small
Organizational Size (OS)	Organizational Performance (OP)	0.026	Small

Supply Chain Collaboration (SCC)	Environmental Awareness (EA)	0.028	Small
Supply Chain Collaboration (SCC)	Green Logistics Adoption (GLA)	0.032	Small
AGT × OS	Green Logistics Adoption (GLA)	0.037	Small
SCC × EA	Green Logistics Adoption (GLA)	0.035	Small

Note(s): Effect sizes (f²) were assessed following Cohen's (1988) guidelines, where values of 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively. The f² statistic reflects the relative contribution of each exogenous construct to the explained variance (R²) of the corresponding endogenous construct in the structural model. Interaction terms are interpreted as incremental explanatory effects beyond the main effects. Results are based on the estimation of Equations 1 to 3.
Source(s): Authors' own work.

The findings indicate that most predictors exhibit small to moderate effect sizes. Access to green technologies shows a moderate effect on organizational size and a small but meaningful effect on green logistics adoption. Institutional pressures and supply chain collaboration exhibit small effect sizes, suggesting that sustainability adoption is driven by multiple complementary factors rather than a single dominant influence. This pattern aligns with prior empirical research in green logistics and sustainable supply chain management (Wong et al., 2024; Zhu & Liu, 2025).

5.4 Collinearity and Diagnostic Checks

To ensure the robustness and statistical validity of the estimated structural relationships, a comprehensive set of diagnostic checks was conducted to address potential concerns related to multicollinearity, residual normality, model linearity, heteroskedasticity, and spurious regression. These diagnostics were performed in accordance with recent methodological recommendations in Decision Sciences, sustainability, and logistics research (Cheng et al., 2021, 2022; Hair et al., 2019; Wong et al., 2024).

Multicollinearity was first examined using inner variance inflation factor (VIF) values obtained from the PLS-SEM structural model. As reported in Table 7, all VIF values range between 1.000 and 1.691, which are well below the conservative threshold of 3.3, indicating that multicollinearity is not a concern and that the estimated path coefficients are stable and reliable (Hair et al., 2019; Kock, 2015).

Table 7: Inner VIF Values

	AGT	EA	GLA	IP	OP	OS	SCC
AGT			1.558			1.000	
EA			1.421		1.390		
GLA					1.301		
IP			1.064		1.048		
OP							
OS			1.691		1.373		
SCC		1.000	1.152				

Note(s): Inner variance inflation factor (VIF) values are reported to assess potential multicollinearity among predictor constructs in the structural model. All VIF values are well below the conservative threshold of 3.3, indicating that multicollinearity is not a concern and that the estimated path coefficients are stable and reliable (Hair et al., 2019; Kock, 2015). Results are based on the estimation of Equations 1 to 3. Source(s): Authors' own work.

Residual diagnostics were subsequently assessed using Stata 17 based on the regression model corresponding to Equation (1). Formal normality tests, including the Shapiro–Wilk test and the skewness–kurtosis joint test, indicate statistically significant departures from perfect normality. Such results are expected in moderately large samples (N = 334), as normality tests are highly sensitive to sample size. Importantly, PLS-SEM does not require normally distributed residuals, and statistical inference is based on bootstrapped standard errors, which are robust to non-normality (Hair et al., 2019).

Model linearity was examined using the Ramsey RESET test, which detected potential higher-order effects. In response to this result, theoretically motivated interaction terms (AGT×OS and SCC×EA) were explicitly incorporated into the structural model. Consistent with the nonlinearity assessment framework proposed by Hui et al. (2017), interaction-based model specification is an appropriate and accepted approach for capturing nonlinear relationships in structural models. The significance of these interaction terms confirms that the identified nonlinearities are adequately modeled within the linear–interaction structure.

Heteroskedasticity was assessed using the Breusch–Pagan test, which indicates non-constant variance; this issue is addressed through the use of bootstrapped estimation, ensuring robust statistical inference.

Although the Durbin–Watson statistic and unit root tests are traditionally designed for time-series data, spurious regression concerns may also arise in cross-sectional settings. In the present study, all constructs are measured using bounded Likert-scale items (1–5), which are theoretically stationary (I(0)) by construction and do not contain stochastic trends. Accordingly, formal unit root testing is not required. This treatment is consistent with recent Decision Sciences literature addressing spurious regression in cross-sectional survey data (Wong et al., 2024; Wong & Pham, 2022).

Taken together, spurious regression concerns are mitigated through bounded stationary measures, theory-driven model specification, latent-variable modeling via PLS-SEM, interaction-based correction of nonlinearities, and bootstrapped inference. A consolidated summary of all diagnostic test outcomes is reported in Table 7A.

Table 7A: Summary of Diagnostic Test Results.

Diagnostic Test	Test Statistic	p-value	Interpretation
Residual Normality (Shapiro–Wilk)	W = 0.982	0.000	Normality rejected (expected in large samples)
Residual Normality (Skewness–Kurtosis)	$\chi^2(2) = 18.06$	0.000	Normality rejected
Ramsey RESET (Linearity)	F(3, 325) = 11.12	0.000	Potential nonlinearities detected; addressed via interaction terms and robustness checks
Nonlinearity Assessment and Adjustment (Hui et al., 2017)	Interaction-based specification (AGT×OS, SCC×EA)	—	Nonlinearity adequately addressed
Breusch–Pagan (Heteroskedasticity)	$\chi^2(1) = 22.87$	0.000	Heteroskedasticity detected
Durbin–Watson	Conceptually addressed	—	Cross-sectional data; serial correlation not expected

Unit Root Property (Likert-scale boundedness)	Bounded scale (1–5)	—	Variables are theoretically I(0)

Note(s): Residual normality was assessed using the Shapiro–Wilk and skewness–kurtosis tests. Linearity was examined using the Ramsey RESET test and addressed through interaction-based specification following Hui et al. (2017). Although Durbin–Watson and unit root tests are time-series diagnostics, spurious regression concerns in cross-sectional survey data are mitigated through bounded Likert-scale measurement, interaction modeling, latent-variable estimation, and bootstrapped inference, consistent with Decision Sciences guidance (Hair et al., 2019; Wong et al., 2024; Wong & Pham, 2022).
Source(s): Authors' own work.

5.5 Model Fit Assessment

Although partial least squares structural equation modeling (PLS-SEM) primarily emphasizes predictive accuracy rather than strict global goodness-of-fit, model fit indices were examined to provide complementary evidence regarding the adequacy and robustness of the proposed structural model. Consistent with recent methodological recommendations, both variance-based (PLS-SEM) and covariance-based (CB-SEM) model fit assessments were conducted to address predictive performance and overall model fit simultaneously (Hair et al., 2019; Sarstedt et al., 2022).

5.5.1 PLS-SEM Model Fit Evaluation

The PLS-SEM model fit results are reported in Table 8. The standardized root mean square residual (SRMR) for the estimated model is 0.099, which falls below the recommended upper threshold of 0.10, indicating an acceptable approximate model fit in the context of variance-based SEM. The SRMR value for the saturated model (0.062) further suggests a close correspondence between the empirical and model-implied correlation matrices.

Table 8: Model Fit Summary (PLS-SEM)

	Saturated Model	Estimated Model
SRMR	0.062	0.099
d_ULS	1.242	3.204
d_G	0.386	0.433
Chi-Square	801.157	840.447
NFI	0.751	0.739

Note(s): Results are based on the estimation of Equations (1)–(3). SRMR values below 0.10 indicate acceptable model fit in PLS-SEM. Discrepancy measures (d_ULS and d_G) and the normed fit index (NFI) are reported for completeness and descriptive purposes. The chi-square statistic in PLS-SEM represents a model discrepancy measure rather than a likelihood-ratio test and should therefore not be used for formal model evaluation or rejection (Hair et al., 2019). Source(s): Authors' own work.

Additional discrepancy measures, including d_ULS and d_G, are reported for completeness, following SmartPLS reporting standards. While these indices do not have universally accepted cutoff values, their magnitudes do not indicate substantial model misspecification. The normed fit index (NFI) values are also reported but interpreted cautiously, as global fit indices play a secondary role in PLS-SEM due to its prediction-oriented nature (Hair et al., 2019).

5.5.2 Covariance-Based SEM Model Fit Evaluation

To further address the Editor's request for traditional goodness-of-fit statistics and to ensure methodological rigor, the proposed structural model was additionally estimated using covariance-based SEM with maximum likelihood estimation in Stata 17.0. The resulting global model fit indices are reported in Table 9.

Table 9: Model Fit Indices for Structural Equation Model (CB-SEM)

Fit Index	Value	Recommended Threshold	Interpretation
χ^2 (Chi-square)	483.017	—	—
df (degrees of freedom)	261	—	—
p-value	< 0.001	> 0.05 (non-significant preferred)	Significant
χ^2 / df	1.851	< 3.0 (good fit), < 5.0 (acceptable)	Excellent fit
RMSEA	0.051	< 0.05 (good fit), < 0.08 (acceptable)	Good fit
RMSEA 90% CI	[0.043, 0.058]	—	—
p-close (RMSEA ≤ 0.05)	0.440	> 0.05	Supports a close fit
CFI	0.924	> 0.95 (good fit), > 0.90 (acceptable)	Acceptable fit
TLI	0.913	> 0.95 (good fit), > 0.90 (acceptable)	Acceptable fit
NFI	0.851	> 0.90 (acceptable)	Marginally below threshold
IFI	0.925	> 0.90 (acceptable)	Acceptable fit
SRMR	0.085	< 0.08 (good fit), < 0.10 (acceptable)	Acceptable
CD	0.993	Closer to 1.0 is better	Excellent
AIC	19631.752	Lower is better	—
BIC	19970.943	Lower is better	—

Note(s): Results are based on the estimation of Equations 1 to 3. Model fit was assessed using covariance-based structural equation modeling (CB-SEM) with maximum likelihood estimation in Stata 17.0. Fit indices were evaluated using established cutoff criteria (Hair et al., 2019; Hu & Bentler, 1999; Kline, 2015). The chi-square statistic is reported for completeness and is sensitive to sample size. GFI and AGFI are not reported as these indices are not provided by Stata's SEM module and have been criticized for bias in complex models (Hooper et al., 2008; Sharma et al., 2005). Source(s): Authors' own work.

The chi-square statistic is statistically significant ($\chi^2 = 483.017$, $p < 0.001$), which is common and expected in models estimated with relatively large samples (N = 334) and does not, by itself, indicate poor model fit (Byrne, 2013). Importantly, the ratio of chi-square to degrees of freedom ($\chi^2/df = 1.851$) is well below the recommended threshold of 3.0, indicating excellent model fit.

The root mean square error of approximation (RMSEA = 0.051) demonstrates good fit, with its 90% confidence interval entirely within acceptable bounds and a non-significant p-close value (0.440), supporting the hypothesis of close fit. Incremental fit indices, including the comparative fit index (CFI = 0.924), Tucker–Lewis index (TLI = 0.913), and incremental fit index (IFI = 0.925), all exceed the commonly accepted threshold of 0.90, indicating substantial improvement over the null model. Although the normed fit index (NFI = 0.851) is marginally below 0.90, this value remains acceptable given model complexity and sample characteristics. The standardized root mean square residual (SRMR = 0.085) also falls within the acceptable range (< 0.10).

5.5.3 Clarification of Chi-Square Statistics Across Estimation Frameworks

It is important to emphasize that the chi-square statistics reported in Tables 8 and 9 are derived from two fundamentally different estimation paradigms and are therefore not directly comparable. In PLS-SEM, the chi-square value represents a descriptive discrepancy-based measure and is not associated with degrees of freedom or likelihood-ratio testing. In contrast, the chi-square statistic reported in CB-SEM represents the classical likelihood-ratio chi-square used for formal global model fit evaluation.

Accordingly, the PLS-SEM results are interpreted primarily based on predictive performance indicators (R^2, f^2, SRMR, and inner VIF), whereas the CB-SEM results are used to assess overall model adequacy using established goodness-of-fit criteria. This complementary dual-estimation strategy has been widely adopted in high-quality sustainability, logistics, and operations research to enhance robustness and address both predictive and confirmatory objectives (Hair et al., 2019; Sarstedt et al., 2022).

Taken together, the PLS-SEM and CB-SEM results provide convergent evidence that the proposed structural model demonstrates an acceptable to good fit and is both statistically sound and methodologically robust. The combination of predictive accuracy, satisfactory global fit indices, and extensive diagnostic testing offers strong support for the validity of the estimated relationships and mitigates concerns related to model misspecification or spurious inference.

5.6 Structural Path Coefficients and Hypothesis Testing

The hypothesized direct and moderating relationships were examined using partial least squares structural equation modeling (PLS-SEM) with a non-parametric bootstrapping procedure of 5,000 resamples. PLS-SEM is particularly appropriate for complex models involving interaction effects and multiple endogenous constructs, as it emphasizes prediction accuracy and does not require multivariate normality assumptions (Hair et al., 2019; Sarstedt et al., 2022).

Table 10: Structural Model Results and Hypothesis Testing

Hypothesis	Relationship	Original Sample (O)	Sample Mean (M)	STDEV	T Statistics	P Values	Decision
H1	AGT -> OS	0.447*	0.449	0.062	7.266	0.000	Supported
H2	AGT -> GLA	0.157*	0.158	0.080	1.966	0.050	Supported
H3	IP -> OP	0.222*	0.228	0.050	4.411	0.000	Supported
H4	IP -> GLA	0.062	0.061	0.051	1.208	0.228	Not supported
H5	SCC -> GLA	0.152*	0.156	0.053	2.866	0.004	Supported
H6	SCC -> EA	0.166	0.164	0.064	2.603	0.010	Supported
H7	AGT×OS → GLA	-0.116*	-0.115	0.042	2.735	0.006	Supported
H8	SCC×EA → GLA	-0.123*	-0.119	0.041	3.006	0.003	Supported
H9	OS -> GLA	0.086	0.085	0.051	1.705	0.089	Not supported
H10	EA -> GLA	0.161	0.162	0.066	2.455	0.014	Supported

H11	OS -> OP	0.174*	0.177	0.062	2.830	0.005	Supported
H12	GLA -> OP	0.117	0.113	0.069	1.684	0.093	Not supported
H13	EA -> OP	0.085	0.088	0.066	1.282	0.200	Not supported

Note(s): Results are based on the estimation of Equations 1 to 3. Standardized path coefficients (β) are reported. Statistical significance is assessed using bootstrapping with 5,000 resamples and two-tailed tests. *p < 0.10, **p < 0.05, ***p < 0.01. Source(s): Authors' own work.

Table 10 reports the standardized path coefficients (β), t-statistics, and p-values for all hypothesized relationships. The results indicate that access to green technologies has a strong and positive effect on organizational size (β = 0.447, p < 0.001) and a statistically significant at the 10% level positive effect on green logistics adoption (β = 0.157, p = 0.050). Institutional pressures exert a significant positive influence on organizational performance (β = 0.222, p < 0.001) but do not directly affect green logistics adoption, suggesting that regulatory and stakeholder forces may shape performance outcomes more strongly than operational adoption decisions.

Supply chain collaboration significantly enhances both green logistics adoption (β = 0.152, p = 0.004) and environmental awareness (β = 0.166, p = 0.010), underscoring the role of inter-organizational coordination in facilitating sustainability-oriented practices. Environmental awareness also positively influences green logistics adoption (β = 0.161, p = 0.014), while organizational size contributes positively to organizational performance (β = 0.174, p = 0.005).

Regarding moderation effects, both interaction terms are statistically significant. The interaction between access to green technologies and organizational size negatively moderates green logistics adoption (β = −0.116, p = 0.006), indicating that the marginal contribution of technological access diminishes as firms become larger. This pattern is consistent with prior findings suggesting that larger organizations may face structural inertia and coordination costs that weaken technology-driven sustainability effects (Liao & Wong, 2008; Moslehpour et al., 2019; Patel & Desai, 2018). Similarly, environmental awareness negatively moderates the relationship between supply chain collaboration and green logistics adoption (β = −0.123, p = 0.003), suggesting diminishing marginal returns to collaboration when awareness levels are already high.

Overall, the results support the proposed structural framework and demonstrate that green logistics adoption is driven by the joint influence of technological resources, organizational characteristics, and collaborative mechanisms rather than isolated antecedents.

5.7 Mediation Analysis

To further examine the underlying mechanisms through which key antecedents influence green logistics adoption and organizational performance, mediation analysis was conducted using bias-corrected bootstrapping with 5,000 resamples. Bootstrapping-based mediation analysis is recommended due to its robustness to non-normal sampling distributions and its superior statistical power compared to traditional causal-step approaches (Preacher & Hayes, 2008; Zhao et al., 2010).

Formally, mediation effects were evaluated by decomposing total effects into direct and indirect components, where the indirect effect is defined as the product of the path coefficient linking the independent variable to the mediator (a) and the path coefficient linking the mediator to the dependent variable (b), such that the indirect effect equals a × b (Preacher & Hayes, 2008).

5.7.1 Specific Indirect Effects

Table 11: Specific Indirect Effects (Bootstrapping Results)

Mediation Path	Original Sample (O)	STDEV	T Statistics	P Values	Decision
SCC → EA → GLA	0.027*	0.016	1.679	0.094	Marginally supported
AGT → OS → GLA	0.039*	0.023	1.666	0.096	Marginally supported
AGT → OS → OP	0.078	0.033	2.365	0.018	Supported
Note(s): Results are based on the estimation of Equations 1 to 3. Indirect effects were estimated using bias-corrected bootstrapping with 5,000 resamples. Significance is evaluated using two-tailed tests. *p < 0.10, **p < 0.05. Source(s): Authors' own work.					

Table 11 presents the estimated specific indirect effects obtained using bias-corrected bootstrapping. The results indicate that organizational size partially mediates the relationship between access to green technologies and green logistics adoption ($\beta = 0.039$, $p = 0.096$), as well as the relationship between access to green technologies and organizational performance ($\beta = 0.078$, $p = 0.018$). Environmental awareness also serves as a partial mediator in the relationship between supply chain collaboration and green logistics adoption ($\beta = 0.027$, $p = 0.094$).

Although some indirect effects are marginally significant, all mediation paths are reported to ensure transparency and to avoid selective reporting. Prior methodological research emphasizes that marginal mediation effects may still be substantively meaningful in complex organizational and sustainability contexts, particularly when multiple interdependent mechanisms operate simultaneously (Hair et al., 2019; Zhao et al., 2010).

5.7.2 Summary of Mediation Effects

Table 12: Summary of Mediation Effects

Independent Variable	Mediator	Dependent Variable	Mediation Type	Result
SCC	EA	GLA	Partial mediation	Marginally supported
AGT	OS	GLA	Partial mediation	Marginally supported
AGT	OS	OP	Partial mediation	Supported
Note(s): Results are based on the estimation of Equations 1 to 3. Mediation type is determined based on the significance of indirect effects in conjunction with remaining direct effects, following established mediation criteria (Preacher & Hayes, 2008). *Source(s):* Authors' own work.				

Table 12 summarizes the mediation results by categorizing the type and strength of each indirect relationship. All identified mediation effects are classified as partial mediation, indicating that both direct and indirect effects coexist within the proposed structural framework. This finding suggests that sustainability-related outcomes in the logistics sector are shaped by multiple, interrelated pathways rather than single linear causal mechanisms.

6. Discussion

This study set out to examine how technological resources, institutional pressures, organizational characteristics, and collaborative mechanisms jointly shape green logistics adoption and organizational performance in the Vietnamese logistics industry. By integrating direct, moderating, and mediating relationships within a unified structural framework and employing both variance-based and covariance-based SEM techniques, the findings provide several theoretically meaningful and context-sensitive insights that extend prior sustainability and logistics research.

First, the results indicate that access to green technologies exerts a positive but relatively weak direct effect on green logistics adoption, while demonstrating a strong association with organizational size. This finding challenges the dominant assumption in the green logistics literature that technological availability alone is a sufficient driver of sustainability adoption (Liao et al., 2012; Liao & Wong, 2008). In emerging economy contexts such as Vietnam, access to green technologies may reflect firms' scale and resource endowment rather than immediate operational integration. Larger firms are more capable of acquiring advanced technologies, yet this does not necessarily translate into proportionally higher adoption intensity. This helps explain why the moderating effect of organizational size weakens the relationship between technological access and green logistics adoption (Diamantopoulos & Siguaw, 2006). Structural inertia, coordination complexity, and bureaucratic processes in larger organizations may dilute the marginal benefits of additional technological resources, a pattern also observed in prior logistics and organizational studies (Moslehpour et al., 2017; Wong et al., 2024).

Second, institutional pressures do not significantly influence green logistics adoption directly but exhibit a strong positive effect on organizational performance. This result suggests that regulatory and stakeholder pressures in transitional institutional environments may operate more as performance-shaping forces than as direct adoption triggers. Firms may respond to institutional expectations symbolically or strategically—by improving reporting, reputation management, or compliance-related performance—rather than by immediately restructuring logistics operations. This finding aligns with institutional theory arguments emphasizing decoupling between formal compliance and operational practices in emerging markets (Liao et al., 2014; Pham et al., 2018). At the same time, the positive performance effect underscores the strategic value of institutional legitimacy, even when operational adoption remains incremental.

Third, supply chain collaboration emerges as a consistent and meaningful driver of both environmental awareness and green logistics adoption. This supports relational and network-based perspectives in sustainable supply chain management, which emphasize that collaborative learning, information sharing, and joint problem-solving can compensate for internal resource constraints (Moslehpour et al., 2019; Wong et al., 2024). In the Vietnamese logistics context, collaboration appears to function not merely as an operational mechanism but also as a cognitive and cultural catalyst that enhances environmental awareness within firms. However, the negative moderating role of environmental awareness on the collaboration–adoption relationship suggests diminishing marginal returns: when awareness is already high, additional collaboration contributes less to adoption outcomes. This nuanced interaction highlights

the importance of balance between internal readiness and external coordination, rather than assuming uniformly positive synergistic effects.

The mediation analysis further enriches the interpretation of these relationships. Organizational size partially mediates the effects of access to green technologies on both green logistics adoption and organizational performance, indicating that technological resources influence outcomes indirectly by enabling firm growth and capacity expansion. Similarly, environmental awareness partially mediates the relationship between supply chain collaboration and green logistics adoption, suggesting that collaboration fosters adoption partly by shaping internal environmental cognition. Importantly, only some mediation paths are statistically significant, while others are marginal. Reporting all tested mediations, including marginal effects, enhances transparency and avoids selective inference, consistent with recent methodological recommendations in SEM and sustainability research (Hair et al., 2019; Zhao et al., 2010). In complex organizational systems, small indirect effects may still be theoretically meaningful, particularly when multiple pathways operate simultaneously.

From a methodological perspective, the study addresses growing concerns regarding model validity and spurious inference by incorporating extensive diagnostic testing, collinearity assessment, and complementary use of PLS-SEM for hypothesis testing and CB-SEM for global model fit evaluation. Recent studies have emphasized that sustainability and logistics research are vulnerable to spurious relationships when complex models are estimated without adequate diagnostics (Cheng et al., 2021, 2022; Wong & Pham, 2022). By demonstrating consistent patterns across estimation frameworks and reporting both predictive and global fit indices, this study strengthens confidence in the robustness of its findings. The results also align with prior high-quality studies that adopt similar multi-method SEM strategies to balance prediction and confirmation (Moslehpour et al., 2018; Wong et al., 2024).

Taken together, the findings suggest that green logistics adoption in emerging economies is not driven by isolated technological or regulatory factors but by a complex interplay of organizational scale, collaborative dynamics, institutional environments, and internal awareness. This complexity helps explain why empirical results in the green logistics literature are often mixed and context-dependent. Rather than viewing weak or marginal effects as limitations, the results highlight the importance of multi-pathway explanations and contextual sensitivity when studying sustainability transitions in developing markets.

7. Conclusion

This study provides comprehensive empirical evidence on the drivers, mechanisms, and outcomes of green logistics adoption in Vietnam's logistics industry. By integrating technological, institutional, organizational, and collaborative perspectives within a unified structural framework, the study advances understanding of how sustainability-oriented practices emerge and operate in an emerging economy context. The findings reveal that green logistics adoption is shaped by complex and interdependent forces rather than by isolated technological or regulatory factors, underscoring the importance of contextualized sustainability research.

Consistent with this view, the results indicate that access to green technologies alone does not guarantee widespread adoption, while institutional pressures play a more nuanced role by influencing organizational performance rather than directly driving adoption decisions. Supply chain collaboration and environmental awareness emerge as critical enablers of green logistics adoption, whereas organizational size both directly and indirectly shapes sustainability outcomes through moderation and mediation mechanisms. Collectively, these findings highlight that sustainability transitions in emerging economies are contingent upon the interaction between internal capabilities, external pressures, and relational resources.

7.1 Theoretical, Methodological, and Contextual Contributions

This study makes several important theoretical contributions. First, it challenges the dominant assumption in the green logistics and sustainable supply chain literature that access to green technologies is the primary driver of sustainability adoption. Instead, the findings demonstrate that technological access must be complemented by organizational readiness, collaborative capabilities, and environmental awareness to generate meaningful adoption outcomes. This extends prior research by highlighting the conditional nature of technological resources within sustainability transitions.

Second, the study contributes to institutional theory by showing that institutional pressures exert a stronger influence on organizational performance than on operational adoption decisions in an emerging market context. This suggests that regulatory and stakeholder pressures may shape strategic outcomes even when enforcement mechanisms remain uneven, thereby supporting the relevance of hybrid theoretical frameworks that integrate the Resource-Based View with institutional and strategic perspectives.

From a methodological standpoint, the study contributes by employing a rigorous dual-estimation strategy that combines PLS-SEM and CB-SEM. This approach allows the study to simultaneously address predictive accuracy and global model fit, responding directly to recent methodological concerns regarding model validity and spurious inference. The incorporation of extensive diagnostic tests, effect size analysis, moderation and mediation modeling, and collinearity assessment further strengthens the robustness of the empirical findings.

Contextually, the study contributes to the limited but growing body of empirical research on green logistics in emerging economies, particularly Vietnam. By focusing on firm-level sustainability practices within a transitional regulatory and institutional environment, the study provides insights that extend beyond developed-country settings and enhance the external validity of sustainability theories in logistics and supply chain management.

7.2 Practical Implications

The findings offer several practical implications for logistics managers and policymakers. For logistics firms, the results suggest that investments in green technologies should be accompanied by internal capability development, including employee training, organizational learning, and the cultivation of

environmental awareness. Firms should also prioritize supply chain collaboration as a strategic mechanism to share resources, reduce implementation costs, and overcome knowledge constraints associated with sustainability initiatives.

For policymakers, the findings highlight the importance of strengthening institutional frameworks that support sustainability beyond compliance-oriented regulation. Targeted incentives such as subsidies, tax benefits, and green financing mechanisms may help firms translate institutional pressures into concrete adoption outcomes. Industry associations can further support sustainability transitions by facilitating knowledge-sharing platforms, promoting best practices, and providing technical assistance, particularly for small and medium-sized enterprises.

7.3 Limitations and Directions for Future Research

Despite its contributions, this study has several limitations that offer avenues for future research. First, the cross-sectional research design limits the ability to capture dynamic changes in sustainability adoption and performance outcomes over time. Future studies could employ longitudinal designs to examine how green logistics practices evolve and generate long-term economic and environmental benefits.

Second, the study focuses on Vietnam's logistics sector, which may limit the generalizability of the findings. Comparative studies across emerging and developed economies would provide deeper insights into how institutional, cultural, and economic differences shape sustainability adoption. Additionally, future research could explore the role of emerging digital technologies, such as artificial intelligence, blockchain, and the Internet of Things, in enabling green logistics practices. Examining leadership engagement, organizational culture, and governance mechanisms may further enrich the understanding of sustainability transitions in logistics and supply chain management.

Overall, this study underscores that sustainable logistics adoption in emerging economies is a multifaceted and context-dependent process. Achieving meaningful environmental and performance outcomes requires a strategic combination of technological resources, organizational capabilities, collaborative relationships, and supportive institutional environments.

Data Availability Statement

The data used in this study are available from the corresponding author upon reasonable request.

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Appendix A. Measurement Items

Variable	Items	Source
Access to Green Technologies (AGT)	AGT1: Our organization has access to the latest green technologies and innovations in logistics. AGT2: We actively invest in green technologies to improve operational efficiency. AGT3: The use of green technologies is a key part of our sustainability strategy. AGT4: Our organization possesses sufficient technological expertise to effectively implement and manage green logistics technologies.	Wang et al. (2023); Moslehpour et al. (2019)
Institutional Pressures (IP)	IP1: Our company faces pressure from regulatory authorities to adopt environmentally friendly practices. IP2: External stakeholders (e.g., customers, investors) influence our environmental policies. IP3: We comply with environmental regulations and standards set by industry leaders.	Ko et al. (2021)
Supply Chain Collaboration (SCC)	SCC1: We collaborate with suppliers to improve sustainability in our supply chain. SCC2: Our organization works with partners to share knowledge on sustainability practices. SCC3: We align our sustainability goals with those of our supply chain partners. SCC4: We jointly develop sustainability initiatives with key supply chain partners to improve environmental performance.	Patel and Desai (2018)
Green Logistics Adoption (GLA)	GLA1: Our company has adopted green logistics practices such as eco-friendly packaging and transportation. GLA2: We prioritize sustainable supply chain management strategies in our logistics operations. GLA3: We continuously invest in green logistics technologies and practices to minimize our environmental impact. GLA4: Green logistics practices are systematically integrated into our daily logistics and operational processes.	Wang et al. (2022); Lee (2021)
Organizational Performance (OP)	OP1: Our organization has seen improved operational efficiency due to the adoption of green technologies. OP2: Environmental practices have led to a positive impact on our financial performance. OP3: Sustainability initiatives have improved our company's reputation and brand image. OP4: The adoption of green logistics practices has enhanced our organization's long-term competitiveness.	Singh et al. (2023); Leung et al. (2023)
Environmental Awareness (EA)	EA1: Our employees are highly aware of the environmental impact of our business operations. EA2: We encourage employees to adopt environmentally friendly practices in their daily activities. EA3: There is a strong culture of environmental awareness across all levels of the organization.	Bouzari et al. (2022); Yu & Li (2024)
Note: All items were measured using a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree)		