

Applied Data Science for Exploring Technological Advancements and Innovations Affecting Green Logistics Management: A Case Study Logistics Enterprises in Vietnam

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ABSTRACT: Technological advancements and innovations are pivotal in transforming green logistics management by enhancing efficiency, sustainability, and environmental responsibility. As the logistics sector evolves, digitalization, automation, and intelligent logistics solutions are key enablers of green supply chain practices. Therefore, the study's objective is to explore the critical factors influencing the green logistics management of enterprises, evaluate the role of specific technologies in supporting sustainable logistics operations and propose policy recommendations for enhancing green logistics management. Formal study methods based on quality and quantitative surveys were used in four Provinces in Vietnam, from the 800 logistics managers interviewed using the questionnaire and processed using SPSS 20.0 and Amos. The findings reveal that technological readiness and internal capabilities are the most influential factors, whereas regulatory pressure plays a secondary role, differing from patterns observed in developed countries. Finally, the authors proposed specific policy recommendations tailored for Vietnam, emphasizing government incentives for digital transformation, sustainable sourcing, and waste minimization; moreover, this model can be used in developing countries or other countries to research and evaluate the impact of factors on green logistics management. Green logistics management has become a global trend, and policy recommendations have been applied to better manage environmental issues toward green growth and sustainable development. Businesses in the transportation sector are not only looking at economic benefits but also aiming to change their operating models to ensure sustainability for the entire planet. This study reinforces the urgent need for strategic investments in emerging technologies to enhance green logistics management in Vietnam and other developing economies.

Keywords: Business, technology and innovations, green logistics policy, management sciences.

I. INTRODUCTION

Green logistics management has developed as a vital technique for sustainable development, addressing growing concerns about the environmental impact of transportation, warehousing, and supply chain operations. As global trade and e-commerce grow, logistics activities increase carbon emissions, resource depletion, and environmental damage. Governments, organizations, and researchers worldwide are now stressing the integration of sustainability into logistics processes to reduce environmental footprints while preserving operational efficiency. Green logistics entails using management and technical solutions to reduce vehicle fuel use while maintaining production efficiency. Thus, green logistics will help enterprises, individuals, and the environment [1, 2]. Benefits include: (1) Reducing transportation costs using green logistics strategies, reducing fuel consumption, optimizing transportation routes, and lowering company transportation expenses. (2) Increase competitiveness through companies and enterprises that adopt green logistics can get a competitive advantage over market competitors by developing sustainable product and service lines that appeal to customers who care about the environment. (3) Compliance with rules through many countries have regulations to control emissions and environmental effects. Businesses implementing green logistical measures can comply with these rules while avoiding fines. (4) Improved environmental impact through green logistics can help protect the environment and mitigate climate change by lowering greenhouse gas emissions and other

environmental consequences, including air and noise pollution. (5) Increased efficiency by green logistics methods can optimize operations and reduce waste, resulting in greater efficiency in shipping and production.

Besides assessing the current state of digital transformation in logistics enterprises, in 2023, the Report of the Vietnam Logistics Association affirmed that logistics enterprises are increasingly showing interest and accurately assessing the critical role of digital transformation. However, enterprises also face several barriers and difficulties, such as (1) Lack of awareness of the role of digital transformation, (2) Incomplete transportation infrastructure, (3) Risks when deploying technology and concern about return on investment, (4) High cost of digital transformation investment, (5) Lack of network security assurance, (6) Heterogeneous information systems of enterprises, (7) Lack of investment resources, (8) Lack of coordination, collaboration, and sharing, (9) Resistance of employees and managers to changes brought about by digital transformation, (10) Lack of digital transformation capacity and low-tech human resources, and (11) Lack of awareness, vision and strategy, etc.

Reporting Vietnam's green logistics during 2022-2024, policies and regulations put out by the government: Environmental protection efforts, particularly the reduction of greenhouse gas emissions, are of the utmost importance, and Vietnam, as one of the nation's hits worst by climate change, is well aware of this. The government of Vietnam has increased the development and implementation of measures to decrease CO2 emissions, fulfilling its pledge during the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26). Sustainable development initiatives, such as green logistics development, have received the full attention and priority of the Vietnamese Party, Government, and relevant agencies, who have promulgated numerous pertinent legal documents and policies to establish a favorable legal corridor.

Green and sustainable logistics activities are of great interest to many Vietnamese firms, including those who provide and receive logistics services, according to a poll conducted by the Editorial Board of the Vietnam Logistics Report 2023. The percentage of businesses that have integrated green logistics into their overall strategy is over 73.2 percent, according to the report. That companies understand the importance of green logistics to long-term sustainability is shown here very concretely. Vietnamese consumers' consciousness has evolved in the last many years. Green logistics services have raised consumer knowledge and preference for environmentally friendly goods and products. Customers are at the end of the product supply chain; thus, any shift in consumer sentiment toward green logistics will significantly impact how companies approach the practice. More than 30% of consumers support using eco-friendly vehicles, fuels, and materials; more than 10% are prepared to pay more for green logistics services, as reported in the Vietnam Logistics Report 2023.

Today, inadequate financial and human resources pose a hurdle to applying logistics activities in Vietnam. According to the study of the Vietnam Logistics Report 2022, the internal component that has the most impact on an enterprise's development of green logistics is its financial capability, which averages 4.24 out of 5. It is entirely reasonable that there are limited financial resources, given that 98% of Vietnamese businesses are small or medium-sized as of 2023. Companies will require investment funds to reorganize current operations and acquire new technological equipment to launch green logistics initiatives. The implementation of green logistics is impeded by financial constraints. Moreover, Vietnam has a critical scarcity of qualified logistics professionals. According to projections made by the Vietnam Logistics Research and Development Institute, our country's logistics industry will require an additional 2.2 million workers by 2030, with a specific demand for approximately 200,000 highly skilled logistics personnel who possess professional certifications, solid professional abilities, and fluency in foreign languages.

Vietnam's logistics industry has experienced rapid growth, contributing approximately 14% to the national GDP, yet it remains less sustainable compared to more developed economies. While countries like Germany, Japan, and the Netherlands have implemented mature green logistics practices such as widespread electric fleets, real-time carbon tracking, and government-enforced emissions targets, Vietnam is still in the early stages of adopting such innovations. Compared to regional peers like Thailand or Malaysia, Vietnam faces unique challenges, including fragmented infrastructure, limited green investment incentives, and regulatory enforcement gaps. However, Vietnam also presents unique opportunities: its young digital workforce, increasing e-commerce penetration, and state-level commitments to decarbonization under the Green Growth Strategy offer a favorable environment for scalable green logistics innovation. This contrast between current limitations and future potential underscores the urgency and significance of this study, particularly in identifying actionable strategies to accelerate Vietnam's sustainable logistics transformation.

The lack of a well-developed logistics infrastructure in Vietnam is one of the external issues holding the country back from embracing green logistics practices. In particular, despite investments in logistics infrastructure, Vietnam faces numerous challenges, such as unreliable roads, ports, and bus stations, inefficient

transportation network planning and construction, and low logistical activity efficiency. Congestion on innumerable routes and ports is common, particularly during peak hours, because the transport system is overburdened with participants. There is a lack of synchronization in the system, which slows down the management and implementation of logistics operations, and a generally poor degree of IT application in organizations regarding logistics-related IT systems.

There has been a concerted effort by the Vietnamese government and party and state leaders to issue rules and regulations to facilitate green logistics initiatives. Nevertheless, numerous challenges persist in applying and implementing rules in practice due to overlapping responsibilities and duties among functional entities. Furthermore, transportation is the most talked-about aspect of logistics, but other functional activities like warehousing and logistics IT systems are just as vital and closely related. A lack of coordination in applying and implementing green logistics results in the prohibition of specific logistics infrastructure while supporting others. Notably lacking are rules governing the repair and recovery of garbage, recycling, developing environmentally friendly packaging, and promoting renewable resource utilization.

A key driver of economic growth in Vietnam is the logistics industry, which is seeing a surge in demand for eco-friendly and effective supply chain solutions due to the country's fast industrialization and urbanization. However, many logistics organizations have difficulties implementing environmentally friendly practices due to insufficient infrastructure, high prices, and lax regulation enforcement. Despite these challenges, new opportunities for sustainable logistics transformation have emerged because of technology developments like blockchain, the Internet of Things (IoT), automation, and artificial intelligence (AI). These technologies also improve environmental and economic performance, which increase fuel efficiency, decrease waste, optimize routing, and enable real-time tracking. Developing green logistics is an inevitable trend and an essential criterion for evaluating the sustainable development of the entire logistics industry. When businesses apply green logistics in their strategies, in the long term, they will increase the number of customers, increase revenue, cut costs, and improve competitiveness. The current trend is that countries apply green standards to imported and exported goods [3, 4]. Moreover, in the logistics industry, "greening" has become a mandatory requirement for businesses to participate in the supply chain of global manufacturers and suppliers. The study seeks to identify key elements affecting green logistics management and to develop policies for improving green logistics management in Vietnamese firms. This study addresses the following research questions (RQ):

- (1) RQ1: What critical internal and external factors influence green logistics management (GLM) in Vietnam?
- (2) RQ2: To what extent do technological advancements and innovations such as the Internet of Things, artificial intelligence, automation, and data analytics contribute to green logistics outcomes compared to regulatory, cultural, or organizational factors?
- (3) RQ3: How can insights from Vietnam's logistics sector inform policy design and operational strategies for sustainable supply chain transformation in developing countries?

These questions are grounded in the urgent need for Vietnam to modernize its logistics systems amid growing environmental and digitalization pressures. Identifying and evaluating these factors' relative impact will help firms and policymakers allocate resources and design targeted interventions that accelerate green transformation in the logistics sector.

Existing literature on green logistics primarily focuses on regulatory compliance, supply chain collaboration, and carbon reduction strategies, but limited research has examined the direct impact of technology on logistics sustainability in Vietnam. This study fills this gap by reviewing technological innovations that optimize sustainability efforts in Vietnamese logistics enterprises. Finally, this structure provides a clear article outline:

- (1) After analyzing green logistics management theory and research, the authors form the study's hypotheses.
- (2) The authors walk through the quantitative and qualitative research process, sample selection, and analysis.
- (3) The authors report structural equation modeling (SEM), descriptive, and reliability results.
- (4) The authors discuss the critical issues, their meaning, and their contribution to knowledge. Finally, the paper concludes with its limitations, future research, and policy recommendations to improve green logistics management.

II. LITERATURE EMPIRICAL REVIEW AND HYPOTHESIS DEVELOPMENT

1. GREEN LOGISTICS MANAGEMENT (GLM)

Green logistics management reduces supply chain environmental implications. This idea optimizes transportation and storage to reduce energy use, carbon emissions, and waste [5, 6]. Green logistics uses sustainable methods, including low-emission vehicles and packaging recycling. These include selecting recyclable materials, optimizing transportation routes, employing renewable energy for warehouses and cars, and establishing reverse logistics systems for product recovery, recycling, or reuse [7]. Green logistics management

aims to provide sustainable company, social, and environmental value. Green logistics boosts business image and supports long-term sustainable development by reducing environmental impacts and following environmental standards. Finally, green logistics management is an emerging field; there isn't a consensus on what it entails. According to this research, green logistics management refers to a particular logistics that uses eco-friendly practices [8]. Besides, technology is to reduce adverse effects on the environment; logistics transfer strategies and approaches to supply chain management that focus on waste management, material handling, packaging, and transportation to lessen the energy and environmental effect of goods distribution are also part of green logistics management. Concurrently, reduce pollutants by using cutting-edge machinery [9]. Several frameworks have been developed to conceptualize the drivers and outcomes of green logistics in both developed and emerging economies. One widely cited model evaluates logistics practices across economic, environmental, and social dimensions. Other studies have adopted the Technology–Organization–Environment (TOE) framework to explain adopting green logistics technologies, emphasizing the interplay between technological readiness, organizational capacity, and external institutional pressure. In Southeast Asia, studies have extended these frameworks to account for resource constraints, regulatory compliance, and green supply chain integration. Drawing from these models, the present study examines how internal factors (e.g., leadership, training, digital competence) and external conditions (e.g., infrastructure, regulation, customer demand) shape green logistics adoption in Vietnam's evolving logistics landscape.

2. ENVIRONMENTAL REGULATIONS AND POLICIES (ERP)

Regulations drive green logistics through corporate behavior influenced by the Paris Agreement, the EU Emissions Trading System, and country greenhouse gas emission laws. These regulations require businesses to reduce pollution, garbage, and resource utilization [10, 11]. Carbon prices encourage sustainable business practices, while green certification incentives encourage eco-friendly practices [12]. Environmental regulations in rising nations like Vietnam are becoming more relevant as they adapt to worldwide environmental standards, driving green logistics. Emissions limits, waste management, and environmental certifications encourage eco-friendly business practices. Compliance with ERP can increase operating costs, but non-compliance risks fines and reputational damage [13, 14]. ERP compliance is essential for businesses in Vietnam's growing industrial sector to stay competitive and sustainable. Thus, the authors gave hypothesis H1 in Figure 1 below.

3. TECHNOLOGICAL ADVANCEMENTS AND INNOVATIONS (TAI)

The Internet of Things (IoT), artificial intelligence (AI), and big data analytics are essential components of green logistics since they allow for better control, optimization, and real-time logistics monitoring. The study found that electric and hydrogen vehicles reduce emissions while route optimization algorithms minimize the use of fossil fuels [15]. Automated warehouse solutions enhance storage and retrieval efficiency while reducing energy use. To make logistics more sustainable, technology goes beyond just lowering costs [16, 17]. Intelligent technologies like electric vehicles, warehouse automation, and data analytics help Vietnamese companies implement green logistics. Real-time logistics monitoring and optimization using IoT, AI, and big data analytics reduce emissions and waste [18]. TAI can boost efficiency, save costs, and reduce environmental impact in a fast digital market, making companies sustainable logistics leaders. Thus, the authors gave hypothesis H2 in Figure 1 below.

4. SUPPLY CHAIN COLLABORATION AND INTEGRATION (SCI)

Green logistics requires supply chain coordination by co-loading and shared distribution networks to maximize vehicle use and eliminate empty loads [19]. Eco-friendly suppliers and third-party logistics providers are needed for a green supply chain, resource reduction, and industrial sustainability [20]. Supply chain cooperation with suppliers, distributors, and other partners is necessary for green logistics. SCI can remove redundancies, optimize routes, and reduce resource consumption in Vietnam's complex supply chains [21, 22]. Companies can minimize their carbon impact and strengthen supply chains by engaging with green partners. Investing in technology and common standards for effective SCI can be difficult in less mature markets. Thus, the authors gave hypothesis H3 in Figure 1.

5. ENERGY EFFICIENCY IN OPERATIONS (EEO)

With energy efficiency, green logistics decreases fuel consumption and waste. Increasing energy efficiency in warehouses is possible through load consolidation, switching to rail or marine freight, switching to lower-emission road transport, and using renewable energy sources [23]. According to studies, hybrid transport models lower high-emission transport modes and meet environmental targets. Energy efficiency cuts emissions and costs in green logistics [24, 25]. Improving EEO for Vietnamese companies requires optimizing transportation routes, consolidating cargo, and implementing energy-efficient warehouse systems. Due to Vietnam's industrial growth, energy efficiency is crucial to reduce emissions and expenses. Investment in renewable energy and facility upgrades can help companies achieve EEO while contributing to sustainability and cost-saving when energy costs vary. Thus, the authors proposed hypothesis H4 in Figure 1 below.

6. WASTE MINIMIZATION AND SUSTAINABLE PACKAGING (WSP)

Waste management reduces packaging, product, and operating waste in green logistics. Environmentally concerned consumers prefer biodegradable and recyclable packaging [26]. Waste-to-energy, material recycling, and end-of-life packaging promote sustainable development and reduce landfill use [27]. Green logistics involves waste reduction and sustainable packaging for organizations with high packaging waste. WSP may aid Vietnamese manufacturing and retail companies by adopting recyclable materials and resource-efficient packaging [28, 29]. Vietnamese consumers increasingly want eco-friendly items; therefore, sustainable packaging fits. However, SMEs who switch to sustainable packaging may need to pay more upfront to implement WSP. Thus, the authors gave hypothesis H5 in Figure 1 below.

7. RESOURCE AVAILABILITY AND SUSTAINABLE SOURCING (RSS)

Green logistics is impacted by sustainable resources such as biofuels, recyclables, and renewable energy. Logistics can reduce its environmental effect by using renewable energy for shipping, warehousing, and partnering with certified sustainable suppliers [30]. These resources' scarcity and high costs may impede green logistics plans. Regular analysis of the availability and reliability of sustainable resources is essential for logistical operations to avoid disruptions [31, 32]. Renewable energy and recyclable materials are sustainable resources that impact green logistics. Local infrastructure, green-certified suppliers, and renewable energy production capability affect resource availability for Vietnamese businesses. Sustainable sourcing guarantees that logistics inputs like fuel and packaging satisfy environmental criteria [33]. Sustainable resources may be expensive or scarce, especially in emerging markets. Moreover, companies must examine their supply chain's sustainability and resource dependencies to reduce risks. Thus, the authors gave hypothesis H6 in Figure 1 below.

8. ORGANIZATIONAL CULTURE (OC)

Organizational culture influences the acceptance, implementation, and success of green logistics management inside businesses. It refers to the attitudes, beliefs, and behavioral norms that shape how businesses approach sustainability, environmental stewardship, and operational effectiveness. A strong organizational culture of sustainability improves green logistics management by encouraging environmentally friendly business practices, increasing employee participation in green projects, and assuring long-term environmental responsibility [34]. Vietnamese SMEs are under pressure from several sources, including changes in the value chain, consumer preferences for more environmentally friendly products, concerns about the global minimum tax, opportunities for green development, regulations about climate change, and environmental protection. Promoting an eco-friendly workplace and sustainable development. The adoption and maintenance of green logistics are also influenced by the organizational culture of enterprises [35]. A culture that values environmental awareness, sustainability, and innovation encourages employee green practices and streamlines green logistical activities. When sustainability is a fundamental value, people are more willing to assist in eliminating waste and optimizing resources. A green organizational culture could boost staff morale, customer loyalty, and compliance with international sustainability standards in Vietnam's fast-growing business environment. Thus, the authors gave hypothesis H7 in Figure 1 below.

9. CORPORATE SOCIAL RESPONSIBILITY (CSR)

As part of their ethical mission, logistics strategies promote environmentally friendly methods, which are significantly impacted by CSR obligations. Logistics forms the backbone of corporate social responsibility efforts. The economy's growth and the Internet's expansion place heavy societal demands on businesses [36, 37].

Protecting consumer rights, improving working conditions for employees, protecting the environment, and making community contributions following regulations and laws are all part of corporate social responsibility. Due to its rapid expansion and extensive influence, logistics companies find CSR more critical and complex. Businesses with a profit motive should work to improve society [38, 39]. CSR activities urge Vietnamese companies to embrace sustainable practices beyond regulatory compliance. Logistics companies can improve brand reputation and consumer confidence by embracing CSR. CSR also helps companies meet global stakeholders' and investors' growing sustainability demands [40]. Sustainable logistics techniques may boost Vietnamese companies' CSR reputation, community ties, and environmental stewardship. Thus, the authors gave hypothesis H8 in Figure 1 below.

Despite growing academic interest in green logistics, most existing studies have focused on developed economies with mature infrastructure and advanced digital capabilities. There is a lack of empirical research on how emerging technologies such as IoT, AI, and automation are adopted within green logistics frameworks in developing countries, especially in Southeast Asia. In the case of Vietnam, although the logistics sector is expanding rapidly, limited scholarly attention remains on the barriers, drivers, and outcomes of green logistics implementation in the context of digital transformation. Furthermore, prior research has tended to treat technology and sustainability in isolation rather than exploring their integrated role in shaping organizational and environmental outcomes. This study addresses these gaps by (1) examining the specific influence of technological innovations on green logistics adoption in Vietnam, (2) analyzing both internal and external enablers of green logistics performance, and (3) providing context-sensitive policy recommendations for sustainable logistics development in an emerging economy.

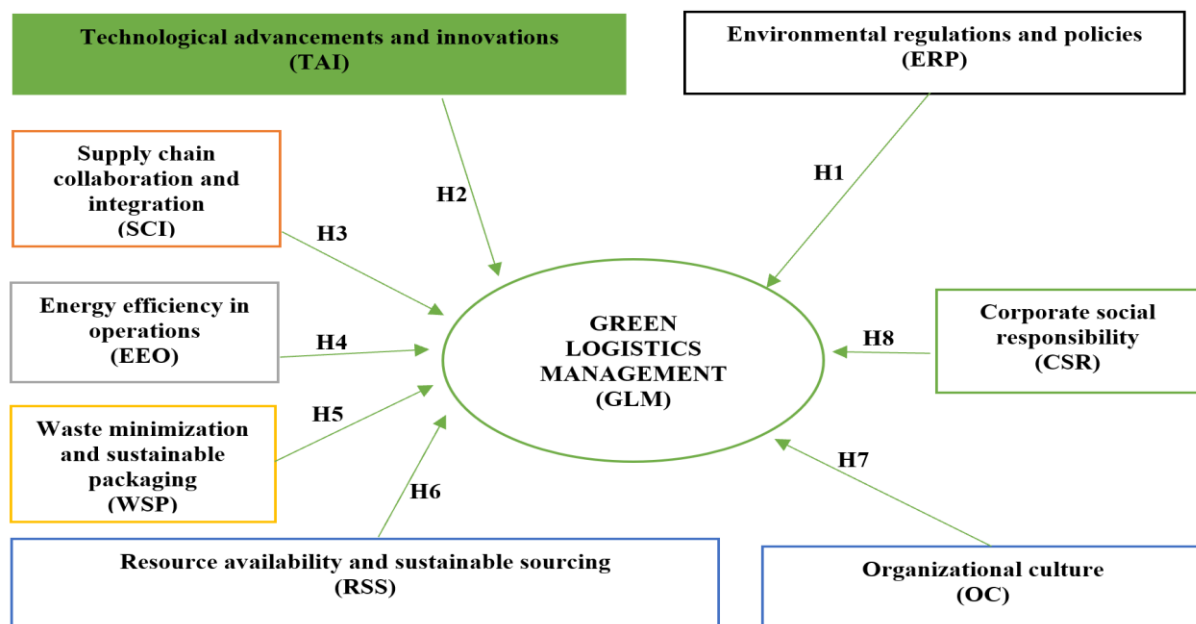


FIGURE 1. A research model for critical factors affecting green logistics management

Figure 1 shows the foregoing demonstrates that a country's production and output are both boosted by green logistics expansion. Essential for creating high-quality green logistics services, promoting sustainable growth, and making significant initiatives and research more accessible. Increasing output while opening up a plethora of possibilities for cross-border cooperation. The authors construct a study model based on green logistics theory and international and domestic studies to examine the impact of eight variables on the efficiency and spread of green logistics practices in Vietnamese businesses. Based on the regulations and policies that provide external pressure, internal drivers like organizational culture, technology, and CSR commitments are essential in embedding sustainable practices. As Vietnam continues its green logistics management, balancing these factors will be critical for enterprises aiming to meet economic and environmental objectives, thereby positioning themselves favorably in the global market. The authors proposed the model in Figure 1 above.

III. METHODS OF RESEARCH

This research consists of three steps: (1) conducting qualitative research, (2) quantitative (preliminary) research, and (3) formal quantitative research. Qualitative research is conducted through an in-depth interview to establish the scales and research hypotheses below.

Phase one involves qualitative research, phase two involves quantitative (preliminary) study, and phase three involves formal quantitative research. Qualitative research is conducted through in-depth interviews to develop the scales and test the hypotheses shown in Figure 1. After obtaining thorough information about the research objectives, methodology, and potential implications, all participants consented to participate in this study before data was collected. Permission to participate was obtained in writing. The participants' written consent was obtained by signing a letter describing the study's goals, their rights, and the guarantees of confidentiality. Table A1 contains the author's study questionnaire questions; all participants agreed to participate and answered them in the Appendix. The Vietnam-based Faculty of Postgraduate Studies at Lac Hong University (LHU) also granted ethical survey clearance (<https://lhu.edu.vn/244/Khoa-Sau-dai-hoc.html>). This study integrates qualitative and quantitative methodologies in a structured mixed-methods approach to investigate key factors influencing Vietnam's green logistics management. Figure 2 shows the 3-stage method that can corroborate empirical findings through quantitative analysis and assure conceptual depth through qualitative discoveries:

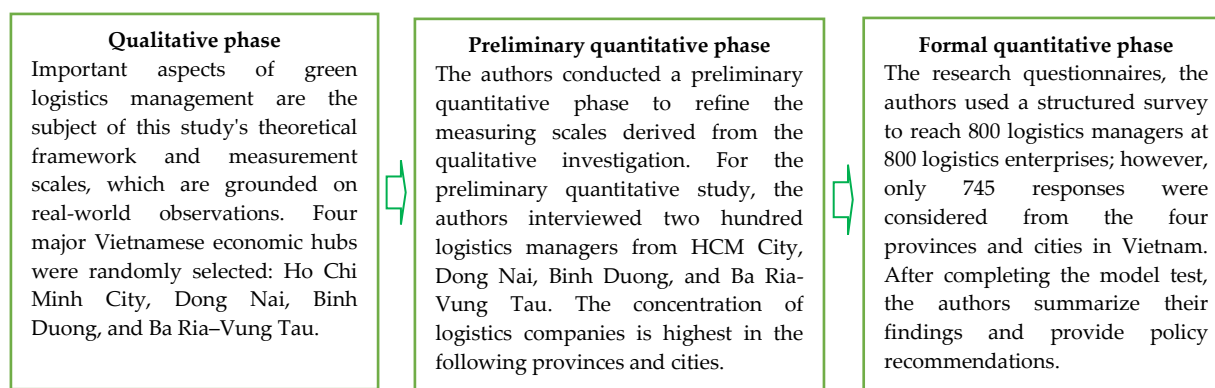


FIGURE 2. A research process for critical factors affecting green logistics management

1. QUALITATIVE PHASE

For the study's conceptual framework and research challenge, the writers must choose an eco-friendly theory of logistics management. Three analyses were conducted as part of the initial phase of the investigation: First, lay the theoretical groundwork for the study of green logistics management concepts. Second, analyze the interrelationships of the research model's concepts. Third, develop a preliminary scale for the study's concepts, which will serve as a scale for factors influencing green logistics management.

In order to identify conceptual metrics for green logistics management, the writers undertake empirical research and focus groups with nine company managers from various provinces and cities in Vietnam, including Ho Chi Minh City, Dong Nai, Binh Duong, and Ba Ria-Vung Tau. Concurrently, the authors polled and interviewed fifteen logistics experts to gather their thoughts on the breadth of green logistics management [41]. At this stage, we need to do two things: (2) Create a set of variables on a new scale to incorporate into the model; (3) Adjust and improve the scale of scaled concepts. The initial study will modify and enhance the original scales through focus group discussions. A study was conducted using focus group interviews. Interviews were conducted with different groups. The absolute scale, now called the variable scale, is modified at this step [41].

2. PRELIMINARY QUANTITATIVE PHASE

As a descriptive study, preliminary quantitative research uses direct interview procedures to assess research idea measuring scales and improve the questionnaire. Formal quantitative analysis determines whether the scale used to evaluate the theoretical model and its assumptions in Model 1 is valid and reliable [41]. The following procedures were outlined in the article as part of the ranking's research and development process:

The authors interviewed fifteen logistics experts in Vietnam for the preliminary quantitative study. Since the questionnaire established after step 2 evaluates green logistics management, it is appropriate for this study's

survey of logistics managers. Fifteen logistics professionals make up the sample size. Many Vietnamese cities and provinces, including important urban areas like Ho Chi Minh City, Binh Duong Province, Dong Nai Province, and Ba Ria-Vung Tau Province, were questioned by logistics experts. Finally, the authors conducted a preliminary quantitative phase to refine the measuring scales derived from the qualitative investigation. For the preliminary quantitative study, the authors interviewed by outlining 200 logistics managers from HCM City, Dong Nai, Binh Duong, and Ba Ria-Vung Tau. The concentration of logistics companies is highest in the following provinces and cities. Each interview lasted 45–60 minutes and followed a thematic guide covering environmental strategies, technological practices, barriers to green adoption, and institutional responses.

3. FORMAL QUANTITATIVE PHASE

Using a non-probability sampling method, the authors first performed quantitative research in Ho Chi Minh City, Dong Nai Province, Binh Duong Province, and Ba Ria - Vung Tau Province from January 15, 2024, to June 15, 2024, to assess the modified scale. Table A1 - Research questionnaires shows that 800 logistics managers from 800 logistics businesses made up the sample, but only 745 of them had their votes counted. Using the data acquired in Step 3, a preliminary scale assessment will be conducted using the authors' exploratory factor analysis (EFA) and the reliability coefficient of Cronbach's alpha. First, exploratory factor analysis (EFA) is performed to calibrate the scales, and second, Cronbach's alpha is utilized to evaluate reliability. The reliability of the scale was determined through the use of the Cronbach Alpha coefficient analysis. The reliability of the scale is enhanced when the coefficient exceeds 0.6. Averaging the correlation coefficient with other similar-scale variables is the main variable. Coefficients that are closer to one another show how strongly the variable is related to the other group variables. A total-variable correlation of more than 0.3 is required. Any variables with a total correlation coefficient below 0.3 are ignored and removed from the scale [41].

To verify the validity of the conceptual scale, the writers employed exploratory factor analysis (EFA). Considering the scale structure and differences between factors is critical, since the authors conducted CFA and SEM investigations after discovering EFA. As a result, the writers ran an exploratory factor analysis using the following standards for success. When factoring along the principal axis, Promax rotation is applied. Second criterion: every variable must have a coefficient load factor maximum of 0.4. Factor loading is the most critical criterion for each variable [41]. The load factor should equal or greater than 0.3 to guarantee factor difference. Half of the total variation was excised. When the value of KMO is greater than or equal to 0.5, the Bartlett test is statistically significant < 0.05 .

During this stage, the authors conducted thorough research in major cities, including Ho Chi Minh City, Dong Nai Province, Binh Duong Province, and Ba Ria-Vung Tau Province, formally. Logistics managers are among those who took part in the study. With a sample size of 800 managers involved in logistics activities, the data will be collected through direct interviews using a prepared questionnaire. Utilizing random sample techniques for assessment, the sampling method applied is probability sampling. After the data was collected, it was cleaned, entered, and analyzed using SPSS version 20.0 and Amos. The authors also surveyed 15 logistics professionals from four major Vietnamese economic regions - Ho Chi Minh City, Dong Nai Province, Binh Duong Province, and Ba Ria - Vung Tau Province to provide a holistic view of the factors that influence green logistics management in urban and regional contexts. These regions are home to many industries and significant trade and financial centers.

Scale reliability was examined in the data using Cronbach's alpha. The writers reevaluated rank reliability after studying the system's amount. Using data from formal study, Cronbach's alpha is determined. Scale value was evaluated by the authors utilizing the EFA and CFA of the SEM framework. Data is generated using an EFA-based scale, and Cronbach's alpha is completed. A measure's reliability can be assessed using the CFA approach. Adding EFA and CFA to SEM as a replacement [41]. The SEM model and standard scale were both created and evaluated using this iterative process of testing hypotheses and evaluating models. By using structural equation modeling, we may assess the flexibility of both theoretical frameworks and research directions.

This study employed a quantitative approach using a structured questionnaire distributed to logistics enterprises across Vietnam. The questionnaire was designed based on validated constructs from prior studies and pre-tested with a small group of logistics managers to ensure clarity. Data was collected through online and in-person surveys targeting managerial-level respondents, e.g., operations managers, sustainability officers, and logistics directors with direct knowledge of their firm's green logistics strategies and technology use. A purposive sampling method was used to select firms that (1) operate within core logistics functions, such as transportation, warehousing, and freight forwarding, and (2) have engaged in environmental or

technological initiatives. 745 valid responses were collected from 15/01/2024 to 15/06/2024, providing a diverse cross-section of enterprise types, e.g., domestic, joint-venture, multinational, and geographic regions in Ho Chi Minh City, Dong Nai Province, Binh Duong Province, and Ba Ria - Vung Tau Province to evaluate the modified scale.

Finally, the model tests led the authors to offer governance implications. The authors constructed a research model, conducted the investigation, and combined theoretical underpinnings with domestic and foreign studies. The authors initially created a study model to test the expected scale's reliability and validity. After designing and testing the scale, they obtained early data from fifteen logistics professionals.

VI. RESULTS AND DISCUSSION

1. ANALYSIS OF THE SITUATION FOR VIETNAM'S GREEN LOGISTICS MANAGEMENT DURING 2022-2024

While green logistics in Vietnam improved between 2022 and 2024, Vietnam still has a way to go before it can reach its sustainable development targets. With the backing of governments, corporations, and international organizations, green logistics has the potential to become an essential differentiator, significantly enhancing Vietnam's economic growth while simultaneously safeguarding the environment. As a result of numerous decisions and directives aimed at fostering development, the Vietnamese logistics service industry has recently grown significantly toward greening, garnering particular attention from the government, ministries, sectors, and associated fields. The Prime Minister emphasized the significance of green logistics in promoting sustainable development and environmental protection. Vietnam is committed to reducing greenhouse gas emissions to zero by 2050 through its efforts, in conjunction with international cooperation, financial backing, and technology transfer, particularly from developed nations. This includes implementing mechanisms under the Paris Agreement.

Furthermore, Vietnam eloquently articulated the industry's strategic achievements: Establishing a synchronous and modern infrastructure system in both economic and social aspects; prioritizing the development of some key national projects on transportation; adapting to climate change; focusing on developing information and telecommunications infrastructure; creating a national digital transformation platform, gradually developing the digital economy and digital society. Stakeholders' comprehension of logistics sector attitudes, policies, and contents has advanced significantly.

Green logistics is now an essential component when it comes to greening the supply chain and achieving sustainable development. Green logistics is booming as more and more people and companies worldwide look for ways to reduce their environmental impact and save energy. Meanwhile, Vietnam's green logistics ecosystem has a firm footing because of substantial investments in infrastructure, yards, and logistical services by the government and related organizations. These investments facilitate import and export activities. Besides, the government has acknowledged the significance of creating a sustainable logistics ecosystem. Vietnam approved the Action Program to transition to green energy and reduce greenhouse gas emissions from the transportation sector. This Decision establishes objectives and rules for the transportation system's long-term viability, emphasizing improving environmental quality monitoring and control. The opportunities and challenges in creating a green logistics ecosystem are assessed below.

Creating a green logistics ecosystem: a review of possibilities and obstacles: (1) Requiring public-private coordination in strategic cooperation towards green transformation, thereby enhancing the long-term autonomy of the economy, is included among the current measures to stabilize the macroeconomy. So, it's safe to say that digital transformation and green ecosystem growth in logistics are here to stay. What's more, they're crucial metrics by which to judge the new generation of logistics' sustainable development. (2) In the present setting, the fourth industrial revolution is a basis to encourage the development of a green logistics ecosystem while simultaneously increasing the demand for logistical operations in a contemporary and intelligent setting. (3) A staggering 73.2% of businesses in this sector focus on developing green logistics as part of their overall strategy. This is encouraging because it shows that companies in the industry are cognizant of the critical need to green their logistics and supply chains. (4) More openness and equity have been introduced to the Vietnamese logistics industry due to technological advancements in supply chain management and the growth of environmentally friendly logistics practices. Improving efficiency and avoiding operational hurdles aids in solving problems associated with inspection, monitoring, and administration of logistical activities.

Analyzing obstacles to developing a green logistics system: (1) Vietnam's logistics industry is actively working to reduce environmental impact across the supply chain and has made significant strides in this direction. Creating a green logistics ecosystem has numerous potential and difficulties within the framework of

the evolving global logistics service sector. Digitizing education and logistics takes time, material, and human resources. (2) The logistics industry needs the state's backing to be greened; the best way to do it is with favorable rules for green logistics companies. Due to these incentive programs, more companies will use green logistics in their supply chains. Meanwhile, targeted initiatives and plans to implement innovative technology (smart logistics) are needed to lessen the reliance on manual labor and advance green logistics. The logistics industry needs mechanisms and policies that promote sustainable development to be finalized soon so companies can take advantage of the favorable conditions. (3) Vietnam Logistics Report, scientific and technological advancements significantly impact the internal and external variables that contribute to the growth of green logistics. Despite the growing importance of infrastructure, logistics companies have been slow to adopt digital transformation and information technology. This demonstrates the importance of solving the technology and application challenges to construct and update the old logistics ecosystem to one less harmful to the environment. (4) High inflation is just one of the numerous adverse effects on many countries' finances, economies, and social security caused by the ongoing global conflict. Rising prices have a chilling effect on the country's economy and finances and impede efforts to build a green logistics environment. Furthermore, in the face of intense competition in the logistics services sector, one of the shortcomings of Vietnamese firms is the high cost of green services coupled with subpar service quality. (5) Choosing the right technology and addressing human factors, such as executives' and employees' knowledge, skills, and habits, are two of the biggest obstacles to creating a sustainable logistics system. Addressing, converting, and implementing green technology in logistics is a complex process that demands extensive knowledge and expertise from all parties involved. Meanwhile, human resources must be adaptable, innovative, and fast to follow the green logistics ecosystem development trail.

While green logistics is still a relatively new idea in Vietnam, it is quickly rising to the forefront of sustainable supply chain discussions. Large expenditures in transportation infrastructure are being prioritized by both the government and industry as a means to develop environmentally friendly logistics. Businesses can save time and money on transportation thanks to the expansion of essential roadways. However, there is still a lack of regional connectivity and tight organization in the domestic logistics system. Green logistics has received legislative and policy backing from the Vietnamese government, demonstrating their dedication to sustainable growth. Logistics companies still confront many obstacles, even if they have a lot of room to grow. In the article, the author suggests some options to promote the green logistics ecosystem and achieve sustainable development in the supply chain.

The most significant empirical dataset on green logistics in Vietnam is provided by this study, which collects data from 800 logistics managers at 800 logistics enterprises across four provinces. This study provides insights relevant to the region, in contrast to previous research that has relied on Western data or small-scale case studies. The dataset makes green logistics research more credible and applicable to developing countries. The findings shed insight into the difficulties associated with technology adoption, infrastructure inadequacies, and financial limitations in Vietnam. The future of sustainable logistics research can be guided by this extensive dataset. This data-driven study aims to find the best solutions for green logistics adoption, which analyzes a large-scale dataset of 800 managers in four provinces. Given Vietnam's growing involvement in global trade agreements that mandate environmental standards and its dedication to sustainable development goals (SDGs), this research takes on further significance. The results will add to the literature on green logistics and provide concrete suggestions for policymakers to implement in Vietnam and other developing countries dealing with comparable issues.

2. ANALYSIS OF DESCRIPTIVE STATISTICS AND CRONBACH'S ALPHA FOR FACTORS AFFECTING THE GREEN LOGISTICS MANAGEMENT

Table 1. Testing descriptive statistics and Cronbach's alpha for critical factors influencing green logistics management.

Items of green logistics management	Cronbach's alpha	Mean	Std. Deviation
1. Environmental regulations and policies (ERP: ERP1, ERP2, ERP3, ERP4)	0.875	2.392	0.676
2. Technological advancements and innovations (TAI: TAI1, TAI2, TAI3, TAI4)	0.958	3.087	0.991
3. Supply chain collaboration and integration (SCI: SCI1, SCI2, SCI3, SCI4, SCI5)	0.909	2.405	0.685
4. Energy efficiency in operations (EEO: EEO1, EEO2, EEO3)	0.944	3.342	0.972
5. Waste minimization and sustainable packaging (WSP: WSP1, WSP2, WSP3, WSP4)	0.965	3.072	0.982

6. Resource availability and sustainable sourcing (RSS: RSS1, RSS2, RSS3, RSS4)	0.856	3.392	0.923
7. Organizational culture (OC: OC1, OC2, OC3, OC4)	0.952	3.059	0.976
8. Corporate social responsibility (CSR: CSR1, CSR2, CSR3, CSR4)	0.950	3.052	0.984
9. Green logistics management (GLM: GLM1, GLM2, GLM3)	0.946	3.349	0.970

Source: Processed by SPSS 20.0

Table 1 tests for analysis of descriptive statistics and Cronbach's alpha for green logistics management factors following:

(1) Environmental regulations and policies (ERP) with an alpha of 0.875, a mean of 2.392, and a standard deviation of 0.676. With a reliability score of 0.875, the items (ERP1, ERP2, ERP3, ERP4) measure a cohesive construct, suggesting internal solid consistency. The low mean score of 2.392 indicates that respondents may view green logistics management as less emphasizing environmental legislation and policies. With Cronbach's alpha of 0.875, we can see that the ERP items reliably measure ecological rules and regulations. But the low mean (2.392) suggests that people think green logistics management doesn't put much focus on environmental laws. This finding might point to problems with enforcing regulations or a lack of a well-developed regulatory framework in this particular setting.

(2) Technological advancements and innovations (TAI) with a 0.958 Cronbach's Alpha, a 3.087 Mean, and a 0.991 Standard Deviation. Items measuring technical advances and innovations (TAI1, TAI2, TAI3, TAI4) have a high Cronbach's alpha of 0.958, indicating outstanding dependability. Respondents say this component is moderately essential, with a mean score of 3.087, indicating that technology is necessary but not preponderant in green logistics management. The items successfully measure the concept of technological breakthroughs and innovations, as noted in the high Cronbach's alpha of 0.958, which indicates excellent internal consistency. Perceptions of technology's function in environmentally conscious logistics are moderate, according to the mean value of 3.087. While there may be obstacles to widespread adoption, this highlights the growing significance of breakthroughs like green technology, data analytics, and automation in attaining sustainability.

(3) Supply chain collaboration and integration (SCI) with a 0.909 Cronbach's Alpha, a 2.405 Mean, and a 0.685 Standard Deviation for the Supply Chain Collaboration and Integration (SCI) scale. The five items that comprise the construct (SCI1, SCI2, SCI3, SCI4, SCI5) have a Cronbach's alpha of 0.909, meaning they are very reliable. Survey takers appear to think that green logistics support from supply chain collaboration and integration is lacking, as indicated by the low mean score of 2.405. The items' consistency in depicting supply chain integration and collaboration is confirmed by a Cronbach's alpha of 0.909, which indicates internal solid consistency. However, with a mean score of 2.405, it seems like supply chain collaboration is not as important as possible. This suggests that logistical fragmentation or a lack of common sustainability objectives within supply chain networks may limit collaborative efforts among Vietnamese supply chain partners.

(4) Energy efficiency in operations (EEO) with a Cronbach's Alpha of 0.944, a Mean of 3.342, and a Standard Deviation of 0.972, WEO is a reliable measure. The reliability of the energy efficiency construct (EEO1, EEO2, EEO3) is quite strong, with a Cronbach's alpha of 0.944. With a reasonably high mean score of 3.342, it is clear that energy efficiency is an essential part of green logistics that respondents have acknowledged. Items faithfully represent the concept of energy efficiency in logistical operations, as indicated by the excellent dependability (Cronbach's alpha = 0.944). Respondents saw energy efficiency as an essential part of green logistics, with a mean score of 3.342, indicating that they know this practice's financial and ecological advantages. This could signify that logistics companies are investing more money into energy-saving technologies and procedures to reduce their adverse effects on the environment and operational expenses.

(5) Waste minimization and sustainable packaging (WSP) with a 0.965 Cronbach's Alpha, a 3.072 Mean, and a 0.982 Standard Deviation for waste minimization and sustainable packaging (WSP). Across all four items (WSP1, WSP2, WSP3, and WSP4), this factor has a dependability of 0.965, indicating that sustainable packaging and waste minimization are consistently measured. A mean score of 3.072 shows that waste management in green logistics is somewhat highly recognized. This component has exceptionally high reliability with Cronbach's alpha = 0.965, indicating that the items reliably assess sustainable packaging and waste minimization. Respondents somewhat acknowledge that green logistics management relies on waste reduction and sustainable packaging (mean score: 3.072). This may indicate that circular economy concepts are gaining popularity, matching global trends toward waste reduction and resource optimization.

(6) Resource availability and sustainable sourcing (RSS) have a Cronbach's Alpha of 0.856, a mean score of 3.392, and a standard deviation of 0.923. With an acceptable dependability score of 0.856, RSS1, RSS2, RSS3, and RSS4 are internally consistent. Due to missing mean and standard deviation statistics, this factor may require extra data gathering or analysis to interpret. Items evaluating resource availability and sustainable sourcing

have acceptable internal consistency, as indicated by the reliability score of 0.856. Respondents' perceptions are limited in their interpretation due to the lack of data on means and standard deviations. Although the scale has a strong Cronbach's alpha, further data is required to draw firm conclusions about how respondents rate the sustainability and availability of logistics operations' resources.

(7) Organizational culture (OC) has a 0.952 Cronbach's Alpha, 3.059 Mean, and 0.976 Standard Deviation. This factor has high internal consistency with Cronbach's alpha = 0.952, which indicates that the four organizational culture components (OC1, OC2, OC3, and OC4) agree well. With a mean score of 3.059 and some variation in replies, corporate culture modestly promotes green logistics. The items are consistent in their representation of corporate culture, as indicated by the strong reliability (Cronbach's alpha = 0.952). Organizational culture's role in green logistics is moderately acknowledged (mean = 3.059), suggesting that environmental values are present in organizational practices but that there is room for improvement in integrating and reinforcing green values to promote sustainability.

(8) Corporate social responsibility (CSR), with a Cronbach's Alpha of 0.950, a Mean of 3.052, and a Standard Deviation of 0.984, is where we have corporate social responsibility (CSR). All four components that makeup CSR are pretty reliable (Cronbach's alpha = 0.950). The average score of 3.052 indicates a moderate focus on corporate social responsibility (CSR) in connection to green logistics, indicating that CSR is recognized but may be further integrated into green logistics processes. The CSR items have firm internal consistency, as shown by a Cronbach's alpha of 0.950. Companies exhibit a moderate commitment to corporate responsibility in logistics, with a mean score of 3.052. This suggests that they are not completely utilizing the potential of CSR to improve sustainability and stakeholder relations, but they are at least somewhat involved. Recognizing CSR's worth and the difficulties in turning CSR principles into all-encompassing green logistics practices may explain its moderate grade.

Table 2. Testing critical factors affecting the green logistics management

Relationships			Standardized estimate	S. E	C. R	P value	Result
ERP	→	GLM	0.084	0.054	3.584	0.001	Accepted H1
SCI	→	GLM	0.079	0.049	2.578	0.010	Accepted H3
EEO	→	GLM	0.083	0.033	2.915	0.004	Accepted H4
RSS	→	GLM	0.174	0.033	5.213	0.001	Accepted H6
OC	→	GLM	0.080	0.024	2.837	0.005	Accepted H7
TAI	→	GLM	0.532	0.030	16.540	0.001	Accepted H2
CSR	→	GLM	0.087	0.031	2.693	0.007	Accepted H8
WSP	→	GLM	0.123	0.024	4.337	0.001	Accepted H5

Source: Processed by SPSS 20.0, Amos.

According to the data presented in Table 2, which includes standardized estimates, standard errors (S.E.), critical ratios (C.R.), and p-values for each hypothesised association, there are several important elements that impact green logistics management (GLM). Now let's take a closer look at each link and how it relates to green logistics management from an academic perspective:

(1) ERP on environmental rules and policies impacts GLM; accepted H1; standardized estimate = 0.084; $p = 0.001$. Environmental laws and regulations positively affect green logistics management, according to the optimistic standardized estimate of 0.084 [3, 5, 42]. This effect is moderate but statistically significant. This conclusion suggests that regulatory frameworks encourage firms to adopt sustainable practices. However, the relatively low impact could be due to variances in compliance levels or limitations in regulatory enforcement. Enterprises must strictly comply with legal regulations related to environmental protection. Environmental regulations are closely linked to economic development and are associated with protecting resources and reducing water, air, and noise pollution from business operations.

(2) Green logistics management (GLM) as impacted by technological advancements and innovations (TAI) with a standardized estimate of 0.532, a p-value of 0.001, and H2 approved [4, 7, 43]. Innovations and technical progress greatly benefit green logistics management, with the highest standardized estimate (0.532) of any component. It is essential to integrate sophisticated technologies such as data analytics, renewable energy solutions, and automation to achieve environmental goals in logistics. Therefore, businesses must incorporate green technology into their supply chains to meet customers' environmental concerns. Customers are now

willing to pay a premium for environmentally friendly products, demonstrating that they are environmentally conscious in their business operations and are demanding that businesses improve this despite the high costs.

(3) This result emphasizes the critical role of technology in allowing sustainable practices. Lastly, we accept H3 and find a standardized estimate of 0.079 for the effect of supply chain integration and collaboration on green logistics management with a corresponding p-value of 0.010 [6, 9, 44]. Green logistics management is marginally and statistically positively affected by supply chain integration and collaboration (standardized estimate = 0.079). It appears that supply chain partners are not making the most of their opportunities to work together, which might be a significant environmental setback. Further amplifying its impact on sustainability could be achieved through enhanced integration. Enterprises need to apply the set of standards on environmental management to help them be aware of integrating green technology into the supply chain, contributing to minimizing harmful impacts on the environment and regularly improving environmental performance.

(4) The acceptance of H4 is based on a standardized estimate of 0.083 for the impact of energy efficiency in operations (EEO) on green logistics management (GLM). The corresponding P-value is 0.004. Operational energy efficiency positively impacts green logistics management to 0.083 [8, 9, 44]. This highlights the significance of implementing energy-saving measures and using resources effectively to promote sustainable logistics. Although energy efficiency significantly contributes to sustainability, other vital factors probably work in tandem with it, as the moderate effect indicates. Businesses must apply sustainable development standards and require partners and suppliers to comply. From there, companies can assess and monitor the compliance level to ensure the supply chain's sustainability.

(5) GLM is impacted by waste reduction and sustainable packaging (WSP), with a standardized estimate of 0.123, a P-value of 0.001, and the acceptance of H5. Waste minimization and sustainable packaging increase green logistics management by 0.123 [11, 12, 45]. This suggests that logistics operations could profit from a circular economy by reducing waste and using green packaging. Enterprises need to plan between applying a green supply chain and the enterprise's goals to create strategic value. Accordingly, enterprises must clearly orient their business goals, including creating product differentiation using natural materials or products designed to minimize environmental pollution.

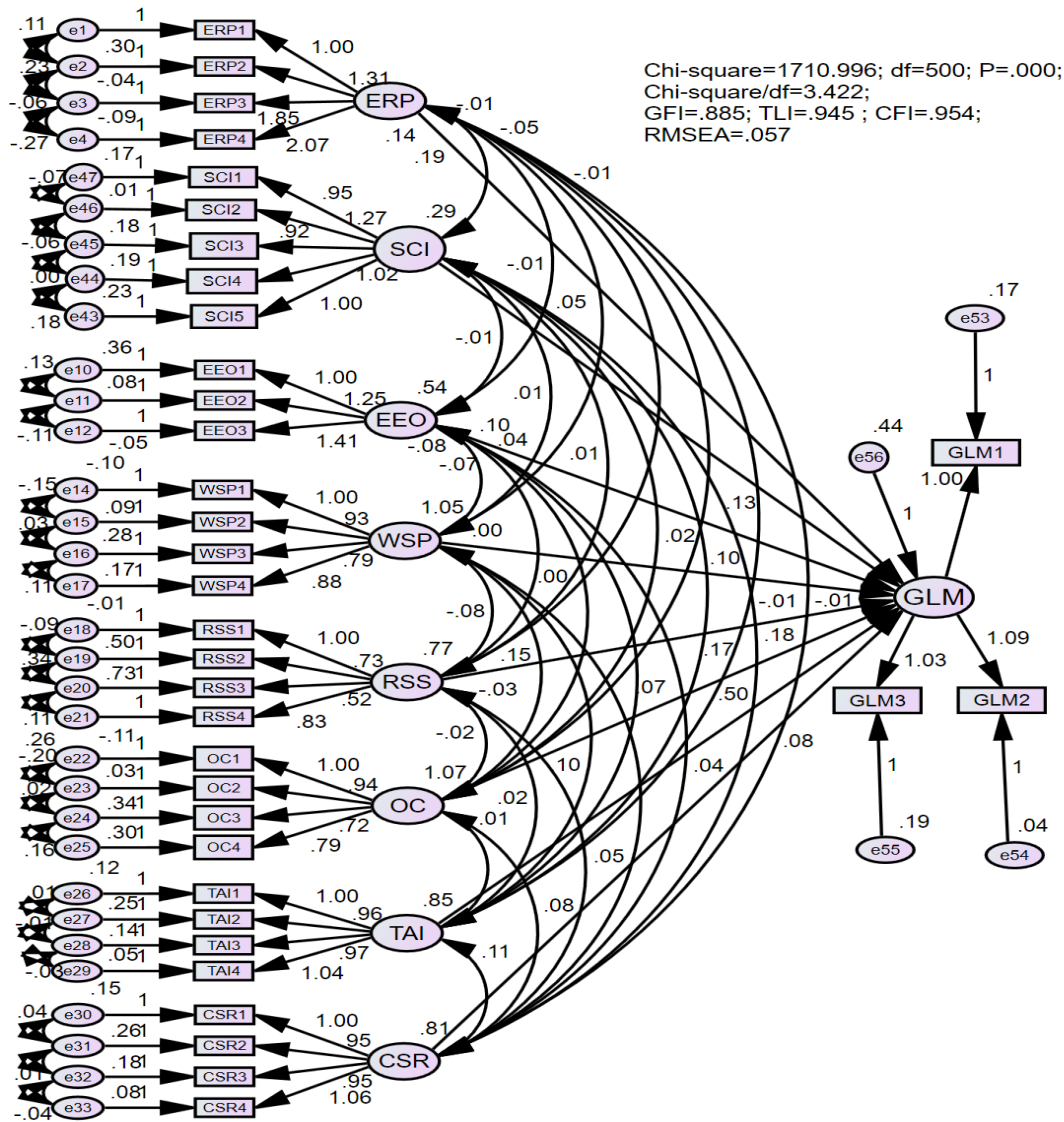
(6) Normalized estimate of 0.174, P-value of 0.001, and H6 acceptance show that resource availability and sustainable sourcing (RSS) affect green logistics management [14, 17, 46]. A normalized estimate of 0.174 shows that resource availability and sustainable sourcing positively benefit green logistics management. Sustainable logistics requires environmentally friendly products and sustainable resources. This suggests developing sustainable supply networks. Creating competitive advantages, minimizing costs, managing risks, and redefining the market. When the green supply chain program is consistent with the goals, there will be indicators to evaluate the success of the enterprise, including environmental indicators, motivation for innovation, support from related organizations

(7) Organizational culture (OC) affects green logistics management (GLM). A normalized estimate of 0.080 shows that organizational culture improves green logistics management [19, 21, 47]. This study suggests a sustainable and environmentally responsible organizational culture makes adopting green logistics easier. The moderate effect size indicates that organizational culture may not matter without structural and technological factors. Enterprises need to evaluate the supply chain as a system, including minimizing input factors such as raw materials, energy, and capital, optimizing production cycles in the impact of the environment, and maximizing output factors such as products and profits.

(8) The authors adopt H8 and find a standardized estimate of 0.087 for the impact of CSR on green logistics management (GLM), with a p-value of 0.007. The fact that CSR positively affects green logistics management (0.087) shows that it encourages companies to be more environmentally responsible [24, 27, 48]. Green logistics is made possible by CSR, which helps to integrate sustainability into company principles and operations. Nevertheless, its impact is still modest, maybe because of difficulties putting CSR promises into action, especially in logistics-related tasks. Managers must view green supply chains as a driving force to improve the organization's operational processes and reduce costs. Pollution and waste represent the use of non-standard and inefficient raw materials. Therefore, businesses integrating green technology into the supply chain will bring financial benefits and improve brand image in the eyes of investors and the social community.

Based on their p-values (< 0.01), the results showed that all eight predicted characteristics positively impact green logistics management. Nevertheless, there is a wide range of severity in these consequences. The most significant influence is exhibited by technological breakthroughs and innovations (0.532), highlighting the vital importance of technology in enabling sustainable logistics operations. Sustainable sourcing and waste management are crucial to green logistics since the moderate-impact factors of resource availability and

sustainable sourcing (0.174), waste reduction (0.123), and sustainable packaging (0.123) all demonstrate substantial positive impacts. Factors with Lesser Impact: Various other elements have favorable but rather minor effects, including environmental rules (0.084), energy efficiency (0.083), company culture (0.080), collaboration in the supply chain (0.079), and corporate social responsibility (0.087). Although crucial, they may need governmental backing, technology integration, or increased organizational dedication for these factors to have a more significant impact. According to the findings, technical innovation, sustainable sourcing, and waste minimization should be the key goals for Vietnamese firms striving to develop green logistics management. Significant improvements in sustainability can be achieved by focusing on these areas, which are high-impact variables. Green logistics could be further supported by strengthening organizational culture, improving supply chain coordination, and incorporating CSR principles. However, these variables may not have much influence without sound technological and regulatory frameworks.



Source: Processed by SPSS 20.0, Amos

FIGURE 3. Testing for critical factors affecting green logistics management (GLM).

Figure 3 showed that the assessment of the critical factors affecting green logistics management: CMIN/DF = 3.422 (<5.0), GFI = 0.885 (>0.800), TLI = 0.945 (>0.900), CFI = 0.954 (>0.900) and RMSEA = 0.057 (<0.08). Model fit indices validated the SEM model's robustness, and all variance inflation factors (VIF) were less than 2.0, signifying the absence of multicollinearity. The purpose of this essay is to identify the five elements influencing

green logistics management in Vietnam, with a focus on the most important of these, technological breakthroughs and innovations, which have a standardized estimate of 0.532 and so have the greatest influence.

Table 3. Testing average variance extracted for factors affecting green logistics management.

Code	CR	AVE	MSV	Results
ERP	0.930	0.780	0.014	Good
EEO	0.946	0.856	0.012	Good
WSP	0.968	0.883	0.030	Good
RSS	0.844	0.591	0.028	Good
OC	0.957	0.850	0.019	Good
TAI	0.960	0.859	0.327	Good
CSR	0.950	0.826	0.135	Good
SCI	0.908	0.667	0.135	Good
GLM	0.948	0.858	0.327	Good

Source: Authors own work

Table 3 illustrates that all constructs meet or exceed the recommended CR and AVE thresholds, confirming the reliability and convergent validity of the measurement scales. The AVE values, consistently above 0.50, indicate that each construct's items effectively capture the intended dimensions. Additionally, the MSV values are lower than the respective AVE values for each construct, verifying discriminant validity and suggesting that the constructs are conceptually distinct within the model.

Table 3. Testing Bootstrap 4.000 samples for factors affecting green logistics management.

Parameter	SE	SE-SE	Mean	Bias	SE-Bias	Result
ERP → GLM	0.057	0.000	0.177	0.008	0.005	1.60
SCI → GLM	0.049	0.000	0.123	0.004	0.003	1.33
EEO → GLM	0.040	0.000	0.087	0.001	0.002	0.50
RSS → GLM	0.043	0.000	0.166	0.005	0.003	1.67
OC → GLM	0.024	0.000	0.060	0.007	0.004	1.75
TAI → GLM	0.043	0.000	0.497	0.000	0.002	0.00
CSR → GLM	0.035	0.000	0.085	0.002	0.003	0.67
WSP → GLM	0.026	0.000	0.094	0.001	0.003	0.33

Source: Processed by SPSS 20.0, Amos

Based on the results given in Table 4, the variables influencing green logistics management were tested using Bootstrap with 4.000 samples at a significant level of 0.01 ($C.R < 1.96$). The principles of Vietnamese applied logistics theory and practice are fully supported by this outcome. This finding provides scientific evidence that policymakers can utilize to inform their predictions.

3. DISCUSSIONS OF FINDINGS

Transporting goods and services from manufacturers to retailers to end users is the goal of green logistics management, which unites many entities, processes, data, and personnel. Economic growth is also greatly impacted by green logistics management. Business operations and GDP growth have been aided by the Vietnamese supply chain. The expansion of Vietnam's supply chain has boosted the country's businesses' global competitiveness and created many new jobs. Table 2 also shows the results and the important factors that have an impact on green logistics management in enterprises. While their relative importance varies, all components are essential to sustainable logistics practice growth. Below are detailed results for each factor:

(1) Technological advancements and innovations (TAI) affect green logistics (GLM) with a standardized estimate of 0.532 and a p-value less than 0.001 in Table 2 [3, 5, 42]. Technological advances include autonomous automobiles, data analytics for route planning and inventory management, renewable energy sources, and electric power generation, enabling eco-friendly logistics. TAI significantly influences, saves money, and reduces environmental impact; thus, green logistics companies should invest in IT solutions. This study proves

that new technologies majorly affect environmentally conscious logistical practices. While most studies have focused on rules and regulations, this one actually measures how much of an impact automation, artificial intelligence, and the Internet of Things have on logistical sustainability. The findings show that technology adoption is more important than complying with regulations regarding green logistics. Companies that use digital solutions are more efficient, save money, and have less of an effect on the environment. This discovery changes how businesses approach sustainability, suggesting they should focus on innovation rather than just complying. Therefore, investing in automation, data analytics, and intelligent logistics solutions is vital for businesses prioritizing technology adoption. These solutions lead to higher cost reductions and sustainability gains. The report also notes that there are obstacles to broad adoption, such as a lack of experienced workers and limited funding, which calls attention to the necessity for government incentives and business partnerships.

(2) Resource availability and sustainable sourcing (RSS) enhance green logistics, as shown in Table 2, by a normalized estimate of 0.174 and a p-value less than 0.001 [6, 8, 43]. This shows that sustainable resources and eco-friendly materials boost GLM. These findings suggest that organizations with environmental-compliant resources are more likely to achieve sustainable logistics. Green logistics requires reliable supply networks and sustainability-focused procurement. Enterprises must perfect their business models by integrating green technology into the supply chain. Accordingly, enterprises need to overcome internal barriers to implement organizational change, create consistency in the supply chain, and focus on the goals and results pursued.

(3) Waste minimization and sustainable packaging (WSP) also moderately affects GLM, as shown by waste minimization and sustainable packaging (WSP), with a standardized estimate of 0.123 and a p-value less than 0.001 in Table 2 [7, 10, 44]. As part of the circular economy, green logistics benefits from waste reduction and sustainable packaging. This finding supports logistics waste reduction as a vital part of environmental management. Reduce packaging waste and increase recyclable and biodegradable material use to reduce environmental impact and meet customer and regulatory needs for green practices. In addition to the above directions, when implementing in practice, businesses need to apply tools to measure and evaluate the standards and performance of the supply chain when integrating green technology solutions based on a system that strictly controls the components of the supply chain.

(4) According to environmental laws and policies (ERP), ERP has a small but significant impact on GLM based on the standardized estimate = 0.084, $p < 0.001$ in Table 2 [9, 12, 45]. Environmental restrictions encourage sustainable business practices, but their minimal impact suggests they won't change green logistics. Dependence on voluntary compliance or inconsistent regulation may be to blame. However, it is crucial as regulatory frameworks provide baseline criteria that support sustainable corporate practices. Apply critical digital applications to optimize production and transportation processes, allowing businesses to accurately track and manage the number of raw materials used, each production step, and transportation efficiency. As a result, companies can reduce the amount of waste and emissions that pollute the environment. The results show that green logistics adoption is moderately but significantly impacted by regulatory rules. Technology has a more substantial influence on promoting sustainable logistics transformation than environmental legislation, carbon reduction goals, and compliance requirements. Low voluntary adoption rates will persist until incentives are offered since many enterprises see green logistics standards more as extra expenses than competitive advantages. Implication: Instead of enforcing regulations strictly, policymakers should provide grants, tax cuts, and incentives for investments in green technology. Logistics companies seeking to switch to more environmentally friendly practices may also find assistance from public-private partnerships (PPPs) in filling the funding gap.

(5) The standardized estimate for organizational culture (OC) is 0.080, with a p-value less than 0.005, showing a small but statistically significant effect on GLM in Table 2 [11, 13, 35, 46]. According to these findings, green logistics is not only driven by a company culture that rewards environmental responsibility. A sustainability-focused culture can empower employees to be environmentally responsible and participate in green activities. Promoting a green culture is beneficial in addition to structural elements like technology and sourcing. Applying digital technology to the supply chain creates a green supply chain that aims to ensure transparency in compliance with environmental protection regulations while actively contributing to nature protection and sustainable environmental development. According to the results, sustainable sourcing of resources (RSS) and waste minimization and sustainable packaging (WSP) are two moderate-impact elements that affect green logistics management, while technical advancements and innovations (TAI) are the most important. Enterprises should focus on these three criteria in sustainability projects to increase their green logistics skills.

(6) Table 2 shows a standardized estimate of 0.087 and a p-value smaller than 0.007 for corporate social responsibility (CSR)'s small but positive effect on GLM [15, 18, 38, 47]. CSR promises to help businesses meet society's sustainability expectations but doesn't produce green logistical results. Due to CSR's reinforcing mechanism, firms will likely follow ethical and sustainable logistics methods. Effective corporate social responsibility (CSR) programs require technical and operational support as part of a strategy framework. Applying digital technology to monitor and track air, water, and soil quality to promptly identify and prevent environmental incidents helps minimize environmental risks and save costs. Although they have less of an effect, other factors like energy efficiency in operations (EEO), organizational culture (OC), corporate social responsibility (CSR), supply chain collaboration and integration (SCI), and environmental regulations and policies (ERP) are crucial. When used together, they boost green logistics' efficiency, but each one might not be enough to bring about significant changes in sustainability on its own.

(7) Supply chain collaboration and integration (SCI) improved GLM slightly, with a standardized estimate of 0.079 and a p-value below 0.010 in Table 2 [18, 36, 48]. It appears from these results that the effect of supply chain collaboration on green logistics could be hindered by logistical fragmentation or by the fact that supply chain partners do not have completely integrated sustainability goals. More integration and better environmental-focused relationships might help SCI improve green logistics. Supply chain integration positively affects green logistics outcomes, however to a lesser extent than technological advancements. This is an additional noteworthy finding. Organizations see improvements in waste management, emission reduction, and energy efficiency when they work on sustainability projects with their distribution, manufacturing, and supplier partners. Nevertheless, the study highlights that a problem, especially for SMEs, is the disjointed nature of supply chain networks. This means that digital platforms shared transportation models, and cooperative sustainability commitments should encourage horizontal and vertical supply chain collaboration, which could boost green logistics efficiency. Blockchain-based transparency solutions should be implemented to keep supply chain partners accountable and monitor their sustainability development.

(8) Energy efficiency in operations (EEO) had a small but significant effect on GLM (standardized estimate = 0.083, $p < 0.004$ in Table 2 [22, 37, 48]. Energy efficiency helps improve logistics sustainability, but it may not be enough to advance green logistics. An effective green logistics plan should include technology, sustainable sourcing, and energy efficiency, but it can save operational costs and emissions. Consider using digital technology as an innovative solution to optimize goods' storage and distribution process. Intelligent automated systems can manage inventory, minimize waste, and maximize storage space. This helps to reduce energy and resource consumption. Findings show that small and medium-sized enterprises (SMEs) and new logistics companies face substantial cost hurdles when implementing green logistics. Many businesses hesitate to engage in sustainability because of the high initial expenses of AI-based logistics, electric car fleets, and environmentally friendly warehousing solutions. Green technology adoption positively correlates with firm financial capability, suggesting that financial competence is a key driver of sustainability reforms. This means that businesses that invest in environmentally friendly technology and infrastructure should be eligible for low-interest loans, subsidies, and grants from government and financial organizations to hasten the adoption of green logistics. One way to alleviate financial strains and boost industry-wide engagement in sustainability efforts is to create cost-sharing arrangements for small logistics enterprises.

The findings of this study confirm that technical developments are the most potent enabler of green logistics management. While regulatory rules, supply chain collaboration, and financial capacity are significant, the most successful logistics companies use AI, IoT, automation, and digital technologies to achieve sustainability. However, problems such as high implementation costs, complex supply chains, and regulatory constraints must be addressed through legislative incentives, financial support, and industry collaboration. The study's findings provide valuable insights into the factors influencing green logistics management (GLM) in Vietnam, focusing on technological advancements and innovations (TAI). The results highlight the dominant role of technology, alongside other critical determinants, in shaping sustainable logistics practices. The findings of this study align with the Technology–Organization–Environment (TOE) framework, reinforcing the notion that green logistics adoption is influenced by internal readiness, e.g., leadership commitment, employee skills, and external pressures, e.g., regulation market demand. Consistent with prior studies in emerging economies, this research confirms that technological factors like IoT and automation are perceived as enablers. Still, their effectiveness is constrained by cost barriers and infrastructure gaps, a pattern not typically observed in developed economies. Notably, this study contributes a new insight by showing that digital transformation efforts in Vietnam's logistics sector remain fragmented, often led by isolated initiatives rather than systemic strategies. This partially contradicts the linear progression of many Western green logistics models and suggests the need for context-specific adaptation of global frameworks when applied in transitional economies.

The results also highlight the emergence of hybrid drivers, such as customer demand for sustainability coexisting with operational cost concerns, pointing toward an evolving “eco-efficiency” mindset among Vietnamese firms.

V. CONCLUSIONS AND POLICY RECOMMENDATIONS

1. CONCLUSIONS

This study examines how technological innovation, internal capabilities, and external factors shape the adoption of green logistics practices in Vietnam. By applying the Technology–Organization–Environment (TOE) framework, the research highlights the growing influence of digital tools and organizational readiness in advancing sustainability while enhancing the contextual limitations of policy enforcement and infrastructure development in a transitional economy. Rather than reiterating statistical results, this conclusion summarizes actionable directions to bridge the gap between environmental goals and implementation realities in Vietnam's logistics sector. The analysis showed eight critical factors affecting green logistics management and revealed a multi-faceted framework where certain elements exert a more substantial influence on green logistics management. This study provides empirical evidence that AI and blockchain technologies significantly enhance sustainability in Vietnam's logistics sector. Future research should explore long-term effects through longitudinal studies and comparative analyses across different economies. One of the most important things that the writers have concluded is that technology is crucial to achieving sustainable logistics. They state that technological breakthroughs and innovations are the main drivers that have a good impact. Environmental regulations, policies, supply chain collaboration, and integration positively but modestly impact green logistics management. While these factors play important roles, especially in setting standards and fostering partnerships, they require complementary efforts from enterprises to achieve substantial improvements in sustainability. This study contributes to the growing body of knowledge on green logistics in emerging economies by providing one of the first empirical investigations into how technological innovations influence sustainable logistics practices in Vietnam. Theoretically, the study extends the application of the Technology–Organization–Environment (TOE) framework by integrating context-specific factors such as infrastructure constraints and regulatory gaps into green logistics decision-making. Practically, the findings identify the most influential drivers of adoption, e.g., IoT and automation, offering actionable insights for logistics firms seeking to prioritize their green investments. From a policy perspective, the study highlights the need for clearer regulatory incentives, public infrastructure upgrades, and workforce training to support digital sustainability transitions. These contributions offer academic relevance and real-world impact and lay the groundwork for future research in other transitional economies.

2. POLICY RECOMMENDATIONS

Based on the standardized estimates, this collection of recommendations adjusts policy interventions to account for the relative importance of each aspect in green logistics management. Focusing on the highest-impact factors, such as technological advancements and sustainable sourcing, while addressing supportive factors like waste minimization, regulatory compliance, and organizational culture, provides a balanced and targeted approach to enhancing green logistics management. These policies create an enabling environment that encourages technological innovation, resource efficiency, collaborative efforts, and strong cultural and CSR alignments in logistics operations. Implementing these strategies will strengthen green logistics practices and position the industry for sustainable growth in line with global environmental goals. The authors had policy recommendations based on factor impact through standardized estimates below.

(1) Technological advancements and innovations (TAI) → GLM (0.532). Utilize the standardized estimate of 0.532 to enhance technological developments and innovations. Since technology investments have a significant influence on green logistics management, businesses should provide incentives for them. Consequently, logistics firms that invest in environmentally friendly technologies should get financial incentives from lawmakers in the form of tax credits, subsidies, or grants. Electric vehicles, automated warehouses, and renewable energy installations are all part of the plan to spur innovation in logistics through subsidies. Support research and development (R&D) in sustainable logistics technology. Besides, enterprises should establish dedicated R&D funds and public-private partnerships to develop next-generation green logistics technologies. Areas of focus could include emissions-reducing equipment, AI for route optimization, and energy-efficient warehousing. Policymakers may help the sector fulfill green logistics ambitions by encouraging technology

development. Businesses could encourage green technology adoption by introducing government-led programs, especially for logistics SMEs. These programs can provide technical help, training, and resource sharing to reduce logistics operations technology hurdles. Technological developments are essential to green logistics, significantly reducing environmental effects. AI-driven route planning, IoT-based tracking, and automation are innovations that improve operational efficiency. Companies that mix big data analytics, machine learning, and autonomous logistics systems experience better sustainability results. The study emphasizes technology's dominance over regulatory measures, demonstrating its effectiveness in lowering emissions. The government should provide logistics companies with financial incentives and digital transformation subsidies to enhance their impact. Regulatory regimes should encourage blockchain implementation for supply chain transparency and AI-powered logistics hubs. Collaboration with technology suppliers and research institutions helps speed up green innovation. Implementing national innovative logistics strategies will encourage adopting environmentally friendly technologies. Encouraging logistics organizations to prioritize technological investments above traditional sustainability initiatives will improve the long-term environmental impact. A well-developed digital logistics infrastructure will help Vietnam become a green supply chain management leader.

(2) Resource availability and sustainable sourcing (RSS) → GLM (0.174). Improve the resource availability and sustainable sourcing based on the standardized estimate of 0.174. Therefore, the government should mandate that logistics companies buy goods and resources from certified sustainable vendors. These guidelines can favor recyclable materials, eco-friendly fuels, and renewable energy in logistics. Corporations should provide subsidies or preferential tax rates to local material suppliers to reduce transportation-related carbon emissions. Local sourcing can also strengthen supply chains by lowering long-distance supplier dependence. Develop sustainable resource networks and databases for logistics organizations to discover environmentally certified suppliers. Businesses may meet green logistics criteria and simplify sustainable sourcing using this. Resource sustainability is critical to achieving long-term environmental efficiency in logistics operations. Many logistics companies rely on nonrenewable resources, unnecessary packaging, and wasteful energy consumption, contributing to pollution. This study demonstrates that enterprises implementing effective resource sustainability strategies have greater environmental compliance. Policies should promote circular economy models, in which waste materials are reused in supply chain activities. The government should implement green procurement standards that require recyclable packaging and low-carbon transportation. A national sustainability certification scheme might encourage logistics companies to use environmentally friendly material procurement and supply chain practices. Financial subsidies and tax benefits can help businesses move to more resource-efficient logistics. Encourage businesses to invest in renewable energy alternatives, such as solar-powered warehouses and electric vehicles, to boost green logistics initiatives. Public-private partnerships should focus on developing resource-efficient infrastructure and decreasing industrial waste. Promoting sustainable resource management will make Vietnam's logistics sector more competitive internationally.

(3) Waste minimization and sustainable packaging (WSP) → GLM (0.123). Utilize the standardized estimate of 0.123 to enhance waste savings and sustainable packaging. So, it's only fair that the government mandates biodegradable or recyclable packaging for logistics firms. Officials in charge of logistics might use packaging regulations to lay out specific goals and deadlines for cutting down on waste. Provide logistics companies with low-interest loans or subsidies so they can invest in waste reduction, recycling, and reverse logistics, all of which are part of the circular economy. This helps firms reduce waste and maximize resource efficiency. Support R&D in logistics-specific sustainable packaging solutions like reused containers or modular packaging. Companies that create and deploy waste-minimizing packaging may receive subsidies or patent tax benefits. Waste reduction is a critical component of green logistics management, yet many logistics companies suffer from excessive packaging waste, inefficient transportation, and ineffective recycling. The study reveals that enterprises implementing structured waste management techniques have better environmental performance. Policies should mandate waste monitoring systems and require logistics companies to measure and disclose their environmental impact. Governments might grant tax breaks for logistics companies that invest in biodegradable packaging and environmentally friendly supply chain procedures. Implementing waste-to-energy systems, which turn logistics waste into renewable energy, can dramatically improve sustainability. Companies should be urged to use reusable packaging, optimize inventories to decrease extra stock, and create recycling programs. Establishing waste reduction compliance frameworks can help firms meet global sustainability standards. Educational programs should focus on educating logistics professionals about waste reduction and environmental best practices. Investments in green warehouse technology, such as solar-

powered storage and rainwater harvesting, will help to reduce environmental effects. A defined national policy on waste reduction in logistics will guarantee long-term sustainability improvements.

(4) Corporate social responsibility (CSR) → GLM (0.087). Utilize the standardized estimate of 0.087 to enhance corporate social responsibility. To that end, CSR filings should mandate that logistics companies disclose their environmental effect to enterprises. This covers emissions, waste reduction, and sustainable resource utilization data, making business sustainability transparent and accountable. Businesses could implement a government-endorsed award or certification scheme for logistics businesses with excellent green CSR practices. This would incentivize enterprises to openly display their green logistics projects, raising industry standards. The government should fund logistics companies participating in community-focused environmental projects, including reforestation, public clean-ups, and sustainability education. Such activities boost the company's social responsibility and community sustainability participation. Corporate social responsibility has a moderate but significant impact on green logistics adoption, promoting sustainability beyond legislative requirements. Many businesses participate in CSR initiatives such as carbon offset programs, community tree planting projects, and sustainable supply chain commitments. According to the report, organizations that incorporate CSR boost customer trust, brand recognition, and stakeholder relationships. Government incentives should be provided to enterprises actively involved in CSR-driven sustainability activities, such as tax breaks for corporations demonstrating strong ESG (Environmental, Social, and Governance) performance. Mandatory CSR reporting should be implemented, requiring enterprises to declare their annual sustainability effect. Industry coalitions should encourage companies to collaborate on carbon-neutral projects, fostering cross-sector green relationships. Businesses that execute CSR programs focusing on sustainability should receive government financing. Employee engagement should be improved through CSR efforts, such as worker education programs on sustainable logistical methods. Logistics firms should incorporate CSR-driven carbon offsets, renewable energy projects, and responsible sourcing practices. Strengthening CSR participation will cement Vietnam's status as a sustainable logistics center.

(5) Environmental regulations and policies (ERP) → GLM (0.084). Take into account the standardized estimate of 0.084 when making improvements to environmental policies and regulations. Consequently, in order to enhance environmental compliance, the government ought to impose stricter regulations on emissions, waste management, and logistical sustainability. Compliance can be enforced through the use of fines for non-compliance and mandatory environmental audits. Logistics certification for the environment: Logistics companies that consistently meet or exceed environmental standards should be recognized by the government through an accreditation program. This certification can demonstrate quality and inspire organizations to adopt greener practices. Eco-taxation or carbon pricing on high-emission logistics activities helps corporations adopt greener practices and technologies. Taxes may fund green logistics initiatives, enabling business change. Enterprise resource planning technologies are critical to optimizing logistics operations and increasing green supply chain efficiency. The survey reveals that businesses that use ERP systems benefit from improved inventory management, less waste, and more outstanding decision-making capabilities. ERP adoption remains low among small and medium-sized logistics enterprises, owing to high prices and a lack of knowledge. The government should create funding schemes and tax advantages for businesses integrating ERP with sustainability tracking systems. Mandating digital supply chain reporting allows firms to maximize ERP's sustainability potential. Training programs should focus on improving logistics managers' technical knowledge of ERP-driven environmental efficiency. Developing industry-wide ERP sustainability criteria can assist organizations in implementing standardized green logistical practices. Collaboration among government officials, ERP software suppliers, and industry leaders can hasten adoption. Encouraging ERP integration with AI-based predictive analytics can help optimize fuel use, reduce transportation waste, and increase logistics sustainability. A comprehensive ERP adoption framework will modernize Vietnam's logistics sector, improving long-term efficiency.

(6) Energy efficiency in operations (EEO) → GLM (0.083). Increase operational energy efficiency by using the standardized estimate of 0.083. For this reason, the government should establish energy efficiency standards for logistical facilities such as warehouses, distribution centers, and transportation fleets. Companies should be incentivized to implement energy-saving solutions and have their energy use benchmarked by these criteria. Provide subsidies for logistics companies to install renewable energy sources like solar panels in warehouses and electric charging stations to accelerate the shift to renewable energy and reduce operational carbon footprints. Develop a green energy certification for logistics companies that fulfill high energy efficiency standards. This accreditation shows environmental commitment, giving accredited enterprises an edge in eco-conscious markets. Environmental efficiency is crucial for lowering emissions, increasing fuel economy, and eliminating energy waste in logistics. AI-driven route optimization, electric car uptake, and fleet electrification

are essential in meeting sustainability targets. The report emphasizes incorporating digital tools to improve logistical efficiency and lower carbon footprints. The government should give financial incentives for fleet electrification programs, encouraging enterprises to replace diesel trucks with electric or hybrid vehicles. Investing in renewable energy-powered warehouses and smart logistics hubs will improve operational efficiencies. Policies should force logistics corporations to document their emissions, ensuring openness in sustainability initiatives. Businesses should be encouraged to choose low-emission shipping options like rail and sea cargo over road freight. AI-powered logistics platforms should be created to monitor and improve environmental performance measures. Financial incentives should be provided to businesses that employ sustainability-driven predictive analytics. A strong focus on optimizing environmental efficiency will minimize logistics sector emissions and improve Vietnam's green reputation.

(7) Organizational culture (OC) → GLM (0.080). Adopt a more positive company ethos in accordance with the standardized estimate of 0.080. Green culture may be promoted through training and certification, which is why the government should institute programs to recognize businesses with eco-friendly company cultures. To make sustainability a core value, logistics companies should educate their employees on environmental consciousness and sustainable operations. Offer government-sponsored logistics management training on sustainable logistics techniques to promote environmental leadership. These programs can foster a future of green logistics leaders. Give financial incentives to organizations that integrate sustainability into their organizational culture and CSR goals to align CSR with green logistics management. This could involve funding employee green culture efforts or defining company-wide sustainability targets connected with green logistics management. A strong sustainability-oriented organizational culture enables businesses to incorporate green logistics principles into their daily operations. Companies should implement employee training programs on green logistics best practices, sustainability reporting, and environmentally conscious decision-making. The study reveals that companies prioritizing sustainability at the top level have higher environmental efficiency. Corporate sustainability strategies should be encouraged through green company certification and award programs. Governments should launch national sustainability education campaigns to increase industry awareness. Encourage workplace sustainability practices, such as carbon-neutral commuting, waste reduction programs, and digital documentation, to improve logistics sector efficiency. Industry associations could host green business networking events to encourage best practices. Large logistics companies should be required to conduct sustainability compliance checks. A cultural shift towards sustainability will speed up long-term industry transformation.

(8) Supply chain collaboration and integration (SCI) → GLM (0.079). Refine the integration and cooperation throughout the supply chain in light of the standardized estimate of 0.079. Consequently, in order to reduce environmental impacts, the government should back shared logistics platforms or hubs where businesses may work together on transportation, warehousing, and distribution. Platforms like this have the potential to consolidate logistics, share resources, and cut down on emissions and waste. Insist that logistics companies, factories, and suppliers work together to reduce their environmental impact. Companies forming such collaborations can improve supply chain sustainability with government incentives. Green supply chain guidelines for logistics companies should include emissions reduction, waste management, and resource efficiency. Supply chain contracts might include requirements such as ensuring all partners support green logistics. Supply chain integration helps logistics players synchronize their sustainability efforts. Blockchain-based data transparency solutions should be incentivized to boost supplier collaboration and sustainability tracking. The government should promote industry-wide digital integration platforms to boost logistical efficiency. Public-private partnerships can improve supply chain sustainability by coordinating green initiatives. Collaboration between logistics companies and environmental agencies should be encouraged to standardize green practices. Financial incentives should stimulate the use of data-sharing platforms to optimize supply chain operations. Firms should be obliged to publish their supply chain sustainability performance to increase responsibility. Integrating artificial intelligence-powered analytics into supply chain networks will aid in identifying inefficiencies. An innovative supply chain infrastructure will help Vietnam become a leading green logistics hub.

In conclusion, the study's implications are based on three implications: (1) Implications for logistics companies - The findings highlight that while technological solutions such as IoT, automation, and route optimization software are available, their adoption is hindered by cost, infrastructure, and skills shortages. Logistics firms should prioritize targeted digital investment, beginning with scalable technologies like warehouse management systems and vehicle telematics. Firms should also implement internal sustainability KPIs to track performance, such as carbon emissions per delivery unit or energy usage per shipment. Training programs to enhance employee awareness of green logistics can further embed sustainability into daily

operations. (2) Implications for policymakers - The study reveals a clear need for government support in the form of regulatory clarity, tax incentives, and infrastructure investment. Policymakers should develop national green logistics standards and provide subsidies or low-interest financing for enterprises that invest in certified green technologies. Improved public logistics infrastructure, such as smart freight hubs and EV charging stations, would enable firms to adopt cleaner technologies more easily. Public-private collaboration platforms should also be established to share best practices and pilot innovative solutions. (3) Implications for researchers - This study opens new avenues for research by demonstrating that green logistics adoption in Vietnam does not follow linear Western models but reflects a complex interaction between digital readiness, cultural factors, and economic constraints. Future research could apply comparative case studies across ASEAN countries or explore the longitudinal impacts of green investment. There is also scope to investigate the role of consumer behavior and digital marketplaces in influencing logistics sustainability strategies.

3. LIMITATIONS AND FURTHER RESEARCH

This study is subject to several limitations. First, the sample size and selection were limited to a few logistics enterprises in Vietnam, mainly concentrated in urban and coastal regions. This may limit the generalizability of the findings to the broader logistics industry, particularly in rural or inland areas. Second, using a case study approach, while valuable for depth, inherently limits the scope for statistical generalization. Third, data collection relies on self-insights, which may introduce response bias. Future research could address these limitations by using larger, more diverse samples, applying mixed-methods designs, and conducting longitudinal studies across multiple ASEAN countries. Most research participants may come from specific sectors or areas within Vietnam's logistics and transportation industries. Research may not be generalizable to other countries or contexts due to the research's focus on a specific location because of the wide variation in economic, regulatory, and technological aspects. Possible omission of other stakeholders' perspectives from the study includes government bodies and environmental advocacy groups. Although the study addresses eight critical elements of green logistics management, it may have omitted a few others. International trade agreements, financial incentives, and consumer demand for eco-friendly products are not factored into this study, but they may influence the implementation of green logistics. To further understand how green logistics practices have changed over time, future research can benefit from a longitudinal approach. Taking a step back and looking at the big picture allows us to observe how environmental policies and consumer tastes change over time, impacting technical developments, new legislation, and corporate culture. Possible future implications on green logistics management may come from various sources, including digital development, consumer desire for sustainable products, and restrictions on international trade. Incorporating such factors might shed more light on green logistics management's internal and external drivers. Finally, this study provides a solid empirical foundation for understanding green logistics in Vietnam, but more research is needed to extend the analysis to other countries and gain comparative insights. Use qualitative methodologies to gather industry perspectives. Long-term sustainability impacts can be measured using longitudinal data. Assess the efficacy of current green logistics policies. Analyze the financial returns of sustainability investments.

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Author Contributions

The authors made contributions to the development and planning of the study. The authors did everything equally; Lu Phi Nga wrote the conception, Phan Thanh Tam wrote method and design, and data analysis. Lu Phi Nga wrote critical revisions of intellectual content and the final approval version.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data is available from the authors upon request.

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Appendix

Table A1. Research questionnaires

Factors affecting green logistics management	5-point Likert scale				
	(1)	(2)	(3)	(4)	(5)
TAI1: Enterprise invests in green logistics technologies like electric trucks and renewable energy	(1)	(2)	(3)	(4)	(5)
TAI2: Enterprise optimizes routes and fuel consumption with technology	(1)	(2)	(3)	(4)	(5)
TAI3: Enterprise consistently implements innovative technology to reduce emissions and waste in the supply chain	(1)	(2)	(3)	(4)	(5)
TAI4: Data analytics improve logistical efficiency and reduce environmental effect	(1)	(2)	(3)	(4)	(5)
RSS1: Business prioritizes eco-friendly materials	(1)	(2)	(3)	(4)	(5)
RSS2: The company sources locally to reduce transportation emissions	(1)	(2)	(3)	(4)	(5)
RSS3: Enterprise ensures suppliers meet sustainable environmental requirements	(1)	(2)	(3)	(4)	(5)
RSS4: Enterprise has renewable logistics resources	(1)	(2)	(3)	(4)	(5)
WSP1: The company uses recyclable or biodegradable packaging in logistics	(1)	(2)	(3)	(4)	(5)
WSP2: The company reduces logistical waste	(1)	(2)	(3)	(4)	(5)
WSP3: Enterprise packaging and materials enhance use and minimize waste	(1)	(2)	(3)	(4)	(5)
WSP4: The company invests in corporate recycling to repurpose logistics resources	(1)	(2)	(3)	(4)	(5)
ERP1: The company meets logistics environmental laws	(1)	(2)	(3)	(4)	(5)
ERP2: Enterprise improves logistical methods to meet new environmental laws	(1)	(2)	(3)	(4)	(5)
ERP3: Enterprise environmental policies exceed laws	(1)	(2)	(3)	(4)	(5)
ERP4: The company prioritizes worldwide environmental standards	(1)	(2)	(3)	(4)	(5)
OC1: Corporate culture promotes sustainable logistics practices	(1)	(2)	(3)	(4)	(5)
OC2: Enterprise values prioritize environmental impact reduction	(1)	(2)	(3)	(4)	(5)
OC3: Employees are encouraged to participate in everyday environmental initiatives	(1)	(2)	(3)	(4)	(5)
OC4: Leadership continually expresses commitment to environmental preservation	(1)	(2)	(3)	(4)	(5)
CSR1: Enterprise protects the environment to benefit the community	(1)	(2)	(3)	(4)	(5)
CSR2: Businesses aim to reduce emissions and safeguard the environment	(1)	(2)	(3)	(4)	(5)
CSR3: Corporate social responsibility reports include environmental activities	(1)	(2)	(3)	(4)	(5)
CSR4: Enterprise social responsibility promotes green logistics	(1)	(2)	(3)	(4)	(5)
SCI1: Enterprises have collaborative agreements with partners to reduce environmental effects in the supply chain	(1)	(2)	(3)	(4)	(5)
SCI2: involves active collaboration with suppliers and partners to optimize sustainable logistics processes	(1)	(2)	(3)	(4)	(5)
SCI3: Supply chain partners receive environmental performance and sustainability data from enterprise	(1)	(2)	(3)	(4)	(5)
SCI4: Enterprise collaborates with partners to decrease emissions	(1)	(2)	(3)	(4)	(5)
SCI5: Sustainable supply chain solutions enhance performance and reduce environmental impact	(1)	(2)	(3)	(4)	(5)
EEO1: The company optimizes transportation routes to save fuel	(1)	(2)	(3)	(4)	(5)
EEO2: Enterprise employs energy-efficient vehicles and equipment	(1)	(2)	(3)	(4)	(5)
EEO3: The company actively reduces logistical energy use	(1)	(2)	(3)	(4)	(5)
GLM1: Implemented eco-friendly logistical methods	(1)	(2)	(3)	(4)	(5)
GLM2: Evaluate and optimize logistics operations for efficiency and environmental effects	(1)	(2)	(3)	(4)	(5)
GLM3: Enterprise personnel are encouraged to participate in environmental preservation projects	(1)	(2)	(3)	(4)	(5)

Note: A 5-point Likert scale states the level of agreement in five points. The 5-point Likert scale consists of the below points – (1) Strongly Disagree; (2) Disagree; (3) Neither Agree nor Disagree; (4) Agree; (5) Strongly Agree.