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The Evaluation of Inland Waterways as A Green Alternative to Road Transportation in Vietnam’s Southern Region

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ABSTRACT:

Sustainable logistics and transportation in the supply chain have grown constantly in recent years to reduce the detrimental impact of emissions on the environment, society, and the economy. In Vietnam's transportation market, road freight is the primary mode of transportation in domestic delivery, causing negative impacts such as emissions, accidents, and noise pollution. Leveraging the geographical advantages of over 19,000 kilometers of inland waterways network in Vietnam, this master's thesis aims to answer the question of the extent to which inland waterways can serve as a sustainable and environmentally friendly alternative to road transportation in Vietnam's Southern region, in terms of environmental impact, economic viability, and logistical efficiency. This study also identifies the current challenges of inland waterways transport in Vietnam's Southern region.

This thesis follows the key theory of green logistics and transportation management. Green logistics covers all the initiatives to reduce the environmental impact of storage and transportation activities, including efficient use of resources, emissions reduction, and cost optimization. The study concentrates on the transportation of goods through the road and inland waterways network. In road freight, logistics services providers mainly use trucks operating on highways to transport the shipment from the destination, while waterborne transport utilizes river and canal systems to carry a large volume of shipments on barges. The ultimate goal of a transportation network is to fulfill the customer demand, the requested delivery date, and shipment quality.

This research used the qualitative approach with semi-structured interviews with logistics and transportation professionals in logistics companies operating in Vietnam's southern region to collect practical data based on their perspectives and experiences. Additionally, online surveys were conducted with logistics operators with 5-point Likert scale questions to measure the perception of respondents of environmental, economic, and logistical aspects of the two modes. The results were then collected, checked, and compared with existing studies to ensure the reliability and validity of the research. The results show that inland waterways transport has strong potential as sustainable transportation by reducing the total emissions, costs, and energy consumption per transported unit. While there are some current infrastructure challenges, both government and business are making a great effort to develop an inland waterways network through funding and the development of electric barges. Finally, this study highlights the importance of collaboration among small logistics companies and effective communication with customers to raise the awareness of environmental benefits of this mode and form the effective multimodal network of road – inland waterways – road transport.

KEYWORDS: sustainability, green transportation, inland waterways transport, road freight network, southern Vietnam

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Abbreviations

3PL	Third-Party Logistics Providers
AI	Artificial Intelligence
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
ESG	Environmental, Social, and Governance
FDI	Foreign Direct Investment
FTAs	Free Trade Agreements
FTL	Full Truck Load
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GPS	Global Positioning System
LTL	Less Than Truck Load
NO_x	Nitrogen Oxide
PM10	Particulate Matter (diameter ≤10 µm)
PM2.5	Particulate Matter (diameter ≤2.5 µm)
SMEs	Small to Medium Logistics Enterprises
SO_2	Sulfur Dioxide
ULDs	Unit Loading Devices
VRP	Vehicle Routing Problem

1 Introduction

1.1 Background of the study

Following a continuously emerging trend in the global economy, sustainable logistics is growing as a considerable concern in achieving sustainable supply chain management. In general, sustainability addresses three main dimensions: environmental, economic, and societal that apply to various areas, including transport and logistics (Lee et al., 2019). During the whole process from storage to final distribution, the key role of green logistics is to balance the environmental impact with operational performance (Liu et al., 2023; Tetteh et al., 2024). Another specific perspective defines 'green logistics' as all activities of observation, measurement, and minimization of the ecological effects of logistics (Demir et al., 2019). Following this attention, in the past decade, many strategies and practices in the academic and industry sectors have been implemented regarding the sustainability of global logistics. These initiatives include route optimization in transportation, technology investment, research and development of alternative energy, or adopting sustainable packaging materials. All of these projects not only lead to the growth of business and competitive advantage but also become significant milestones to the target of net zero emissions by the United Nations in 2050 (Tetteh et al., 2024). However, logistics operations still account for a large number of emissions, especially greenhouse gases (GHGs), resulting in adverse effects on the environment (Tetteh et al., 2024). According to the growth forecast until 2050, logistics industry and freight transportation have the expected growth of 60% and 160%, respectively, resulting in the second-largest source of global emissions (Calderón-Rivera et al., 2022).

Concerning the Vietnamese market, the transportation sector has witnessed significant growth since 2010. From 2010 to 2019, freight traffic has grown constantly with the average rate of about 3.3%. Considering transportation modes, air freight had significant growth of about 8.9%, followed by road freight with 8.7% (GiZ, 2024). In practical operations, truck is the most flexible and efficient mode for domestic transportation, especially for short-haul distances in last-mile deliveries (Calderón-Rivera et al., 2022). However, this over-reliance on road freight becomes Vietnam's significant challenge in the context that the global logistics sector is advancing sustainable solutions. Specifically, one important drawback of truck transportation is the amount of pollution, accidents, and resource depletion (Nguyen Thi Bich & Le Dinh, 2024). Additionally, these adverse effects of road freight are also associated with numerous social impacts, including noise issues, social health, or visual intrusion due to vehicle exhaust (Calderón-Rivera et al., 2024b). In transportation activities in Vietnam such as passenger transport, motorbikes, inland waterways transport, road freight release most emissions with around 84.4% of carbon dioxide (Asian Transport Outlook, 2023). Therefore, along with global goals towards a greener future of transportation, in the Environmental Pollution Reduction Program for the 2020 – 2030 period, Prime Minister Pham Minh Chinh approved the Action Program in Decision No. 876, dated July 2022, to reduce by 90% carbon and methane emissions released to the air (Nguyen Thi Bich & Le Dinh, 2024). This program emphasis the strong commitment from Vietnam's government towards sustainable development, in which the needs of business and individuals are ensured while reducing the adverse impact of emissions and wastes. Consequently, the transportation solutions require an innovative approach from business perspective to balance between operation continuity and environmental protection (Calderón-Rivera et al., 2024b).

As a result, to minimize the negative impact of roadway transportation, inland waterways transport has grown as a vital alternative solution to minimize the environmental impact. Inland waterways are specialized for cargoes with high volumes through rivers and canals systems (Dang et al., 2022). To support this system, Vietnam has the natural advantages of a long coastline of about 3,200 km and a high density of rivers and canals, which create approximately 19,000 km of inland waterways. This advantage is a critical factor in developing integrated inland waterway transportation systems with road freight, dry ports, and deep-sea terminals (Cang et al., 2021). In recent years, the development of inland waterways has attracted attention from academic researchers, industry leaders, and government policymakers. The system has consistently demonstrated its beneficial advantages to economics, fuel efficiency, and cost-effectiveness as a mode of transportation. Particularly, waterborne transport was presented with a reduction in environmental impact, freight costs, and energy consumption. In addition, by reducing the frequency of road freight in large cities such as Ho Chi Minh, Binh Duong, or Hanoi, the traffic congestions and accidents are reduced accordingly (Bu & Nachtmann, 2023; T. M. H. Nguyen et al., 2024). Bu & Nachtmann (2023) also pointed out, as an experiment in his study, that, on average, one gallon of fuel is equal to the transportation of 576 miles by barge, 413 miles by rail, and just 155 miles by truck. In relation to the container industry, this domain is on the rise, and private logistics firms have the potential to gain more advantages by utilizing inland waterway transport to facilitate the movement of higher-value industrial and consumer goods (T. V. Nguyen & Nguyen, 2020). For Vietnam's Southern region, the Vietnam Chamber of Commerce and Industry report in 2023 about the potential of the Mekong Delta also stated that the inland waterways infrastructure at the Mekong Delta only satisfies about 20-25% of the total demand transported by sea. As a result, approximately 70% of export goods to Cat Lai Port in Ho Chi Minh City or Cai Mep Port in Ba Ria – Vung Tau are still transported by trucks. This reliance on road freight causes private enterprises to increase transportation costs by about 10-40%.

In conclusion, with the current national direction to transform conventional logistics into green logistics, especially in freight transportation to reduce the environmental impacts of road freight, it is necessary to re-evaluate and enhance the utilization of inland waterway transport, especially among private enterprises. This is vital for a developing country like Vietnam, where strategic sustainable solutions are under global attention.

1.2 Research gaps, questions, and objectives

The world of academic research witnessed many different perspectives on the development of inland waterways transport. To access these contributions, a systematic search was conducted on five main keywords: "inland waterways transport", "green transportation", "sustainability", "road freight network", and "Vietnam", individually and in combination. The central databases supported for this study include EBSCO, Emerald Journals, Springer Nature Link, and Google Scholar, with the time horizon from 2019 to 2025.

Table 1 summarizes the results of supported studies for this thesis. To ensure high relevance and alignment with the research scope, only studies focusing on green transportation development and the role of inland waterway transport globally and within Vietnam were selected, which are about the green transportation development and the importance of inland waterways globally and in the Vietnam region. Next, because this thesis aims to evaluate the environmental performance of inland waterways and roads, only studies that contain comparison theories and methodologies concentrate on these two modes that are selected. Additionally, this study also leverages the Tritonia library system and filters for the University of Vaasa only to search for core reading books as a knowledge base.

Table 1. Summary of keyword search for literature review

Keywords	**Timeline**	**Database Used**	**Number of records**	**Focusing criteria**
“inland waterways transportation”	2019–2025	EBSCO, Emerald, Springer	69, 101, 215	Inland Waterways studies overall.
"green logistics" AND "road"	2019–2025	EBSCO, Emerald, Springer	0, 186, 135	Studies for the green logistics field, particularly road freight.
"sustainability" AND "green transportation"	2019–2025	Emerald, Springer	44, 8	Studies related to the relationship between sustainability and green transportation.
“Inland waterway transport in Vietnam”	2019–2025	Google Scholar	16,200	Specialized inland waterways studies in Vietnam region.
“Sustainable logistics and supply chain management”	All time	Tritonia library	26	Books or e-books that cover the general logistics and supply chain management practices.

Among the studies identified for this research, Wang et al. (2020) proposed an assessment framework to evaluate the sustainability of 66 large inland waterways systems around the world to identify the "Golden Inland Waterway" based on socio-economic, environmental, and navigational indices (Y. Wang et al., 2020). In the context of container shipping in Europe and Asia, particularly China, Bu & Nachtmann (2023) analyzed the landscape of sustainability performance by moving containers by barge. Meanwhile, optimization methodology was also applied to inland waterway transport by Binsfeld et al. (2024) to develop the optimization model to minimize transportation costs and greenhouse gas emissions for multimodal freight networks of inland waterways transport and trucks.

In Vietnam, while the public awareness for inland waterways transport are being spread out rapidly, the current research has focused mainly on port location optimization, (T. M. H. Nguyen et al., 2024; C.-N. Wang & Thanh-Tam, 2024), supplier selection for barge service on inland waterways (Le & Tran, 2025), or regulation solutions to boost the usage of inland waterways transport (T. V. Nguyen & Nguyen, 2020). Although previous research has mentioned about the benefits of modal shift from road to waterways transport, more conditions such as strategic decision making, operational performance, customer satisfactions, and economic incentives are required from business perspective (Calderón-Rivera et al., 2024a). Liu et al. (2023) further suggested that some enterprises may not evaluate the performance of green logistics and lack confidence to pursue alternative solutions.

Overall, much of the existing literature tends to focus on the national planning level and northern regions, with little attention given to business-oriented perspectives or logistical challenges faced by enterprises in the south. To bridge this gap, this research aim to leverage the current knowledge base and study to examine the critical businesses criteria influencing strategic adoption of inland waterway transport in Vietnam's southern region, with a particular focus on the comparison of road and inland waterways among different criteria to promote the integration of inland waterways transport to transport planning phase through one case reference example route from Can Tho to Ho Chi Minh City.

Accordingly, to address the identified research gap, this study focusses on the unique research question:

Research Question*: To what extent can inland waterways serve as a sustainable and environmentally friendly alternative to road transportation in Vietnam's Southern region, in terms of environmental impact, economic viability, and logistical efficiency?*

In pursuit of answering this question, three specific objectives are developed:

1) To assess the environmental performance of inland waterway transport compared to road transport in terms of greenhouse gas emissions, energy consumption, and pollutant output.

The first objective is to evaluate the comparative performance of inland waterways and trucks in terms of environmental key indicators. This assessment is crucial given that sustainability is one of the core drivers of the global economy's shift towards a greener supply chain solution, in which inland waterways offer the potential to reduce the amount of transportation emissions significantly.

2) To evaluate the economic feasibility and cost-effectiveness of shifting freight transport from roads to inland waterways in the Southern region of Vietnam.

For domestic transportation, most companies still leverage the substantial advantages of trucks, which include flexibility, fast delivery, and versatility in volume dimensions. Suitable vehicles can be chosen from small vans to container transportation based on the type of goods. However, inland waterways transport is more effective in consolidating large shipments for large barge or vessel transportation. Therefore, apart from environmental performance, the selection between a truck or inland waterways transport also varies depending on the associated economic and cost performance of each mode.

This objective aims to develop a comparative framework to understand what is different between the two modes and what could be the potential trade-offs when deciding to implement inland waterways transport.

3) To analyze the logistical and infrastructural challenges and opportunities associated with expanding the use of inland waterways as a primary mode of freight transport in the region.

The share of inland waterways transport remains low compared to road transport, in which only multinational corporations such as Gemadept or CMA CGM account for most of the utilization. By exploring insights from industry professionals, this objective provides insight into practical opportunities and strategic barriers of logistics firms to enable inland waterways transport as the primary means of transportation. Understanding these barriers helps explain why inland waterways transport is underutilized despite its feasibility and advantage in reducing transportation costs and negative environmental impacts.

1.3 Definitions and scope of the study

This thesis covers key concepts of sustainability, green logistics, transportation management, road freight, and inland waterways transport.

In generic terms, sustainable development refers to all the development that satisfies the present needs while maintaining the efficient resources and opportunities for future generations (Okyere et al., 2022). In particular, sustainability covers three main dimensions: environmental, social, and economic (Lee et al., 2019). Applying to logistics and supply chain management, sustainability addresses all the environmental challenges affecting the whole chain, from sourcing the raw materials, manufacturing the raw materials into finished products, storing them in warehouses, and distributing to end-customers. To ensure the concise scope in the research this thesis focuses specifically on logistics and transportation management activities. Other supply chain functions, such as manufacturing, warehousing, and purchasing, are excluded from the thesis.

Logistics management is about all activities to ensure the continuous flow of products from suppliers to end customers. These activities include warehouse management, logistics services management, or transportation management. The process starts from the sourcing of raw materials until final delivery to end customers (Wu et al., 2023). Green logistics involves a comprehensive approach to apply environmental implications and technologies associated with each activity, covering both inbound and outbound flow, delivery, and return of physical products (Rahman et al., 2024; Wu et al., 2023). Besides its environmental significance, green logistics also plays a key role in business branding to gain more attention from shareholders and investors. Through efficient use of resources and strategic transportation planning, companies can reduce the transportation costs and negative impact on the environment such as emissions or energy consumption. As a result, the financial performance and long-term sustainability of the companies are improved accordingly (Liu et al., 2023). Given the broad scope of logistics activities, this study particularly narrows its focus to inbound freight transportation and forward logistics operations only. Reverse logistics activities are excluded from the scope of this research.

Freight transportation is the sub-activity of logistics operations. It is the movement of goods from the origin to the final point, from the shipper to the end users, through various modes, including road, air, ocean, rail, or inland waterways. After being released by the shipper, the shipments are handled by third-party logistics providers (3PL) and transport carriers via suitable modes until final delivery. Cargoes can be handled via single mode or intermodal transport, in which goods are transported through the standardized unit loadings (ULDs) between different modes of transport (Demir et al., 2019). Hence, transportation planning and mode selections may vary depending on the characteristics of goods, service level, customer requirements, or as agreed upon in negotiations between shippers and buyers. According to Demir et al. (2019), transportation is the most essential concern for making logistics activity greener due to its significant contribution to global emissions. Consequently, with the current attention of global supply chain to sustainability, freight transportation is considered as the core of green solutions. To maintain a concise research focus, the study considers only road and inland waterway freight transport and excludes analysis of the other modes.

Road freight transportation is one of the transportation modes to deliver shipments through road vehicles such as trucks, semi-trailers, or containers. It is commonly classified into two consolidation methods: Full Truck Load (FTL) and Less Than Truck Load (LTL). This mode is extensively utilized due to its flexibility and accessibility to transport the cargo between regions and last-mile delivery, especially in economic areas that have a high density of connected road networks (Paulauskas et al., 2022). However, road freight is associated with limitations such as capacity, fuel consumption, and traffic congestion (Paulauskas et al., 2022). Despite its detrimental impact on the environment, road freight remains the crucial mode for domestic transport in Vietnam. Therefore, this study aims to explore this extensive reliance on road freight in Vietnam's southern area as the core research region.

Another focus of this thesis is the inland waterways transport. Inland waterways use barges or container vessels to transport products on rivers and canals (Arnab Chowdhury et al., 2024). In many countries, including Vietnam, inland waterways transport highlights the strong ability to connect dry ports and seaports with inland industrial regions and can be utilized to deliver the large number of cargoes in terms of weight and sizes (Paulauskas et al., 2022). There are different types of cargoes that can load barges for inland waterways transport, such as containers, wood, coal, agricultural materials, or liquids. For the Vietnam waterways system, there are three main types of vehicles used for transportation: ferries, barges, and vessels. Route and mode selection also depend on the characteristics of goods, channel depth, or weather conditions. This study will cover the central inland waterways system of Vietnam's southern regions, particularly the Mekong River system, the Dong Nai River system, and some other main canals such as the Cho Gao canal and the Thap Muoi canal. Specialized cargoes such as refrigerated, hazardous, or liquid shipments are excluded from this study due to their specialized handling and equipment.

Given all the background information mentioned, research gaps, research objectives, and key definitions, one limitation of this study is the methodology. For an in-depth study, the perspectives of six to eight leading industry experts from logistics service companies are collected through qualitative interviews and secondary data from industry reports. The study does not include detailed cost modeling, optimization, or analysis of governmental policies. Instead, it aims to evaluate the current inland waterways practices and operational strategies for sustainable freight transportation.

1.4 Structure of the study

This thesis is organized into six chapters, beginning with the introduction section, which provides an overview of the research and emphasizes the significance of inland waterways in green transportation in Vietnam, especially in the southern region. This section outlines the research questions, objectives, definitions, study's scope and limitations.

The second chapter presents a comprehensive literature review, examining all the related works in the global and Vietnamese contexts. The literature review explores fundamental concepts, theories, and methodologies related to green logistics and inland waterways systems.

Chapter three details the research methodology, including the overall research design, sampling approach, data collection techniques, and methods of qualitative analysis. It justifies the choice of qualitative analysis and explains how primary and secondary data sources are systematically integrated.

Chapter four presents the research findings and analysis. This chapter discusses the key insights from expert interviews and secondary data to identify the main barriers preventing inland waterways adoption in Vietnam alongside potential opportunities for their strategic development. This chapter also interprets the findings in relation to the green logistics goals in Vietnam.

The fifth chapter details the key performance differences between road and inland waterways transport along one example route from Can Tho to Ho Chi Minh City. This comparative analysis contributes to the higher-level decision-making process by considering sustainability factors in mode selection. The most significant strategies obtained from experts are also discussed to highlight the need for green transportation.

The sixth chapter serves as the conclusion, summarizing the core findings of this study suggesting directions for future research and deeper investigation in inland waterways transport as well as green transportation initiatives.

2 Literature review

The section is conducted to review the previous and current contributions on green logistics, sustainable transportation, road freight, and inland waterways system in Vietnam’s Southern region. Additionally, this chapter also investigates how the modal shift between road and inland waterways has been developed from past to present. And finally, the summary of theoretical frameworks is presented to illustrate how the key concepts and keywords in this study are connected to each other.

2.1 Green logistics in Vietnam’s Southern Region

2.1.1 Concept and development of green logistics

Traditionally, logistics management is a part of supply chain management, which includes all initiatives to minimize costs and maximize revenue across all distribution and storage activities from the original point to the final consumption point (Yingfei et al., 2022; Verma, 2024). Logistics is essential to boost international trade by directly affecting economic performance, cost efficiency, and customer satisfaction (Yingfei et al., 2022). This is particularly significant for Vietnam, where international trade is currently the main strategy from government through many participations in Free Trade Agreements (FTAs) signed in the past 10 years. However, conventional logistics has been considered as a primary source of greenhouse gas emissions that negatively impact on the environment (Zhang & Deng, 2024). As a result, logistics companies face many pressures from the governmental policies and customer demands to transform their traditional activities towards green logistics to mitigate the carbon footprint and energy consumption in their operation. (Kotlars & Skribans, 2025).

Green logistics is defined as the solution to balance economic, social, and environmental impact (M. N. Tran, 2024). It has been recognized as a concept in logistics and supply chain management and has received much attention in the academic field. Due to its complex nature, encompassing both environmental impact and operational efficiency, scholars have described multiple perspectives on green logistics. Kotlars & Skribans (2025) describe green logistics as the company's competitive advantages in the market by offering sustainable solutions for appropriate customers, who are paying attention to environmental risks. In another research, Verma (2024) addressed the costs effectiveness of green logistics to society and environment. From this perspective, green logistics is considered as the expansion of conventional to sustainable activities, which take more considerations into environmental concerns and social well-being. From another perspective by Roy & Mohanty (2024), 3PLs should create the strong foundation of green logistics in their operation first, then develop the whole sustainable procedure in their supply chain operation. In the long-term development, green logistics not only creates economic benefits but also make positive impact on the environment and society, thereby achieving reliable, efficient, and sustainable development (Zhang & Deng, 2024).

Green logistics is a relatively new development in Vietnam's logistics sector because Vietnam's logistics is still in the traditional and development phase, in which most local logistics companies are still unaware of green logistics practices. However, green logistics have been mentioned in the national strategic plan towards sustainable development. According to the Vietnamese government's 2022 Logistics Market report on green logistics, Vietnam has committed to the Paris Agreement to achieve net-zero emissions by 2050. Several authors have observed a growing trend in Vietnam’s green logistics, and several studies have been conducted in this field. M. N. Tran (2024) developed a Green Logistics Performance Index to measure the impact of green logistics on trade performance. In this framework, sustainable indicators such as CO_2 and CH_4 were used for the analysis of impact across different free trade agreements. The result presented a positive correlation between green logistics and Vietnam’s economic performance and highlighted the potential for green logistics to contribute not only to environmental protection but also to national economic growth and operational business efficiency. In another study of logistics center development in Vietnam's southern region, Chu et al. (2024) used a qualitative study to examine the impact of infrastructure, location, regulations, and business competitive on logistics centers. This study serves as a reference for recommendations on infrastructure development and business strategies to enhance logistics capacity in Vietnam’s southern region by developing dedicated e-commerce warehouses or connecting the Cai Mep–Thi Vai seaport to the inland waterways system.

2.1.2 Green logistics practices in Vietnam’s Southern Region

Green logistics management is described as the green practices in physical flows of products, such as product handling, storing, and transportation, to mitigate the carbon footprint and environmental impact and meet customers' requirements (Apeksha Garg & Sudha Vemaraju, 2025; Shoaib et al., 2023). In other words, green logistics practices on financial performance and consider other environmental issues at the same time (Shoaib et al., 2023). Previous research in the Vietnam region showed that these practices commonly include packaging, fuel management, route optimization, emissions management, and reverse logistics (Phan et al., 2024). According to the Ministry of Industry and Trade (2022), enterprises have initiated various green projects to align with the national direction towards greening logistics activities. Khoa & Nhung (2020) took DHL Group as a case study to adopt green logistics in Vietnam through route optimization and GPS tracking to minimize transport distance in domestic delivery in Vietnam. Nguyen Thi Bich and Le Dinh (2024) used finance, infrastructure, and regulation as the key criteria for a multi-criteria decision-making approach to propose policy solutions to develop green transportation in Ho Chi Minh City. In addition, the study highlighted the lack of infrastructure investment and the inconsistency in the national policy framework as two main challenges to green logistics in the Ho Chi Minh City area.

It is undeniable that developing green logistics in Vietnam, especially in the southern regions, remains a significant challenge, as most Vietnamese logistics companies are small and medium sized enterprises. These companies continue to follow conventional practices due to a lack of expertise and resources to overcome current barriers (Van Vo

& Nguyen, 2023). Infrastructural, financial, and regulatory factors were considered in many previous studies to investigate their impact on green logistics practices in Vietnam. Do et al. (2024) examined the impact of infrastructure, legal policies, financial performance, and information technology on green logistics practices using a comparative framework in Hanoi and Ho Chi Minh City. The study concluded that businesses in Ho Chi Minh City paid more attention to infrastructure than those in Hanoi, and it also suggested a legal framework supporting green transformation. Phan et al. (2024) examined regulatory pressure, green logistics systems, progress in green logistics development, and customer demand for green practices in Vietnam. The findings concluded that green logistics systems have the most significant influence on green logistics practices, highlighting the need to develop green logistics centers, route-optimization systems, and fuel-monitoring systems to improve overall green logistics efficiency.

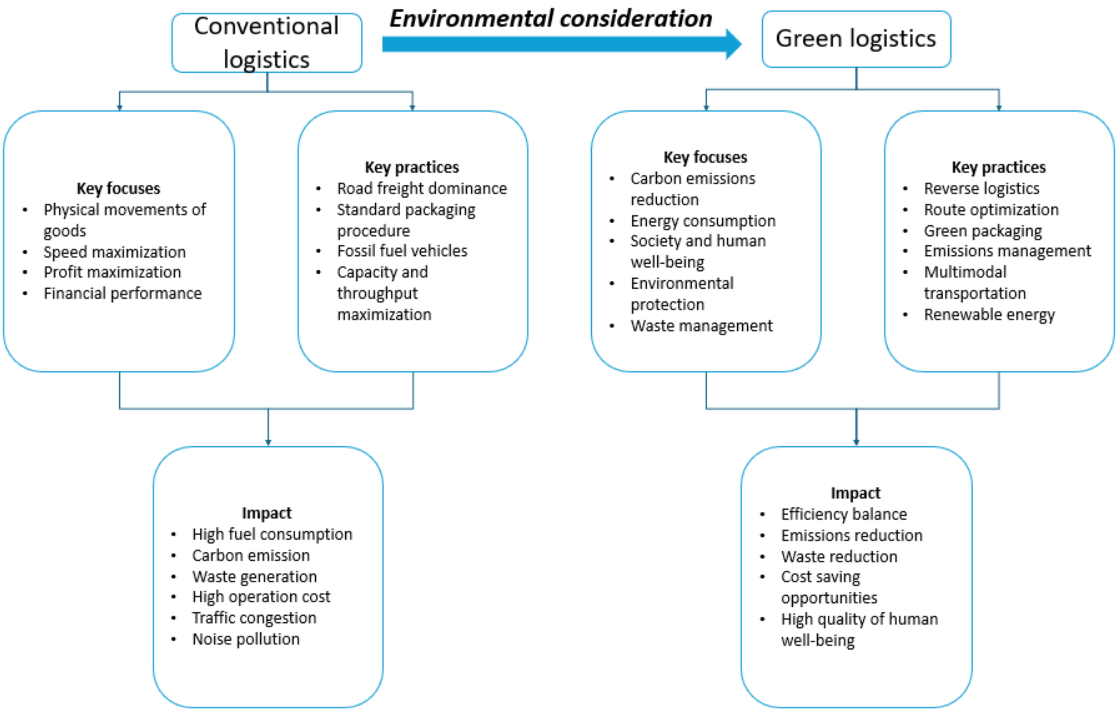


Figure 1. Conceptual diagram to compare conventional and green logistics practices

Figure 1 illustrates a conceptual diagram comparing the key focuses, practices, and associated impacts of conventional and green logistics in Vietnam. This diagram emphasizes that the main difference between conventional and green logistics is environmental considerations. In traditional logistics, the primary strategy focuses on efficiency and profit maximization, as competitiveness is measured mainly by cost and delivery time. While these practices result in fast delivery and large-scale goods distribution, they are environmentally costly. For instance, the dominance of roads significantly generates a large amount of carbon emissions, and the conventional packaging materials generate more waste due to one-time usage. This chapter highlights the need for green transformation to focus on the broader consequences of traditional logistics practices, such as environmental degradation, fuel dependency, and social externalities. Therefore, logistics firms should be able to consider society and environment into their core strategic planning to create a long-term impact and business's reputation. Through the integration of digital transformation, more innovative initiatives are introduced to customers, including route optimization, green packaging, or emissions management. Indeed, the goal of green logistics is to protect the environment. These practices are developed and standardized for sustainability to balance the companies’ economic performance and sustainability imperatives.

In conclusion, the comparison shows that while conventional logistics focuses on short-term benefits, green logistics concentrates on the long-term orientation towards sustainability, resilience, and inclusive business growth. In Vietnam current practice, many small and medium logistics enterprises are still in the development phase, which combines conventional efficiency practices with incremental adoption of green logistics. Although there were numerous previous studies have examined green logistics practices, research in specific regions of Vietnam remains limited. Addressing this gap, this study focuses on a single southern region in Vietnam, thereby helping to bridge the region's deficiency in this area.

2.2 Sustainable transportation in Vietnam's Southern Region

2.2.1 Environmental impacts in freight transportation

Global warming is one of the critical causes of severe effects on humans and environment, in which greenhouse gas emissions is a primary contributor to climate change and global warming (Zhu et al., 2023). Pham Van et al. (2023) also concluded with the similar findings that atmospheric emissions are the main reason for climate change, in which the allocation of carbon dioxide, methane, nitrous oxide, hydrofluorocarbon, and other compounds are 79.4%, 11.5%, 6.2%, 2.8%, and 0.1%, respectively. Zhu et al. (2023) claimed that carbon dioxide emissions from transportation activities directly lead to an increase in global greenhouse gas emissions, which accounts for roughly 25% of annual emissions in the world. Therefore, the adverse effects of carbon emissions on freight transportation have been discussed by a significant number of authors in previous works to investigate the leading causes and effects to develop suitable mitigation approaches based on each specific region and resource.

Vietnam is considered highly vulnerable to climate change due to negative effects from transportation activities (Hoang Phuong Nguyen & Van Tai Pham, 2020; Tuan et al., 2023). Specifically, emissions released into the air mainly come from gasoline and oil used in vehicles through the combustion process in their engines. During the combustion process, carbon dioxide, sulfur dioxide, or nitrogen dioxide are released and cause environmental pollution. Another impact of vehicles is noise pollution, especially in high-density residential areas such as Ho Chi Minh City in Vietnam's southern region. Noise pollution not only causes annoyance and frustration but also affects daily activities, work productivity, and sleep issues. Regarding the total emissions in Vietnam, one research by Nga (2025) shows that the national emissions have increased from 324,901 megatons in 2022 to 372,949 in 2023, equivalent to an increase of 14.79%. Because industrialization and international trade have grown significantly in recent years, the energy consumption in the whole country increases accordingly. Therefore, Nga (2025) investigated the energy consumption level from transportation activities and concluded that two main sources of vehicles are oil and gasoline, while the adoption of electrification in Vietnam remains limited. This is due to the investment challenges in the electric vehicle field, where only electric cars serving passenger transportation by Vinfast Corporation are produced in large quantities. Meanwhile, the primary vehicle still relies on engine vehicles. Different perspectives for the impact of carbon dioxide on country’s economy growth were conducted by Parker (2022) to understand the decoupling relationship between carbon emissions from transportation with the growth of economy. The analysis identified the weak decoupling relationship between carbon emissions and economic growth. Specifically, carbon emissions increased more slowly than the overall GDP. However, the increase in carbon emissions remains considerable, with the main contributors being the shift in economic structure, growth in income levels, and high demand for transportation. In freight transportation services, road freight is the primary source of carbon emissions, followed by air freight and ocean freight, which have a minor contribution to the change in carbon emissions. Inland waterways and rail are still limited, which leads to a limitation in the potential opportunity to enable a modal shift for these two modes.

2.2.2 Sustainable implementations in freight transportation

The continuous increase of emissions leads to the important need to implement sustainable solutions for freight transportation to mitigate the negative impacts on the environment. One sustainable transportation system should be able to balance the operational cost, performance, service level, and environmental measurements (Pathak et al., 2019; Roy & Mohanty, 2024). Roy & Mohanty (2024) highlighted that externalities, society, and environment should be considered sustainable solutions. The same theme was conducted by V. T. K. Hanh & Nga (2024) to investigate all factors that influence sustainable dimensions in Ho Chi Minh city. The examined factors include historical context, political dynamics, information technology applications, facility capacity, e-commerce development, and environmental mitigation strategies. The results indicated that environmental strategy is the strongest influencing factor on sustainability, including congestion reduction, fuel optimization, and emissions control. To achieve the objectives of sustainable transportation, close collaboration between stakeholders is crucial, especially from government policymakers and logistics enterprises (Zhu et al., 2023).

From the governmental strategy, the Vietnam Prime Minister committed to implement more solutions to reduce the greenhouse gas emissions by 9% and 27% from domestic and international resources, respectively (Pham Van et al., 2023). According to the decision 876/QD-TTg and 896/QD-TTg in 2022, the government set the target to develop a green transport system to reduce greenhouse gas emissions to zero by 2050. These decisions were made to provide stronger motivation for businesses to apply green practices to reduce fossil fuel usage in various sectors, including transportation.

From the logistics services providers' perspective, these firms face pressure from both customers and the government to shift from traditional to green transportation activities. With the high-density characteristics of the route in Vietnam, it is difficult to determine the optimal route to transport cargo from the origin to the destination. Therefore, Dini et al. (2024) developed the dual-phase decision making model for route selection for multimodal transportation in Vietnam. This integrated model included economic, environmental, transit time, and reliability factors to help logistics firms reduce costs, penalties, and emissions by choosing the optimal route. The result indicated that multimodal route such as road – ship–rail provides better performance in terms of economic and environmental factors than unimodal ones. Other solutions from businesses to obtain carbon-neutral delivery might include route optimization modeling or electric vehicle adoption. However, these implementations are still at an early stage (Phuong, 2025). The research also recommends businesses invest in AI, data analytics for route optimization, eco-friendly delivery solutions, and green programs to increase awareness from consumers. In route optimization, the most common problem that catches attention in academic researchers and industry leaders is the Vehicle Routing Problem (VRP). Pham et al. (2024) developed the optimization algorithm to address VRP problems with capacity constraints to optimize distance, cost, and delivery efficiency. This study also applied the method into practical logistics operations in Vietnam and suggested business to integrate AI algorithms into their transportation planning applications for last-mile and bulk delivery.

With the integration of environmental factors into strategic transportation planning, the aim of transportation remains unchanged to meet the demand from customers and internal financial capabilities (Karuppiah et al., 2022). This poses an important barrier to solving when executing any green initiatives, especially with small and medium-sized companies. These enterprises face significant challenges in upfront investment and sufficient company resources (Karuppiah et al., 2022). This barrier was also addressed through the study conducted by Pham Van et al. (2023) to compare the adoption level of green implementations between domestic and foreign-invested companies in Vietnam. The results highlighted that international enterprises are more likely to adopt green solutions to reduce environmental impacts compared to domestic enterprises. Therefore, international companies with foreign investment, such as Maersk (Denmark), DB Schenker (Germany), or DHL Group (Germany), had more opportunities for research and development of green programs in Vietnam. The second reason was that carbon emissions mitigation was not a top priority for domestic companies. Among these solutions, the most common activities are to optimize the transportation loading factor and minimize empty truckloads rather than shifting from one road to another mode of transportation, such as rail or inland waterways (Pham Van et al., 2023). This can be explained by the reliability and flexibility level that road freight brings to operational excellence at the business level. Especially for small businesses, the key concern of these enterprises is to ensure fast delivery to fulfil customers' needs first, instead of reducing carbon emissions (Karuppiah et al., 2022). From a customer behavior perspective, Phuong (2025) noted that although the general awareness of environmental protection has increased in recent years, local customers still tend to prioritize low cost, convenience, and fast delivery.

Table 2. The adoption status sustainable freight implementations in Southern Vietnam

Measurements	Description	Adoption status
Greenhouse gas emissions reduction	Initiatives and efforts from the government and enterprises to	In progress

	reduce the net carbon emissions to zero in 2050	
Inland waterways development	The development projects funded by World Bank and Vietnam's government to develop the inland waterways' infrastructure, including canal's depth, bridge clearance, and port.	Growing up
Multimodal solutions	Solutions provided by logistics companies to use more than one mode of transportation to save costs and reduce carbon emissions.	Maturing at some multinational companies (MNC)
Electric vehicles adoption	The implementations of electric vehicles in transportation to replace fossil fuel and cut direct emissions into the atmosphere.	Early stage
Logistics system digitalization	The use of digital software, machine learning, and artificial intelligence for route optimization, load consolidation, and cost savings.	Maturing at some multinational companies (MNC)

Table 2 summarizes the five major implementations for green freight logistics from the literature review and their adoption status in Southern Vietnam. Greenhouse gas emissions are strategic long-term efforts through all industries to reduce the net emissions to zero by 2050 (Pham Van et al., 2023). According to the Vietnam Transport Climate Profile by Asian Transport Outlook, the process is ongoing with various directions set by the government and initiatives from the operational level at logistics and manufacturing enterprises. Specifically, utilization of road freight decreased from 96% in 2015 to around 84% in 2023. In addition, the carbon emission intensity relative to Gross Domestic Product (GDP) decreased from 52.4 gCO_2 per USD in 2000 to 26.2 gCO_2 in 2023. Consequently, these figures strongly demonstrate the positiveness in the national development program from the government towards the 2050 vision across all transport sectors. Particularly, attention for inland waterways development is growing. The infrastructure and handling capabilities of logistics firms in Vietnam are still limited due to the underdeveloped canal navigation, bridge clearance, and vessel capacity. Therefore, Vietnam has worked on the funding project from the World Bank to develop waterways corridors in the south since 2017, and the project got approval on 21 June 2025. The project aims to increase the barge capacity, navigation on waterways, and cargo safety of inland waterways (World Bank, 2025). With the target close date on 15 December 2029, this project aims to increase the fleet tonnage up to 600 tons and vessel capacity up to 1500 tons, which equates to 128 trucks, thereby boosting the sustainable shift of cargoes to inland waterways. This modal shift is crucial for Vietnam's economy to decarbonize the transportation sector, boost the competitiveness of waterborne transport, and increase the country's trade capability. From the government commitments to achieve net-zero emissions by 2050, Vietnam specifically divided the roadmap into two periods: 2022 – 2030 and 2030 – 2050. At the first stage of the action plan, the initial investment and research plan was conducted to promote electric vehicles for inland waterways. By 2025, Vietnam has set the target to adopt 100% electric vehicles and completely upgrade its infrastructure to meet green criteria.

The multimodal solution was already adopted by many medium to large logistics companies in their operations to leverage the advantage of inland waterways transport. However, this is still the challenge for small logistics providers when road is still the most reliable mode to increase their competitiveness in the market. The option of electric vehicles in freight transport is still at the early stages, when most of the electric vehicles operating currently are used for passenger transport, heavy trucks are not yet common on Vietnam's highways, and still rely on diesel power (Phuong, 2025). This is due to the high investment cost of heavy electric trucks and periodic maintenance. Regarding the digital logistics systems, major third-party logistics providers have already implemented different technologies such as route planning, blockchain, and large language models to optimize the supply chain lead time, speed, and capacity. Particularly in multinational logistics providers such as DHL, Maersk, or DB Schenker, the management system and technology are widely used to streamline the workflow and maximize productivity. Digitalization also allows logistics businesses to monitor and control the carbon generation from their logistics activities. The decisions are then made by a data-driven approach to analyze and optimize operations to minimize the carbon footprint and maximize efficiency.

Overall, Viet Nam is on a good track to enable green logistics in all fields, including warehouse management, transportation, and emission management. Besides multinational enterprises, local businesses are starting to partly apply digital technology and sustainable initiatives to their daily operations. With the support from the government in terms of logistics infrastructure, small to medium logistics companies could have more opportunities in the future to overcome the current challenges.

2.3 Road transportation in Vietnam's Southern Region

2.3.1 Environmental impacts of road transportation

As the most dominant mode of transportation for domestic movement, the associated environmental impacts of road freight have been widely discussed in academic literature. These impacts include all the adverse externalities that are caused on the environment and society, including greenhouse gas emissions, noise pollution, traffic jams, and accidents (Hoang Phuong Nguyen & Van Tai Pham, 2020; Nguyen Thi Bich & Le Dinh, 2024). Nga (2025) stated that about 92% of carbon emissions come from road freight, particularly in industrial and economic areas such as Ho Chi Minh City and Binh Duong province. Therefore, these cities are experiencing severe environmental problems from daily human activities, industrial production, and freight transportation. The emissions released from smoke and dust mostly contain CO_2, CO, SO_2, NO_x, and other organic substances (Lo Dinh, 2021). When these compounds are released into the atmosphere, they cause odors, sight reduction, and climate changes, which are harmful to the natural environment. To understand the primary cause of emissions, the study by Lo Dinh (2021), Nga (2025), and Hoang Phuong Nguyen & Van Tai Pham (2020) all conclude that the critical reasons for climate change and greenhouse gas emissions are the amount of carbon dioxide and methane in the atmosphere. Nga (2025) also explained in detail the fuel combustion process, which creates carbon dioxide from vehicles. Because the adoption of electric vehicles is still limited, energy is mainly taken from gasoline and oil. Therefore, the chemical burning process to create energy in the internal engine cylinders also releases a great amount of atmospheric carbon dioxide. Additionally, the combustion process in vehicle engines is normally incomplete, which leads to the creation of other detrimental pollutants, including nitrogen oxides or nitrogen monoxide. All of these emissions, together with carbon dioxide, contribute to the pollution of the air and cause environmental impact. Additionally, the detrimental effects of road transportation also result in public health issues (Lo Dinh, 2021). Air pollution poses a severe risk to human health, especially children and elderly people. In addition, emissions from the air are the primary reason for human diseases such as asthma, lung cancer, Alzheimer's, and Parkinson's disease.

In the study on the sustainability of road transportation from C.-N. Wang, Le, Chang, et al. (2022), three main factors were proposed to evaluate the effect of this mode on the environment: fuel consumption, CO_2 emissions, and air pollution emissions. The first criterion is the amount of fuel consumed by road vehicles to transport the products from one place to another. It is normally measured by liters per kilometer or liters per ton–kilometer. Paulauskas et al. (2022) agreed that with the over-utilization of road vehicles, fuel consumption leads to a higher increase in environmental impacts in comparison to other alternatives, such as inland waterways transport or rail freight. CO_2 emissions refer to the amount of carbon dioxide released from trucks during fuel combustion processes (Nga, 2025; C.-N. Wang, Le, Chang, et al., 2022). Carbon dioxide is measured by grams of CO_2 per ton-kilometer or kilograms per trip or per vehicle. And the last factor, air pollution, contains all the emissions from sulfur oxides, nitrogen oxides, and carbon monoxide. These substances are measured by the grams of each pollutant per ton-kilometer or per kilometer. Energy consumption is also a significant input for environmental assessment (C.-N. Wang, Le, Yu, et al., 2022). In this study, the authors explained that energy consumption is the amount of energy consumed by a mode of transportation. This is the standardized measurement in case different fuel types are used. Besides these factors, Thi and Thi Ngoc (2020) considered one more criterion, which is noise pollution, to assess the impact of freight transportation in the Mekong Delta region in the south of Vietnam. The main source of noise pollution normally comes from the working engine in vehicles. While the noise has the least impact on the environment, the well-being and social health of residents is affected by the amount of noise during peak hours or at night, resulting in sleep disruption or stress.

2.3.2 Economic factors of road transportation

Road freight is one of the most essential and reliable modes of transportation to the national economy in the global trade context (Thang & Tuan, 2025). For the domestic supply chain, Thi & Thi Thu (2020) state that the utilization of trucks is more than that of barges, ferries, and other vessels. Dr. V. T. K. Hanh (2021a) also pointed out that in terms of GDP, transportation logistics is the second-largest service with around 7.35% in the Ho Chi Minh City region. This is due to the development of infrastructure in Ho Chi Minh City to enhance transportation capability. The forecast for road transportation is expected to increase in the Mekong Delta in the period 2020 – 2030 to boost the transportation activities in Vietnam's Southern region (Thi & Thi Thu, 2020). To evaluate the economic performance of road transportation, cost is the most important factor (C.-N. Wang et al., 2020). The freight rate in road transportation depends on different factors such as fuel prices, distance, types of vehicles, and shipment characteristics (Yin et al., 2025). According to C.-N. Wang et al. (2020), for distances from 0 to 60km, the truck is the optimal solution, while from 60 to 135km, roadside shipping offers the best performance in terms of cost. The correlation between cost efficiency and economic performance has been studied by several studies. Nguyen et al. (2021) explored the correlation between logistics infrastructure and economic growth in Vietnam and found that cost efficiency has a positive correlation with the growth in Vietnam's GDP. Thi & Thi Ngoc (2020) considered cost as one of the key criteria to analyze the impact of transportation on the rice supply chain in Vietnam's Southern region. Yin et al. (2025) also investigated the relationship between carbon prices and transportation cost, the result of which is that the fluctuations in carbon prices significantly affect transportation cost and mode selection from the industry's professional perspective. The high fuel prices result in a decrease in the use of short-haul road freight. Therefore, the carbon price is one of the important factors to consider in transportation network planning and node selection. Regarding transport operations in Vietnam's southern region, the two main transportation modes in this area are road and inland waterways. However, Thi & Thi Thu (2020) demonstrated that the cost for road transport is about 2.6 times higher than inland waterways transport. This increase in cost comes from several factors, such as labor cost, fuel cost, congestion, and load capacity.

Table 3. Transportation cost for freight based on distance (Source: World Bank, 2022)

Distance	Unit of measurement	Road freight	Inland waterways
From 0 to 30 km	VND / ton-km	3,200 – 3,500	1,100 – 3,500
From 30 to 200 km	VND / ton-km	2,500 – 2,700	207 – 744
From 200 to 500 km	VND / ton-km	2,050 – 2,200	207 – 744
From 500 km	VND / ton-km	1,200 – 2,000	207 – 744

Table 3 summarizes the cost comparison between road freight and inland waterways based on the information retrieved from the World Bank's documents of the project: "Southern Waterways Logistics Corridors". The figures support the decision to choose road freight as the primary mode for short distances due to the small gap in cost. When the cost-saving opportunity is low, logistics companies tend to choose road freight because this mode provides fast and reliable deliveries for end customers.

Kabashkin (2023) suggested more criteria for economic assessment of transportation mode, which are capacity, risks, and market accessibility. Capacity is directly related to cost efficiency for road transportation. Based on customer demand and requirements, the capacity of the truck must meet the demand of customers and achieve cost optimization from the logistics business's perspective. For container transport, logistics firms can determine either LTL or FTL according to the product characteristics, routing, and customers' requirements. Risk refers to all the unexpected factors during transportation that can have an impact on business operation performance. Finally, market accessibility denotes the ease of access to destinations such as warehouses, distribution centers, or production sites.

2.3.3 Logistical efficiencies of road transportation

Besides cost, transportation operations also need to concentrate on logistical efficiencies to satisfy the demand from customers. Road freight is associated with the highest performance in reliability and flexibility (Thang & Tuan, 2025). Indeed, this mode is widely used for transportation between regions or domestic movement due to its fast characteristics (Paulauskas et al., 2022). Road freight can be applied to "door – to – door" delivery services from point of sales to final customers, from ports to destinations such as manufacturing sites or warehouses, and between regions by integrating road freight with other modes of transportation to create the multimodal transport solution (C.-N. Wang, Le, Chang, et al., 2022). With the role as the transit for all modes of transportation, road freight is the most flexible mode in terms of schedule, volume, and routing (C.-N. Wang, Le, Chang, et al., 2022). The delivery time can be decided and negotiated between suppliers and buyers instead of relying on the flights or vessels' schedule in air or ocean freight (Dr. V. T. K. Hanh, 2021a). Thanks to the connection between road network, ports, airports, warehouses, and distribution centers, the schedule for road freight can be modified to adapt to the fixed schedule of other modes, creating flexibility in multimodal transportation. In the research about transportation in Ho Chi Minh City by Nguyen Thi Bich & Le Dinh (2024), the authors also highlighted the utilization of roads in this area due to the high flexibility to serve this hub of economy through highway transportation networks to connect all the nodes, including suppliers and buyers' locations. Additionally, the route for road delivery can be changed based on different variables such as congestion, vehicle utilization, delivery time, or customer demands to define the most optimal route.

A series of recent studies has indicated that logistical efficiency inputs are significant factors to evaluate the performance of road transportation systems or support the decision-making process. Thi & Thi Thu (2020) used lead time, flexibility level, and traffic safety together with other factors such as financial performance and environmental protection to evaluate the impact of freight transportation management on rice logistics, focusing on the Mekong Delta region in the south of Vietnam. Lead time is one of the most important measurements in logistics management. It includes the time for collection, handling, storing, and outbound transportation (Thi & Thi Thu, 2020). The efficiency of transportation is not only about the success of how businesses manage their transportation activities in the region, but also about how the activities satisfy customers. With that, customer satisfaction level must be met to ensure the quality of transportation (Yekimov, 2023). C.-N. Wang, Le, Chang, et al. (2022) addressed the total length of transportation routes, the total number of vehicles, and the turnover rate in volume to measure the road transportation performance with the Multi-Criteria Decision-Making method. Pham Van et al. (2023) concentrated on operational costs, route optimization, empty travel, capacity utilization, empty backhaul reduction, and multimodal integration as the efficiency factors to investigate the green transport initiatives between domestic and international companies in Vietnam. Phan et al. (2024) analyzed the external factors that influence the green logistics practices from the logistics companies' perspective. These factors include customer service level, route optimization, and environmental factors. This research contributed to research and development by providing a comprehensive evaluation framework that uses logistical efficiencies, regulatory requirements, and environmental considerations. Khoa & Nhung (2020) conducted a case study on two companies: DHL and Murphy companies, to evaluate the high flexibility in road transport in route optimization and freight consolidation to develop green logistics solutions. These practices are considered as recommendations applied to the Vietnamese logistics enterprises to enhance their transportation efficiency. The study also highlights the potential of road transportation to enable technology integration in real time tracking and predictive scheduling.

Despite the high performance of road transportation in terms of logistical efficiencies, which benefits both enterprise and customers at the same time, the development of road transportation still faced several operational bottlenecks and limitations. Particularly, the current road network in Vietnam's southern region may be insufficient and underdeveloped to meet the high demand in freight transportation in the future (Huyen et al., 2024). The infrastructure challenges lead to ineffective connectivity between road and industrial zones or ports, which causes congestion, high operational costs, and delays in delivery. These consequences significantly impact logistical performance and customer satisfaction overall. The overutilization of road freight can also lead to environmental issues due to high engine power, resulting in high fuel consumption costs. The capacity of road vehicles is also another limitation of road transportation (Dr. V. T. K. Hanh, 2021a). For road freight, the common unit loading is containers, with the maximum loading capacity of about 30 tons for 40-foot containers, while the loading capacity for waterways is up to 300 tons of goods for ferries. Phi & Dang (2020) studied the mode of transportation selection in Cuu Long Delta in the south of Vietnam and indicated that despite this region having a high freight demand and high utilization of road transport, the transport infrastructure in this region is still limited such as road network, which causes the bottleneck in the accessibility of this region to the nearest economic region, which is Ho Chi Minh City. Finally, the author highlighted the opportunity to enable multimodal transportation to leverage cost-efficient waterways transport for long-term sustainability due to the urban congestion in Can Tho hubs. This congestion issue affects most of the firms operating in this southern area, with high transportation cost pressures and a lack of alternative modal solutions.

Table 4. Comparison matrix between modes of transportation

Transportation mode	Cost	Capacity	Emissions	Speed	Shipment characteristics
Road	High	Low	High	High	All types of shipment, especially time sensitive, perishable, and dangerous goods. High reliability level for last-mile shipments. (E.g., domestic retail goods and e-commerce deliveries).
Rail	Low	High	Low	Low	Bulk, heavy, and low-value commodities. These cargoes are often less time-sensitive and do not need special protection. (E.g., raw

					materials, wood, minerals, or general containers).
Sea	Very Low	Very High	Very low	Very Low	Containerized, out-of-gauge, and non-urgent cargoes in large volume. (E.g., manufacturing products, electronics, textiles).
Air	Very High	Low	Very High	Very High	High-value and urgent shipment (E.g., semiconductor, pharmaceutical or perishable goods).
Inland waterways	Very Low	Very High	Low	Low	Bulk, liquid, containerized, or non-perishable goods which are not time sensitive (E.g., rice, cement, sand, coal, or general cargoes).

Table 4 summarizes the comparison matrix of five main transportation modes over four factors: cost, capacity, emission, and speed from the reviewed literature. This comparison matrix clearly illustrates the trade-offs needed when choosing the transportation mode. For instance, road freight and air freight are known as the fastest and most reliable modes of transportation, especially for high-value, urgent, or special cargo. However, these two modes have poor environmental performance and high freight costs in comparison to other modes. Thi & Thi Thu (2020) reported that the emissions rate for trucks can be up to 110gCO_2/ton.km, while that for inland waterways vessels is only about 71gCO_2/ton.km. Dr. V. T. K. Hanh (2021b) also noted that the emissions rate and cost for sea transport are relatively small compared to road freight. In fact, this is the lowest cost and lowest emissions mode due to large-scale shipping. One large vessel can handle up to thousands of tons, which results in low cost and emissions per unit of freight, which is only about 2-20gCO_2/ton.km. According to the Vietnam Logistics Report in 2022, two major ports of Vietnam, which are Hai Phong and Cai Mep – Thi Vai, can receive the large container vessels with a capacity of more than 132,000 DWT (Deadweight tonnage). In the research of (T. T. Tran & Ge, 2022) on rail freight and multimodal transportation, the authors highlighted that transporting via rail is significantly cheaper than road transport due to lower fuel and labor costs. The emissions reduction for carbon footprints and

PM2.5 is 92% and 87% respectively. However, one drawback of rail is that the rail network in Vietnam has not been developed yet. That is the reason why logistics companies in Vietnam only use rail freight for low-value and less time-sensitive shipments. In terms of capacity, Dr. V. T. K. Hanh (2021a) stated that the maximum capacity for one truck is about 30-40 tons according to shipment characteristics, while the capacity of waterways vessel and freight train can be ranged from 300 to 3000 tons (Huy et al., 2023) and 500 to 1500 tons (T. T. Tran & Ge, 2022), respectively. Therefore, rail, sea, and inland waterways transport are usually suitable for general cargo which can be consolidated in bulk shipment, providing the capacity and cost effectiveness, while road and air freight trade off by offering the highest reliability, shipment protection, and speed but at the higher prices and emissions generation. To balance the trade-off between cost, capacity, emission, and speed, logistics businesses are currently implementing multimodal transportation to leverage the advantages of each mode with an appropriate transport network, shipment characteristics, and delivery time window to minimize the cost and maximize capacity.

In conclusion, road transportation is still the most reliable and flexible mode for domestic delivery and an intermediary mode in multimodal transport. However, the over-utilization of road freight causes several drawbacks to society, the environment, and logistics performance. Therefore, it is necessary to evaluate the performance of road freight with one potential mode, which is inland waterways transport, to enable the greener and customer–driven transport solutions.

2.4 Inland waterways transportation in Vietnam's Southern Region

2.4.1 Environmental impacts of inland waterways transportation

Besides road freight, inland waterways transport is under exploration to increase the utilization of this mode and support the green development of the transportation system in Vietnam (Huy et al., 2023). With the existing geographical advantages of rivers and canals, waterways transport is expected to have potential for cargo transport in the country. In terms of energy consumption, this mode has higher performance than road freight because of the ability to carry large volumes at the same time on barges or container vessels (Huy et al., 2023). Vessels operating on the waterways system use much less diesel than rail or road vehicles (Dr. V. T. K. Hanh, 2021a). Therefore, while it has been discussed that trucks are the optimal solution for transporting short distances, in the meantime, one part of goods volumes could be split into other environmentally friendly modes such as inland waterways (Paulauskas et al., 2022). Le & Tran (2025) states that inland waterways transportation is more environmentally friendly and fuel-efficient than road freight. In fact, inland waterways transportation still generates pollution to the aquatic ecosystems, surrounding habitats, and atmosphere (Calderón-Rivera et al., 2024a). T. C. H. Nguyen et al. (2019) mentioned the threat of water pollution, operational discharges of mineral oils or lubricants, and organic substances from waterborne shipping operations, and highlights the need to develop water traffic control and water pollution treatment to mitigate environmental risks while leveraging the advantages of the inland waterways system.

However, the cost of emissions is lower than that of other modes, leading to another differential advantage of the inland waterways system: lower emissions levels. For Vietnam's transportation sector, road freight accounts for approximately 92% of total carbon dioxide emissions, while waterborne transport accounts for around 5%. The emissions for waterways are estimated based on two primary elements, which are fuel consumption and emissions factors such as PM10, PM2.5, SO_2, CO_2, or CH_4 (Huy et al., 2023). In both studies by Huy et al. (2023) and Thi & Thi Thu (2020), the same result was given that the transport emissions by inland waterways transport are relatively less than road transport. Consequently, inland waterways transport can be considered as an effective alternative solution to reduce environmental impacts. The reduction in road congestion indirectly leads to the reduction in emissions through the reduction of wasted fuel consumption during congestion (T. V. Nguyen & Nguyen, 2020). The noise pollution in high-density residential areas can also be reduced because of the slower and constant speed from vessels, which generates less urban noise in comparison to trucks (Calderón-Rivera et al., 2022). In conclusion, by modal shift from road freight to inland waterways freight, Vietnam can also reduce traffic congestion and noise pollution from vehicles, fuel consumption, and carbon emissions, which are the primary contributors to environmental degradation (Bu & Nachtmann, 2023; Le & Tran, 2025).

2.4.2 Economic factors of inland waterways transportation

The most apparent advantage of economic factors is cost reduction. Transportation of bulky items or a large amount of containers by barge can reduce the total operating cost and fuel consumption per unit transported (Bu & Nachtmann, 2023). For example, one barge can replace more than 80 trucks, resulting in the advantage of less expensive and more consolidated shipments for long transporting distances (Calderón-Rivera et al., 2022). In addition, shipment integration and consolidation offer several operational conveniences and economic advantages through economies of scale (Cang et al., 2021). Taking Binh Duong province in southern Vietnam as an example, there is a strong emphasis from the local administration on significantly reducing shipping costs by implementing an integrated transportation process between road and inland waterway transportation, as well as infrastructure development for the waterborne system in the south (Cang et al., 2021).

Moreover, owing to the containerization trends on the global scale in recent years, the inland waterways transport receives more interest as a cost-effective solution in multimodal transportation (Bu & Nachtmann, 2023; Cang et al., 2021). It serves as an intermediate mode in the overall transportation system, connecting other modes of transportation for cost-saving purposes. Inland waterways provides economic advantages for logistics firms by facilitating seamless processes, including storing, loading, and unloading through standardized containers without repacking during the whole transportation phases among ocean terminals, seaports, road systems, and accessible inland waterways networks (Cang et al., 2021). In multimodal transport solutions of road and inland waterways, the shipping cost is reduced by optimizing each transport leg with a suitable mode. For instance, road freight is more cost-effective for short distances of about 60km, while inland waterways are preferred for long distances of more than 200km. Therefore, using barge transportation for long-haul shipments offers better cost performance than trucks. Consolidation of container shipping also benefits the logistics industry by increasing cargo safety, which can avoid the cost of risks related to damage or loss of cargo (Calderón-Rivera et al., 2024a). As a result, these advantages support the government policies to enhance the modal shift from road to other sustainable solutions.

2.4.3 Logistical efficiencies of inland waterways transportation

The measurement of reliability performance largely depends on the distance transported by inland waterways. According to T. V. Nguyen & Nguyen (2020), the average travel distance of inland waterways transport is about 212km, while the distance covered by road is only about 59km. Therefore, the more distance transported, the higher reliability level of inland waterways (T. V. Nguyen & Nguyen, 2020). Additionally, a primary advantage of waterway transport is its ability to carry cargo in large quantities. This advantage is directly related to the cost-effectiveness mentioned above and is associated with consolidating large shipments in both dimensions and quantities. Currently, vessels operating in Vietnam's waterways system have enough capacity to serve the shipment consolidation (Huy et al., 2023). There is a total of 27 categories of vessel fleets, and they are classified into eight main categories (Huy et al., 2023), including freight and passenger vessels.

Table 5. Eight categories of vessel fleets

Fleet type	**Categories**
Fleet 1	Oil tanker
Fleet 2	Container ship
Fleet 3	Dry bulk ships (< 1500 tonnes)
Fleet 4	Dry bulk ships (1500 – 3000 tonnes)
Fleet 5	Dry bulk ships (> 3000 tonnes)
Fleet 6	Push convoys
Fleet 7	Passenger ships

Fleet 8	Ferries

Based on the summary of the eight types of vessel fleets presented in Table 5, logistics firms can utilize suitable vehicles with demands from customers to enhance the transport capacity and reduce road congestion (T. M. H. Nguyen et al., 2024). The ability to handle large capacity is especially advantageous for conventional or non-time-sensitive shipments, which can leverage the consolidation in bulk shipment to reduce costs while maintaining the customer satisfaction level. The Dong Nai and Mekong River systems are the most significant routes in southern Vietnam. These two systems connect manufacturers and shippers located in Binh Duong and Long An province to international deep-sea ports such as Cat Lai or Cai Mep for exportation. Barges can use key rivers and canals in this two-river system to reduce the number of trucks and congestion on highways.

In the study about the development of the waterways system during the COVID-19 pandemic in Vietnam, waterways transport had the least impact during the pandemic. It indicates high resilience despite not meeting the volume required by the government (Dang et al., 2022). This is due to the low dependence on human interaction in barge shipping and fewer road traffic restrictions.

2.4.4 Logistical and infrastructure challenges of inland waterways system

Waterway transport offers numerous advantages to the environment, economy, and society, including reduced greenhouse gas emissions, cost savings, and improved fuel efficiency. The development of inland waterways transport is still facing various logistical and infrastructure challenges. There have been numerous studies by Vietnamese researchers investigating these challenges. T. V. Nguyen & Nguyen (2020) pointed out the weak enforcement of regulations due to the overlapped and fragmented regulatory framework. All of these limitations lead to the underutilization of the waterways system. T. V. Nguyen & Nguyen (2020) also highlighted the importance of upgrading and maintaining waterborne infrastructure, as it is strategically significant to enhance Vietnam's connectivity with Class I seaports (international deep-sea ports) to support export operations. Therefore, an enhancement in capital investment is necessary to ensure Vietnam's efficient management of the waterways infrastructure network and maintain a sustainable competitive advantage.

While Vietnam has various types of vessels in capacity and functionality, the shallow depth and narrow dimensions of the canals limit the development of the waterways system (T. V. Nguyen & Nguyen, 2020). Outdated port facility with little attention to mechanization and maintenance is also an important infrastructural challenge (T. V. Nguyen & Nguyen, 2020). That is the reason why T. M. H. Nguyen et al. (2024) worked on the dry port location selection problem to apply multi-criteria decision-making models to choose the most promising port for investment. However, this research only considered the northern region, and the coverage for other regions was limited. In the south, a similar infrastructural concern is raised for the Cuu Long Delta region. According to the author, numerous efforts have been made by the local government in this region, particularly in the road and inland waterways systems, to improve connectivity with Ho Chi Minh City. The decision on transportation mode varies based on the economic structure of the enterprise, whereas the current policy of capital allocation fails to consider these variations (Dang et al., 2022; Phi & Dang, 2020).

Lead time of waterways transport is also different compared to road freight (Dang et al., 2022). Lead time is the crucial measurement of logistical efficiency. However, waterways transport has the lowest speed among all means of transportation (Calderón-Rivera et al., 2024a). Therefore, this mode is more suitable for transporting a large volume of cargoes and oversized shipments than time-sensitive goods (Calderón-Rivera et al., 2024a). This is challenging for logistics businesses to have sufficient transportation planning with customer-centric considerations to determine the most suitable transportation mode (Dang et al., 2022). The poor port facility also leads to delays in waiting time for loading and unloading cargoes (Calderón-Rivera et al., 2024a; T. V. Nguyen & Nguyen, 2020).

Weather conditions are another factor that lengthens the transportation time of this mode, as fluctuations in weather patterns directly affect port operations and water levels. For instance, Vietnam has two main seasons: the dry season and the wet season. In the dry season, the utilization of barges may drop due to drought in some small canals. In the meantime, the higher water level in the wet season allows smooth movement of the barge, but it still causes heavy rainfall, which delays the operations at port (Cang et al., 2021).

2.4.5 Opportunities for future development of inland waterways system

According to Paulauskas et al. (2022), a country with natural rivers and channel systems should prioritize investments in its waterway system to benefit from reduced traffic issues and fuel consumption. Therefore, Vietnam still has the potential to develop a waterways system as a part of multimodal transportation to connect industrial and economic areas with a seaport system. Despite financial constraints, the country has made significant progress in developing this mode by leveraging its current waterway resources. The promising development is also supported by the direct connection between existing waterways and major domestic and international ports, especially in Vietnam’s two most economically significant hubs, the North and the South. Many production sectors in rural areas, such as fishing, timber, livestock, farming, industrial crops, as well as container transport, are on the rise, which creates more opportunities for logistics firms to utilize the potential of inland waterways to transport higher-value products and consumer goods (T. V. Nguyen & Nguyen, 2020). Specifically in the Mekong Delta region, the freight volume through this region is forecasted to rise up to 64 million tons by 2030 and 208 million tons by 2050 (C.-N. Wang & Thanh-Tam, 2024). This illustrates the strong position in driving the country’s economic growth. In terms of GDP and the nation's total import and export volume, this region contributes around 40% and 50%, respectively. In terms of commercial and logistics activities, the country's southern region contributes approximately 60% of the country’s total goods and handles more than 60% of container transportation (Le & Tran, 2025). This result is attributed to the ideal natural conditions of the 28,000 km long river systems, including the country's waterway route from Ho Chi Minh City through neighboring areas such as Kien Giang, Ca Mau, or Can Tho via the Hau River.

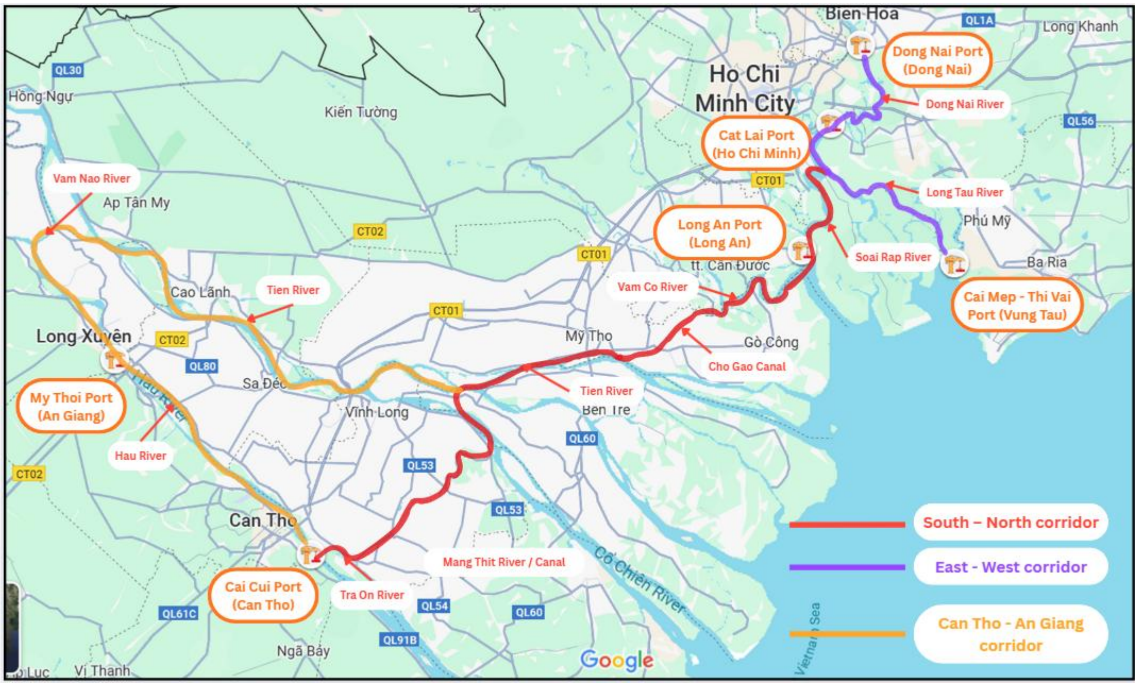


Figure 2. Key southern inland waterways channels and ports

Figure 2 illustrates the key waterways corridors, canals, and ports in the southern region. Cat Lai and Cai Mep – Thi Vai are the two largest and busiest ports in the south. The capacity of these two ports can be up to millions of tons of cargo, specializing in containerized trade. On the one hand, Cat Lai port is a crucial gateway for Ho Chi Minh city, which connects two main waterways networks from Vung Tau and the Mekong Delta region. From the delta region, large barges can use the Tien River system and the Cho Gao Canal to transport rice, fruit, or seafood directly to Ho Chi Minh City. The Cho Gao canal is also under phase I of the development project for the southern corridors (World Bank, 2022). On the other hand, Cai Mep – Thi Vai is the critical deep-sea gateway in the southern region, which handles all inbound and outbound shipments in the south. From Cai Mep – Thi Vai port, vessels can use Long Tau and Soai Rap River to transport shipments to the Mekong Delta region or the Dong Nai River system to Dong Nai port to serve the Long Thanh industrial area. In the Mekong Delta region, Cai Cui Port is the primary export terminal for agricultural products and industrial materials such as rice, fruit, or cement. Leveraging the high density of rivers, canals can feed into the Hau and Tien Rivers, such as Mang Thit, Vam Nao, and Tra On Rivers. Barges and vessels can easily access nearby regions, such as An Giang, Kien Giang, or Ho Chi Minh City. Although it has some limitations in terms of capacity and efficiency, Cai Cui Port in Can Tho still plays a pivotal role in connecting the national logistics network with Mekong Delta exports.

Regarding the vessels operating in the waterways system, the vessels are designed to adapt to the bulk cargo and heavy shipments (T. V. Nguyen & Nguyen, 2020). Vietnam’s waterways system consisted of more than 170,000 vessels, with most small and dry cargo barges in comparison to the global fleet system. However, the number of larger and specialized ships is increasing (T. V. Nguyen & Nguyen, 2020). These large and specialized vessels are suggested to be more cost-effective and better aligned with the current growing logistical demands.

In conclusion, waterborne transport has been gradually recognized as the strategic component of Vietnam's freight transportation system due to its advantages to the environment and national logistics development (Le & Tran, 2025). Moreover, the highway routes connecting the seaport to Ho Chi Minh City have significant congestion. This highlights the importance of promoting alternative solutions to mitigate the pressure on road corridors.

2.5 Modal shift analysis between road and inland waterways

2.5.1 Modal shift analysis between road and inland waterways transportation

Several previous kinds of literature have proved that road is the primary reason for environmental and societal problems, congestion, air pollution, traffic accidents, noise pollution, and climate change, while the global demand for more reliable, flexible, and cost-effective freight transport has grown significantly in recent years. To address this challenge, a modal shift towards more environmentally friendly transportation modes is crucial to reducing the associated cost and negative impacts (Raza et al., 2020). Waterborne transport has emerged as a viable solution for this modal shift because of the benefits it brings to the operation, including cost optimization by utilizing the most suitable mode for each transportation leg, economic performance, and energy efficiency (Raza et al., 2020). Consequently, the modal shift analysis has been explored in prior studies by researchers all over the world. Feng et al. (2023) explored the containerization of bulk cargo as a strategic decision to leverage economies of scale and enhance logistical performance. The result highlighted that container shipping offers many advantages in terms of transportation cost, cargo protection, enhanced security, and better resilience to severe weather conditions. Jiang et al. (2024) evaluated the potential reduction in CO_2 emissions from a modal shift from road transport to inland waterway transport using the case study conducted in China to demonstrate the effectiveness of this transition. The ultimate objective is to analyze the whole chain of transportation associated with CO_2 emissions to make better policy decisions towards emissions reduction strategies. Jiang et al. (2024) also clearly differentiated operational activities between the two modes. Road freight contains only three simple stages: loading, transportation, and unloading. In contrast, inland waterways follow a more complex operation, including loading at warehouses or distribution centers, road transportation (first leg), shipping by vessels, road transportation (second leg), and final unloading at receiving sites. Therefore, the emissions reduction is calculated as the difference between the two modes under ideal conditions with the same freight demand, transport flow, and direction. Santén et al. (2021) presented five case studies in the North Sea Region to explore the efforts to encourage modal shift towards inland waterways transport. Despite its potential, this mode still faced competitive challenges from road freight. From case study analysis, the author identified four essential steps to facilitate the modal shift, including understanding the current situation, identifying potential solutions, testing the solutions, and promoting the solutions. The initial phase involves analyzing the existing transport capabilities to recognize all the potential barriers towards modal shift and all key stakeholders influenced by the shift. Next, the second phase focuses on developing the solutions with stakeholders' engagement. In the third phase, these solutions are piloted for performance monitoring before being promoted through organizational materials and operational procedures.

In the Vietnam region, despite the ongoing trend to leverage inland waterways as a sustainable solution, the research and development of this modal shift is still limited. Only some previous works focus on the modal shift analysis between road and inland waterways transport. Lan et al. (2021) examined the impact of shifting freight and passenger transport from road and air modes to rail and inland waterways transport as a strategy for energy conservation and carbon emissions reduction. The study investigated how much modal shifts influence the overall energy system and CO_2 emissions. The finding also indicated that transitioning to more sustainable transport modes result in a significant decrease in energy consumption in the transportation sector. From an economic perspective, the modal shift can also reduce the total transportation costs. Thi & Thi Thu (2020) analyzed the impact of public decision–making on road and inland waterways transportation of rice logistics industry in the Mekong Delta region in the south. Le & Tran (2025) supported the modal shift from road to waterborne transport to utilize Vietnam's long coastline and inland river system, particularly in the southern region. The study assessed the logistics and service quality of barge providers because these providers are important in the inland waterways system. Through the decision–making framework, the research identified and evaluated key performance criteria to determine the most suitable service providers for shippers. Dang et al. (2022) highlighted the modal shift from road to inland waterways as the resilience strategy during the pandemic to keep the seamless transport operations.

In conclusion, from a governmental and enterprise perspective, attention to the modal shift from road to waterways transport has increased in recent years. However, the detailed comparative analysis of the performance and trade-offs between these modes has not been fully addressed in the Vietnam region, particularly in the southern region.

2.5.2 Modal shift drivers

Environmental, social, and economic are the three main drivers of the modal shift from road to inland waterways (Hofbauer & Putz, 2020). It comes from the need to drive the transportation solution towards the global sustainable goals while maintaining and balancing the current operational excellence of the logistics business (Hofbauer & Putz, 2020). In each dimension, different key performance indicators were set to measure the effectiveness of transportation, such as greenhouse gas emissions, traffic noise, total time spent on delivery, or external costs. Hofbauer & Putz (2020) clearly identified all the external costs associated with mode comparison, which include accidents, noise, air pollution, and climate change. The analysis in this research revealed that inland waterways transport contributes to a low percentage of costs. Besides external costs, internal costs such as transportation rate, up-front costs, or special shipment costs are also considered in the study (Hofbauer & Putz, 2020). They also noted that when analyzing the modal shift, it is essential to take the costs for pre- and post-haulage into account for the appropriate allocation of each transport mode to each connection point.

Reliability and quality are also two crucial factors to evaluate the performance of transportation (Gbako et al., 2025). From previous studies, inland waterway transport was perceived as less competitive than road freight due to longer transit and handling lead time at the port. From the shipping companies' perspective, the financial challenge is the driver that has the biggest impact on the decision to launch the new waterways service. These include fixed costs, piloting fee, or transshipment expense (Santén et al., 2021). The pre-and-post-haulage costs for the inland waterways system are relatively higher than road transport, which represents the major financial burden for companies. From a transport service user perspective, the modal choice is not only influenced by price but also by time performance, service reliability, and quality issues. Therefore, quality is considerable when designing the modal shift from road to waterways transport (Santén et al., 2021).

Regarding strategic context in Vietnam, previous studies also mentioned similar drivers when considering the modal shift from road to inland waterways. T. C. H. Nguyen & Nguyen (2019) mentioned cost efficiency, geographic advantages, and environmental sustainability as the main drivers for the development of the waterways system. T. V. Nguyen & Nguyen (2020) focused on policy vision from the government and potential opportunities for private logistics firms to leverage the shift from road to waterways to reduce the costs of congestion and emissions. Le & Tran (2025) and T. M. H. Nguyen et al. (2024) highlighted the potential of cost savings opportunities and intermodal solutions to solve the existing drawbacks of road transportation. Overall, from all the literature reviews, cost and environmental factors are the two main factors to drive the need for business and policy makers to develop alternative solutions in parallel with road transportation. In the meantime, other drivers such as pandemic, regulation, strategic alignment, and reliability are still significant to have a successful modal shift in Vietnam.

Table 6. Key benefits and challenges of modal shift from road to inland waterways transport

Dimension	**Benefits**	**Barriers and challenges**
Environment	• Significant reduction in carbon emissions, energy consumption, noise, and accidents. • Contribution to Vietnam's net-zero roadmap to 2050.	• Risk of water pollution from vessels. • Risk of seasonal weather and fluctuating water level, which affect the vessel schedule and performance. • Limited digital system for carbon management in small enterprises.
Economic effectiveness	• Reduction in total transportation cost. • Advantages in economics of scale to carry large quantities and heavy shipment. • Fuel-saving per shipment unit.	• Financial burden for small companies due to high initial investment cost. • Slow modernization of vessels and port facilities. • Poor infrastructure in waterways navigation and bridge clearance
Logistical operation	• Reduce congestions in highway, especially in Ho Chi Minh City – Mekong Delta region through national highway 51. • Resilience during disruption.	• Increase the overall transit time. • Delay due to waiting time for loading / unloading at port. • Increase cargo safety concerns.

	• Service diversity through multimodal solutions. • High capacity in bulk and container transport.	• Customer demand for fast delivery
Government policy	• Strong support and funding from the government to increase volume share of inland waterways transport. • Strong national orientation towards sustainability. • High utilization of dense river network.	• High upfront investment cost.

Table 6 summarizes the main benefits and challenges of the modal shift from road freight to inland waterways transport in the Southern Vietnam context. The comparison is divided into four main dimensions: environment, economic effectiveness, logistical operation, and government policy. While the modal shift provides obvious environmental and economic advantages and aligns with the national strategy towards net-zero emissions in 2050, the challenges highlight critical areas for improvement in the future, including infrastructure modernization, financial support, and reliability improvement.

2.6 Summary of the theoretical framework for transportation in Vietnam's Southern Region

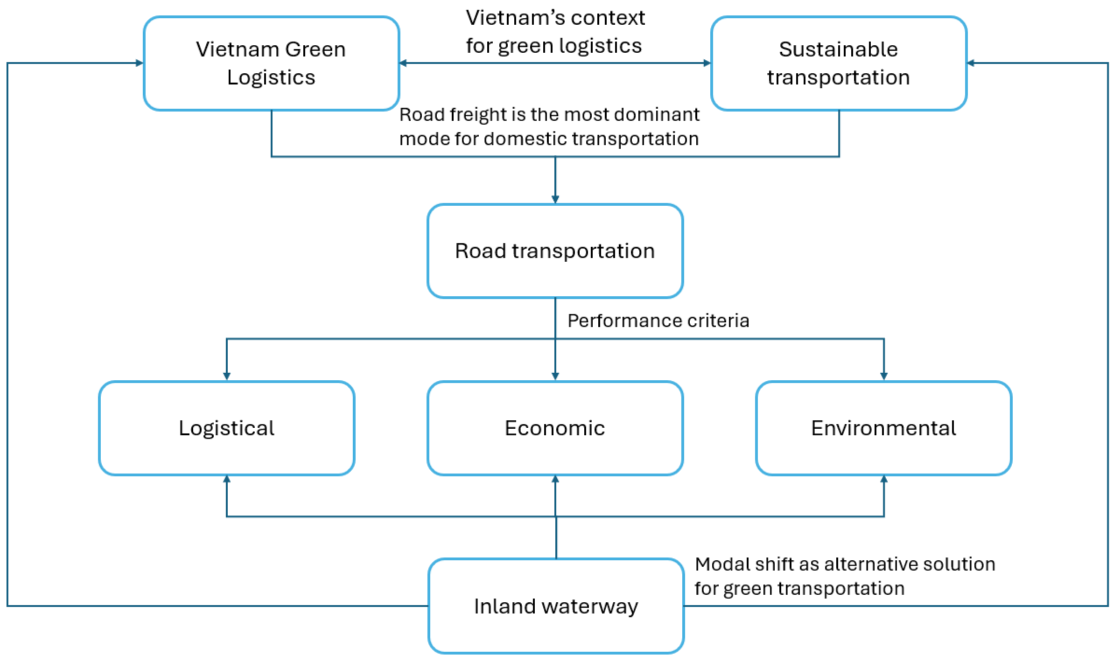


Figure 3. Theoretical framework for transportation in Vietnam's Southern Region

Figure 3 illustrates the theoretical framework of all concepts mentioned in this study, which includes green logistics, sustainable transportation, road freight, inland waterway system, and performance indicators. This framework is developed based on the current research problem about green logistics in Vietnam, the need to adopt sustainable transportation solutions to mitigate the detrimental effects of road freight on human and the environment. While previous studies in the literature review confirmed the high reliability and dominance of road freight in Vietnam, the major problem for this mode is the number of emissions released to the atmosphere. Therefore, the alternative solution could be the modal shift from road to inland waterway transport to enable the multimodal approach to balance the economic efficiency with sustainable development, which directly contributes to the growth of Vietnam's green logistics and transportation.

The objective of this research is to focus on three dimensions: economic benefit, logistical performance, and environmental protection, to compare and measure the efficiency of road and inland waterway transport as the research's objectives are to assess the environmental, economic, and logistical performance of road and inland waterways transport, thereby investigating on what circumstance inland waterways can be used as a sustainable solution. Therefore, these three dimensions act as the primary criteria throughout the whole set of questionnaires for surveys and interviews to ensure consistency of concentration. The data collection and analysis process will be based on the performance criteria mentioned in the theoretical framework to measure and make a comparison between the two modes in Vietnam's southern region to highlight the potential development of the inland waterway transport and investigate the infrastructural challenges accordingly. Comparing two modes across the same performance criteria allows researchers to investigate the synergies, relationships, and trade-offs of the criteria. To be more specific, while road freight has the high performance in terms of logistical efficiency by providing the fast and door – to – door delivery services, this mode also leads to high emissions generation and transportation cost. In this scenario, inland waterways can be a suitable solution for bulk and general commodities to leverage the large capacity of vessels to reduce the total costs and emissions. By analyzing all the sub-factors in these three criteria, the researchers could identify to what extent the modal shift could be implemented as a green transport solution to cut costs, emissions, and reduce congestion on highways. Consequently, this modal shift strengthens both national sustainable transport policies and Vietnam's commitment to the net-zero emissions goal by 2050.

In conclusion, the theoretical framework acts as a guide for this research to clearly indicate the relationship between concepts to analyze the modal shift from road to inland waterway transport. This framework connects the research questions to associated objectives through performance criteria to evaluate the feasibility and advantages of waterborne transport as a greener alternative for Vietnam's domestic transportation sector.

3 Methodology

The aim of this section is to represent the research approach in this thesis. The research methodology is developed based on the research onion by Saunders et al. (2019), which concisely summarizes all the core decisions of the research methodology, including research philosophy, theory development, methodology development, research strategies, time horizon, and research techniques (see figure 4). From the outer layer of the research onion, the researcher states how knowledge in the study is generated and formed in such a logical way. Following theory development, the researcher determines whether the study is deductive, inductive, or abductive. The third layer indicates methodological choices such as qualitative, quantitative, or mixed approaches. In the next step, the researcher determines the research strategies through case studies, surveys, or experiments. Finally, the time zone for the study and data collection techniques is defined as the core of the study. In this study, the research onion is used as the general guide to narrow down from broad philosophy to specific methodology and techniques to analyze the potential and barriers of modal shift from road to inland waterways transport in Vietnam.

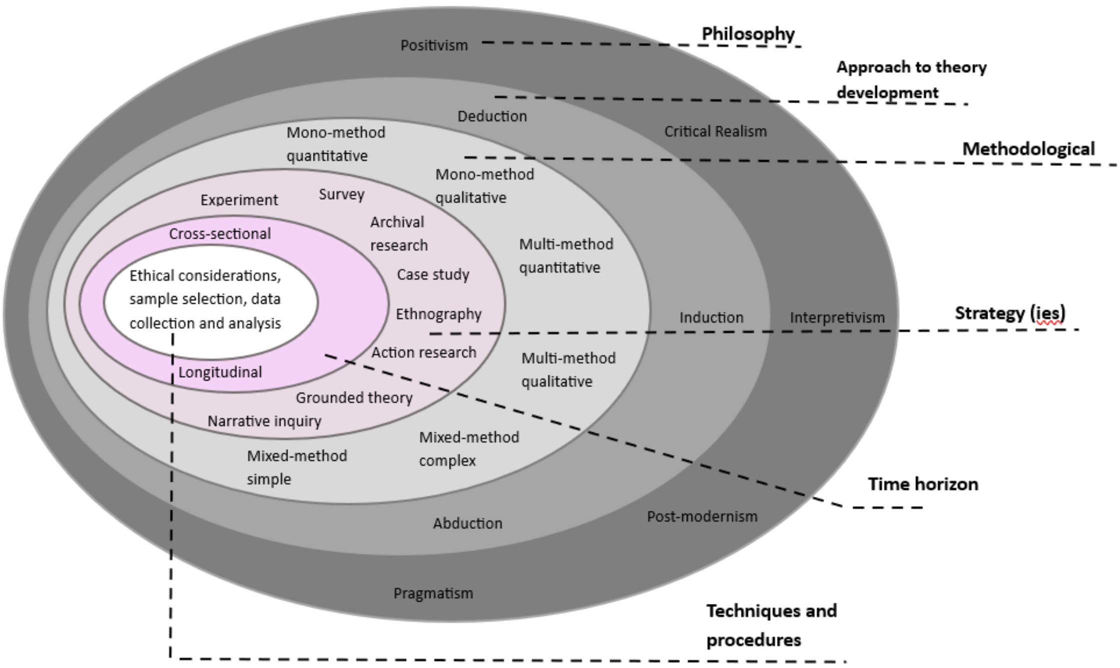


Figure 4. The Research onion (Saunders et al., 2019)

Specifically, research design, theoretical development, and methodology are mentioned in the first section. The second section describes the data collection strategies and techniques, particularly in how the data is collected from the chosen sample size. This chapter also includes the rationale for choosing the research population and research sample, which align with the pre-determined research question: *To what extent can inland waterways serve as a sustainable and environmentally friendly alternative to road transportation in Vietnam's Southern region, in terms of environmental impact, economic viability, and logistical efficiency?* The final chapter describes in detail the data analysis process through an empirical example, along with the comparative analysis based on performance metrics mentioned in the literature review.

3.1 Research design

After finalizing the research questions, conducting a literature review, and formulating the general theoretical framework, which clearly indicates the relationship among concepts used in this thesis, this thesis decided to use the mixed methodology to further investigate the research objectives. A mixed methods approach is the combination of qualitative and quantitative data to have a meaningful explanation of the research topic. The significance of mixed methodology has been proven to offer a logical foundation and generalize insights of the researched questions to the large population (Dawadi et al., 2021). For instance, the quantitative approach allows researchers to gather general data from a sample, which can be used to generalize the findings to a broad population. Following a qualitative approach, researchers can use open-ended questions or interviews to dig into the data to get more valuable insights from the voices of participants. As a result, the issue is deeply investigated to generate insightful findings into the research questions, which cannot be fully addressed by using only a qualitative or quantitative approach (Dawadi et al., 2021). Qualitative methodology is an exploratory research approach that is mostly used by researchers to discover the hidden patterns, meanings, and diverse perspectives by seeking to understand human behaviors and experiences

(Abuhamda et al., 2021). This methodology is different from the quantitative approach, which relies on numerical data to identify the relationship with statistics among pre-determined factors (Abuhamda et al., 2021). In a qualitative study, the descriptive data is collected through open-ended questions, transcripts, or in-depth interviews to develop a comprehensive understanding of the research subject (Abuhamda et al., 2021). In the quantitative approach, numerical data can be collected through reports, performance metrics, closed-ended questions, or a 5-point Likert scale to measure the level of preference, behaviors, and frequency of the event. Consequently, the qualitative methodology is suitable for understanding the prevailing perspectives from logistics business leaders regarding the decision in transportation mode with environmental consideration. Besides, due to the limitations of real statistics from logistics companies related to the environmental and economic performance of transportation modes, this thesis does not aim to test hypotheses or formulate optimization models. Instead of that, this research intends to explore the comprehensive knowledge and understanding of logistics professionals to find out the environmental and economic performance between road and inland waterways transport.

With the above rationale, the two primary data collection methods chosen for this research are online survey and semi-structured interviews. The online survey is used to examine the perceptions and evaluations of participants who are working in logistics companies in Vietnam’s Southern region regarding two freight modes. This survey is designed to use both closed-ended using 5-point Likert and open-ended questions to get quantified data for evaluation across key dimensions in environmental, economic, and logistical efficiencies. This structured data allows researchers to conduct comparative analysis between two modes and support thematic analysis with transcribed data from the interviews to identify patterns, preferences, or various viewpoints within the logistics community. Therefore, the survey results act as the foundation, which contains general insights for deeper validation and analysis of themes generated from the interview. Additionally, through in-depth interviews with logistics leaders, the actual barriers and opportunities to implement inland waterways transport, which are directly related to the company's strategy, can also be addressed through sharing from the practical experience of the interviewees. Open-ended questions are used in the semi-structured interview to collect the viewpoints from actual operations of the companies in three factors: environmental influences, economic performance, and logistical efficiency of road freight and inland waterways transport. A semi-structured interview is one of the most common and effective data collection methods for qualitative research. Through the interviews, researchers can explore the perspectives and experiences of individuals while maintaining the clear concentration of the study's objectives (Ruslin et al., 2022). The interviews are conducted virtually using online platforms such as Zoom, Google Meet, or Microsoft Teams, with permission from the interviewees. An online interview creates convenient and direct interaction between the interviewer and participants (Ruslin et al., 2022). Since the targeted participants are working in Vietnam, the online interview makes the process more efficient and accessible. Through a virtual format, the interviews are recorded for transcription purposes for the later analysis stage of this research. The transcription allows researchers to fully understand the conversation without taking notes during interviews. The data generated from the interviews is then analyzed by using Thematic Analysis.

The research flow chart is indicated in figure 5 below. The process starts with the formulation of research questions and objectives. The next step is to conduct a literature review to find out what has been done in previous work about the research topics and develop the framework based on existing theories. In the third phase, research methodology and analysis techniques are chosen for data collection and analysis, which is the core of the study. The questionnaires used for online surveys and interviews are developed before choosing the suitable participants from the population, who are working in logistics companies in the south of Vietnam. The data collection and analysis process begins after contacting the appropriate interviewees. Finally, conclusions, discussions, and some recommendations are drawn from the results of the analysis.

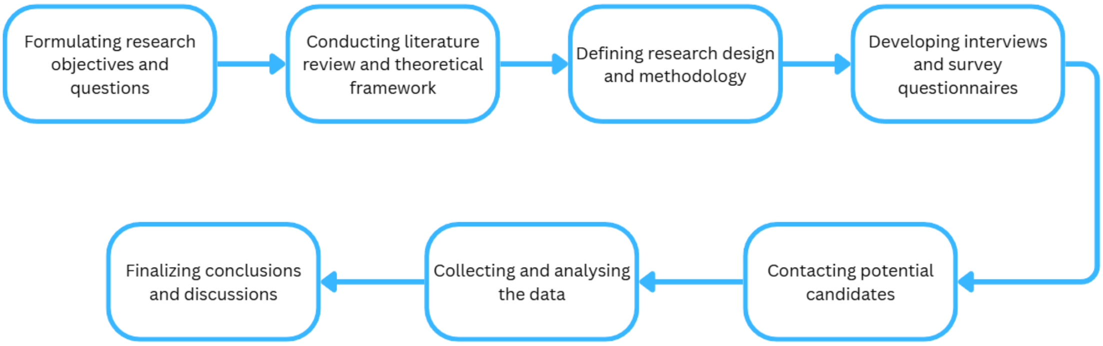


Figure 5. The research process of the study

3.2 Data collection process

3.2.1 Sampling

The study's objective is to evaluate the environmental impact, economic performance, and logistical efficiency of road freight and inland waterways transport. Therefore, the sampling criteria should be aligned with the research objectives to ensure coherence throughout the study.

Table 7. Sampling requirements of the study

Objective	Sampling requirements
1. Assess the environmental performance of the two modes	- Both local and multinational companies ensure comparison of environmental awareness, perception, and emissions measurement practices. - Logistics companies need to locate or have transportation service in Vietnam Southern region to understand the actual operations of transportation network in the South.
2. Evaluate the economic efficiency and cost-effectiveness of modal shift	- Logistics companies have at least one transportation service related to the objectives: road, inland waterways, or multimodal solution to ensure comparative evidence.
3. Analyze the logistical and infrastructure challenges, opportunities, and future trends	- The company size and capacity should be sufficient to understand the current challenges and have long-term strategy for sustainability.

Table 7 indicates the preset requirements before selecting the research samples for data collection. This study aims to collect the actual opinions and perspectives of operators, leaders, and senior management levels in logistics, transportation, and supply chain management. To understand the actual situations and current transport networks in the South, such as congestion, routing, port operations, and shipping references, the chosen companies should have solid experience in handling either road freight or inland waterways in the South. Local and multinational companies are welcome to ensure a comprehensive comparison of environmental awareness, priorities, and current practices. Additionally, the company should have sufficient capability and resources to enable inland waterways as a primary transport mode.

For that reason, purposive sampling is chosen as the main sampling technique in this study. This method is often used in qualitative analysis to reduce biases and strengthen reliability and quality of the results (Nyimbili & Nyimbili, 2024). In purposive sampling, the author chooses predefined criteria to select the sample for online surveys and interviews. In recent developments, researchers have started to apply basic sample size estimation tools such as Slovin's formula and online sample size calculators. The web-based tools offer a convenient, accessible way to estimate sample size based on defined parameters.

In this study, the companies are chosen based on their business operations, geographical service coverage, company types, and size. Table 8 below summarizes the defined criteria for choosing target companies.

Table 8. Sampling criteria of the study

Factor	**Criteria**
Business services	Logistics, trucking, inland waterways, or multimodal transport solutions
Geographical service coverage	Vietnam Southern Region
Company size	More than 200 employees
Company type	Local and multinational

After searching Vietnam's business directory for all current companies operating in the South of Vietnam in the manufacturing, trading, and retailing industries, there are approximately 261 logistics companies based in Ho Chi Minh City, the largest economic hub in the South. The results was then narrowed down to 16 companies that meet all the defined criteria. Each company will have one manager at the highest operational level for logistics services, and the company's size is estimated due to the confidential information from each company regarding the number of employees.

Table 9. Sampling population of the study

Company	Estimated employee	Company type	Key operations
Gemadept Logistics Corporation	1,570	Local (Vietnam)	Integrated ports and logistics provider, multimodal transport, container transport.
Transimex Logistics	244	Local (Vietnam)	Road freight forwarding, container trucking, warehousing.
Indo Trans Logistics (ITL)	1,000	Local (Vietnam)	Domestic trucking and 4PL services.
Sotrans (South Logistics)	1,200	Local (Vietnam)	Road freight forwarding and inland container depot services.
Bee Logistics	1,000	Local (Vietnam)	International freight forwarding, domestic trucking, and specialized cargo.
Vinafreight JSC	300	Local (Vietnam)	Road freight forwarding and container transport.
MP Logistics	500	Local (Vietnam)	International freight forwarding, domestic trucking, and specialized cargo.
Thamico Shipping	800	Local (Vietnam)	International freight forwarding, domestic trucking, and specialized cargo.
Vinatrans Logistics	500	Local (Vietnam)	International freight forwarding, domestic trucking, and specialized cargo.
A.N.C Company Limited - International Forwarder & Logistics	200	Local (Vietnam)	International freight forwarding, domestic trucking, and logistics consulting services.
Saigon Newport Corporation	1,000	Local (Vietnam)	Container trucking, logistics centers, marine and waterways services.
DHL (DP DHL Group)	1,500	Multinational (Germany)	Transport solutions, contract logistics, international freight forwarding, waterways transport.

DB Schenker Vietnam	1,000	Multinational (Germany)	International freight forwarding, domestic trucking and inland transport.
Nippon Express Vietnam	900	Multinational (Japan)	International freight forwarding and multimodal transport.
APL Logistics Vietnam	200	Multinational (Singapore)	Multimodal transport solutions and container trucking.
Maersk Vietnam	600	Multinational (Denmark)	International freight forwarding, domestic trucking, and inland transport.
Total	**12,514**		

From Table 9, the estimated population for logistics managers and operators is 16 and 12,514, respectively. The sample is calculated based on this number by using the online web-based tool from Survey Monkey, which is provided in the thesis information course by the University of Vaasa. The predefined parameters are a 90% confidence level and 5% margin of error. The result of the calculation is 267 online survey forms. Regarding semi-structured interviews, due to the limited time frame of the research, this study decided to choose a maximum of 10 participants to ensure the quality of analysis.

3.2.2 Questionnaires development

The questionnaires used for online surveys and interviews should fully cover the research objectives. Therefore, the questionnaires consist of three key factors: environment, economic, and logistical barriers to road and inland waterways transport. Additionally, the questionnaires use both open-ended and closed-ended questions to enable comparative analysis between these two modes. The questions are understandable, transparent, and concise for respondents to get more accurate and detailed responses. To measure respondents' perceptions, the online survey uses a 5-point Likert scale from Strongly Disagree to Strongly Agree, and the questions are grouped into four main categories: demographics, environment, cost, and logistics. At the end of the survey, optional open-ended questions are used to collect new ideas and share them with respondents about research topics.

Although the open-ended questions at the end of each section collect qualitative information from respondents, they are optional and depend on respondents' decision to answer. Therefore, this study primarily uses the 5-point Likert scale as its main data collection method, with closed-ended questions. Due to the practical limitations on time horizon, collecting and analyzing a large volume of qualitative data, such as opinion responses, would require lots of resources. The Likert scale provides a structured and efficient way to capture perceptions that can be measured and compared across respondents. The use of a Likert scale and a few open-ended questions at the end of the survey balances the research's objectives and limited resources by ensuring respondents answer all Likert-scale questions and contributing to additional insights in their own words.

The insights from online surveys are then verified and further investigated through semi-structured interviews with logistics managers with experience in handling multimodal decisions. The interview questions are arranged logically to create a convenient environment for sharing. The order starts with an introduction that provides the general background, context, and company services of the interviewee. Then the questions deepen into three research objectives: to understand the company's current transport strategies, and to examine the preferences and criteria for choosing transportation modes. Finally, the interview seeks to investigate the current barriers faced by logistics companies and to obtain recommendations from the operational level for implementing waterways transport. The long-term strategic outlook from logistics leaders about the potential of inland waterways transport in Vietnam is also discussed in this last part.

The questionnaires aim to investigate the viewpoints from four main perspectives. They are the company's internal strategy, the supply chain industry, individual opinions, and future outlook. By dividing the questions into different perspectives, all dimensions and factors that affect the company's strategies are addressed, then improving the clarity and flow of the interview. The questions also ensure the anonymity of the participants according to the confidential policy of the research. All the questions and interviews are held in both Vietnamese and English, which creates a convenient environment for learning and sharing. The details of the questionnaires are documented in the appendix.

3.3 Comparative analysis approach

3.3.1 Empirical route selection and assumptions

According to a VIWA (Vietnam Inland Waterways Administration) report, Vietnam has a complex network of highways, canals, and seaports from the north to the south. Therefore, choosing one specific corridor as the empirical example makes this study more focused on the comparison between road and inland waterways transport. In addition, a comparative analysis of the same routing allows the study to highlight the differences between road and inland waterway transport in real operation. Consequently, this study chose the route from Can Tho to Ho Chi Minh City as the benchmark for the data collection phase. This route is one of the key routes in the south, which contributes for the largest share of rice and container transport from Mekong Delta region to Ho Chi Minh City (Le & Tran, 2025). This empirical approach also allows researchers to conduct a detailed examination of variables that affect transport decision-making, such as travel distance, lead time, and operational bottlenecks.

Figure 6. Routing from Can Tho to Ho Chi Minh city via waterways system

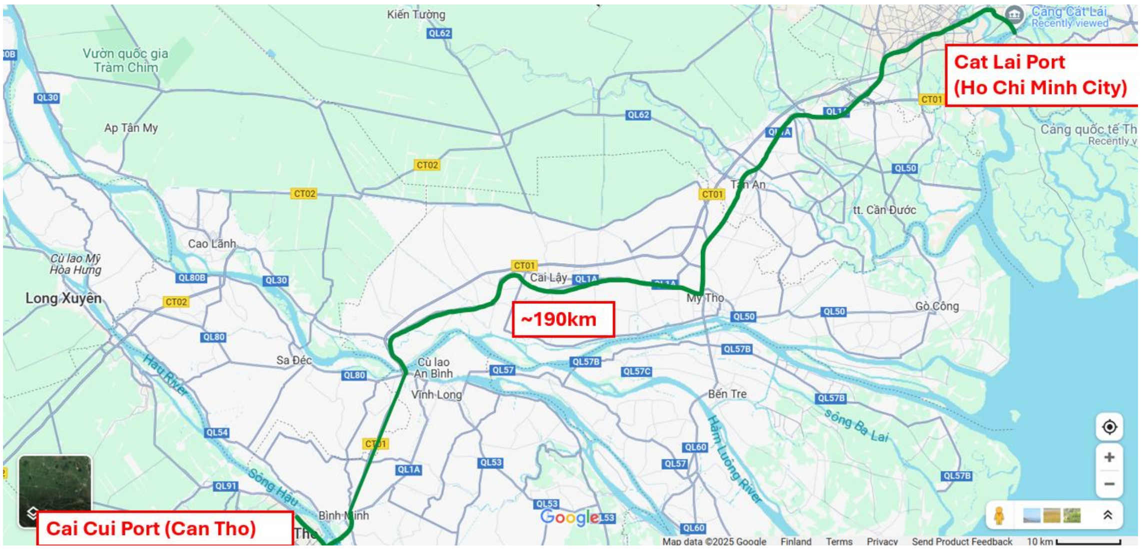


Figure 7. Routing from Can Tho to Ho Chi Minh City via road

Figures 6 and 7 indicate the route from Can Tho (Cai Cui Port) to Ho Chi Minh City (Cat Lai Port) with the estimated distance. Regarding the route via the waterways system, the total travel distance is about 190km via rivers and canals. Specifically, the route starts at Cai Cui Port, the Hau River, the Vam Nao River, the Mekong River, the Cho Gao canal, the Vam Co River, and the Soai Rap River, and finishes at Cat Lai Port. Road freight mainly uses the national highway route from Cai Cui Port to Cat Lai Port.

Waterborne vessels have sufficient capacity to handle various types of goods, including agricultural products, industrial materials, and containers. Therefore, this empirical example assumes that the two routes handle the same type of goods.

3.3.2 Performance evaluation

The performance metrics are used to align the questionnaires with the research objectives. These indicators are the key evaluation criteria to compare the performance of inland waterways and road transport. The metrics are reviewed and derived from previous academic papers and the transport assessment framework, as outlined in the literature review. The rationale of selecting the metrics from academic literature is to ensure the theoretical and practical aspects of the pre-set criteria. Particularly, the metrics are classified into four main dimensions: environmental impact, economic efficiency, logistical performance, and operational challenges.

Table 10. Performance evaluation metrics of transportation mode

Dimension	Criteria	Sources
Environmental impact	Noise pollution, accidents	(Hoang Phuong Nguyen & Van Tai Pham, 2020; Nguyen Thi Bich & Le Dinh, 2024), (Huy et al., 2023; Thi & Thi Thu, 2020).
	Fuel consumption, air pollution emissions	(Nga, 2025; C.-N. Wang, Le, Chang, et al., 2022).
	Road congestion	(T. V. Nguyen & Nguyen, 2020).
Economic efficiency	Cost performance	(C.-N. Wang et al., 2020), Pham Van et al., 2023), (Cang et al., 2021), (T. C. H. Nguyen & Nguyen, 2019).
	Capacity utilization, market accessibility	(Kabashkin, 2023) (Thi & Thi Thu, 2020), Pham Van et al., 2023).
	Cargo safety, damage and loss	(Calderón-Rivera et al., 2024a).
	Transport quality	(Gbako et al., 2025)
Logistical performance	Reliability, flexibility	(Thang & Tuan, 2025), (Paulauskas et al., 2022), (Thi & Thi Thu, 2020), (Gbako et al., 2025)
	Delivery lead time	(Dr. V. T. K. Hanh, 2021a), (Thi & Thi Thu, 2020)
Operational challenges	Financial	(Santén et al., 2021)
	Limited infrastructure	(T. V. Nguyen & Nguyen, 2020), (Phi & Dang, 2020)
	Lead time	(Dang et al., 2022)
	Weather variation	(Cang et al., 2021)

Table 10 summarizes the specific evaluation criteria from academic sources. Environmental indicators focus on the impact of transportation on the atmosphere and society, including noise pollution, road congestion, fuel consumption, and air emissions. Economic indicators address costs as the main criteria, with other associated factors such as space utilization, cargo safety, and special handling charges. While it is true that waterways transport offers the cheaper solution by transporting goods in bulk, perceptions among logistics operators may differ. For example, additional special handling charges at ports or terminals may increase total transportation costs. In addition, the trade-off between costs and other factors such as lead time or environmental protection may impact on the respondent’s opinions. Therefore, the measurement through a 5-point Likert scale can examine the acceptance and perception level of participants regarding these factors. Logistical efficiencies are metrics that are directly related to customer satisfaction levels. Road freight is associated with high reliability and flexibility in delivering from door-to-door to final customers, whereas the waterborne system must integrate with other modes of transport, such as road or maritime transport. Consequently, the reliability and flexibility of inland waterways transport might not be as good as those of road freight. However, this mode performs well with high cargo capacity and low time-sensitive shipments, making this mode suitable for customers who are seeking a transport solution to deliver bulk commodities such as coal or agricultural products. Finally, the questions aim to investigate the challenges facing the waterways system to fully understand the reason why this mode is still a challenging problem for small and medium logistics companies, despite being aware of the benefits in terms of cost and environmental performance. In a theoretical study, it has been shown through statistics that inland waterways provide a cheaper and greener solution; the actual barriers from a business perspective that are preventing the adoption are explored in this study.

3.3.3 Comparative techniques

Thematic Analysis and fundamental descriptive analysis are used to analyze the empirical data from online surveys and semi-structured interviews. All the results from online surveys and transcriptions from interviews are organized and structured in Excel. The statistical comparison between two modes is handled through descriptive analysis, while thematic analysis explains the hidden and detailed insights for investigation and verification of the survey’s results. The questions used in the online survey are mostly closed-ended with five options, indicating the degree to which they agree, prefer, or score the answers. Therefore, the nature of data in Likert scales can be divided into ordinal and interval data. Descriptive statistics can be used to measure the tendency or frequency of attitudes of respondents, such as computing the mean, median, and standard deviation for each statement. The information from surveys is gathered during interviews to get more information about the statement.

Regarding the transcription from interviews, Excel is used as the central database. The data is separated by each row and column based on themes and codes in thematic analysis. Thematic coding is the most common technique for analyzing qualitative information, grouping key insights under the exact words, patterns, or themes. From the thematic analysis, the researcher can find valuable insights supported to the research questions and objectives (Ahmed et al., 2025). This study follows Braun and Clarke's six steps of thematic analysis, including data familiarization, code generation, theme identification, theme revision, theme finalization, and insight presentation (Naeem et al., 2023).

Initially, the data is transcribed from the interview records for general understanding. This phase is crucial for developing an initial understanding on the data. During this phase, researchers take notes and select a potential quote or sentence to use in formulating the code and theme. The early notes might include repeated concerns about logistical and infrastructure challenges faced by logistics companies in implementing waterway transport, or the dominance of road freight due to its high reliability and flexibility. In the next step, keywords are selected to highlight the significant parts in the whole transcripts. The purpose of this step is to shorten the transcription, allowing researchers to focus on meaningful keywords. The code can be some keywords or phrases that represent an important part of the data (Naeem et al., 2023). For instance, the codes generated from the transcription include cost, congestion, weather fluctuations, emissions, or pollution. At this stage, the researcher also needs to avoid over-coding and inconsistencies in the code. Based on the similarities, the codes are then grouped into themes that clearly indicate meaningful patterns and relationships with the research objectives. Researchers also analyze the relationships among different codes. This stage provides the researcher with more solid understanding about the topics by connecting fragmented codes into concise themes. The themes should reflect the research objectives, such as "barriers to implement waterways transport" or "Environmental impacts of road transportation”. The fourth phase of thematic analysis is theme revision, in which themes defined in the previous step are evaluated to ensure their relevance to the research objectives and the extracted data. At this stage, the finalized themes should be coherent, consistent, and clearly differentiated from others (Ahmed et al., 2025). The theme name is reviewed and revised to be clear, descriptive, and meaningful. Finally, the researcher summarizes the findings and documents them in the thesis report. All the themes are explained and supported by evidence from the data and existing theories. The documentation may need to be rechecked to ensure completion of the analysis.

4 Results and findings

In this section, the results of the semi-structured interviews are analyzed to identify significant insights from transportation professionals regarding the situation of inland waterways in Southern Vietnam. The interview covers the current state of inland waterways transport in Southern Vietnam and the environmental benefits of this mode within overall transport solutions. Additionally, current challenges facing logistics enterprises are mentioned in the questionnaires. Finally, strategic recommendations are discussed to improve the operation of inland waterways transport.

4.1 Interview results analysis

There is a total of seven participants in this data collection process. The selected participants come from the logistics and supply chain sector, have at least 5 years of industry experience, and hold a leadership or managerial position. Some participants are primarily responsible for domestic transport, while others are experienced with international transport or last-mile delivery. The operational scope and participant summary are provided below. For confidentiality reasons, only the title and scope of work are shown in this research. The author approaches participants through a personal supply chain network and community on LinkedIn or email. Accordingly, the interview invitation, schedule, and questionnaires are sent in advance to ensure the interviewees have enough preparation to provide high-quality responses. All the interviews were conducted through Microsoft Teams so that the author could record and take notes on the transcript.

Table 11. Participant’s profile in data collection process

Interviewee	Title	Company	Years of experience	Interview date
1	Assistant Manager, Transportation	YCH Protrade	More than 8 years	10/09/2025
2	Regional Logistics Development Manager	DHL Supply Chain	More than 10 years	13/09/2025

3	Head of Vietnam Logistics Research and Development Institute	Vietnam Logistics Research and Development Institute (VLI)	More than 10 years	17/09/2025
4	Director	Vinatrans CanTho	More than 10 years	20/09/2025
5	Transport representatives at Mekong Delta region	Thami Shipping Corporation	More than 8 years	20/09/2025
4	Transportation planner	DB Schenker Vietnam	More than 5 years	25/09/2025
7	Area Environment and Sustainability and Quality Manager	Maersk Vietnam	More than 7 years	26/09/2025

Table 11 summarizes the general information for participants who agreed to take part in the data collection for this study. Most participants work in the logistics and transportation industry, except for one who works at the Vietnam Logistics Research and Development Institute (VLI). This individual has made significant contributions to the development of logistics in Vietnam, particularly inland waterways transport through numerous research and studies. Therefore, this individual's participation significantly contributed to the success of this research.

The interview records and transcripts were analyzed and summarized in a Word file for content analysis. Following the six steps of thematic analysis (Naeem et al., 2023), as mentioned in section 3.3.3, Figure 8 below graphically illustrates these steps.

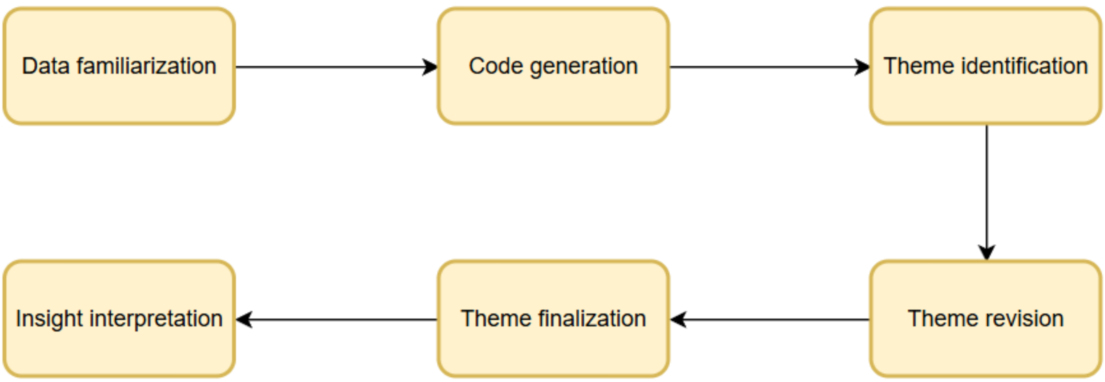


Figure 8. Thematic coding process (Naeem et al., 2023)

Initially, the author familiarizes with the data by listening to the recordings again and takes note of all key points and phrases related to the research objectives, such as “inland waterways are cheaper than road for bulk shipment” or “the customer will choose road freight for time-sensitive shipment and short lead-time”. Because all the interviews were conducted in local languages for convenience, the quotes and phrases were then translated from Vietnamese to English by the author to document in this thesis. This process is repeated until the author has a complete understanding of the recordings and can generate codes and themes. The code and theme must be relevant to the initial research questions and objectives to ensure the consistency of this study. Finally, six themes are identified based on the interview results.

Table 12. Thematic coding results from the interviews

Theme	**Sub-code**	**Example quote**	**Research objective**
Environmental awareness	Emissions sources	“Most trucks used diesel fuel, which remains the dominant energy source in freight transport.” **- Interviewee #1** “Barge is using diesel power” **- Interviewee #3**	Objective 1
	Environmental benefits of inland waterways	“In practice, waterway transport is the most environmentally friendly mode.” **- Interviewee #2**	
Economic and cost performance	Freight comparison	“From an economic perspective, they are also more cost-efficient because freight rates are consistently the lowest.”” - **Interviewee #2**	Objective 2
	Handling and transshipment costs	“Multiple handling operations and limited port access increase the total logistics cost**.” - Interviewee #4**	
	Fuel efficiency	“Some companies are concerned about fuel consumption, so they often switch to waterways, rail, or invest in EURO 3 or EURO 4 trucks” **- Interviewee #1**	
	Transport mode decision	“Waterway transport is suitable for standardized packaging shipment that can be loaded	

		into containers" **- Interviewee #6**	
Logistical and infrastructure constraints	Financial investment and infrastructure constraints	"Given their limited financial capacity and competitiveness, many Vietnamese enterprises currently find it challenging to adopt low-carbon logistics solutions across their supply chains." **- Interviewee #7**	Objective 3
	Port capacity and congestion	"Inland waterway transport faces limitations in port availability and door-to-door connectivity" **- Interviewee #4** "There is a lack of modern river ports and nearby ICD facilities, which limits logistics efficiency." **- Interviewee #5**	
	Waterways conditions and scheduling bottlenecks	"Inland waterways face operational bottlenecks and congestion, especially at Cho Gao Canal" **- Interviewee #3** "Shallow navigation channels during the dry season often cause grounding issues and operational delays." **- Interviewee #5**	
Customer and business behavior	Customer preference	"Customers are accustomed to using trucks because they are fast, flexible, and easy to control" **- Interviewee #5**	Objective 2 and 3
	Business behavior and attention	"From my observation, only a few Vietnamese companies actually consider sustainability in their logistics operations." **- Interviewee #6**	
	Lack of environmental awareness	"In terms of sustainability awareness, public knowledge remains limited, most people only know about recyclable packaging or biodegradable materials such as paper or leaf-based products." **- Interviewee #2**	
Future opportunities	Government investment and policy	"Many projects have been raised for funding, such as World Bank project to improve inland waterways corridors, I was in the core team from 2017 to plan for the project	Objective 3

		and it was approved in May this year" **- Interviewee #3**	
	Sustainability roadmap	"Vietnam has committed to achieving net-zero emissions by 2025." **- Interviewee #6**	
Practical practices and solution recommendation	Electrification initiatives	"In the inland waterway sector, we are also planning to develop and deploy electric barges to enhance environmental performance." **- Interviewee #7**	Objective 3
	Business motivation	"Market pressure, social awareness, and overall societal development level play key roles in shaping the entire supply chain, with government policy acting as a critical driver" **- Interviewee #2**	
	Customer awareness and segmentation	"Most shippers are not logistics experts, and they prefer road transport because trucks are fast and convenient" **- Interviewee #3**	

Table 12 summarizes the main themes, codes, example quotes, and related research questions to create the linkage and coherence between themes and research objectives. The complete theme identification is shown in Appendix 2, with more related quotes.

Theme 1 focuses on environmental awareness, including sources of emissions and the environmental benefits of inland waterways. This theme supports objective one by highlighting diesel-powered truck engine emissions and the benefits of inland waterways transport in reducing them. As the objective of this study is to investigate the environmental potential of waterway transport, it is necessary to examine interview insights to support this objective.

Theme 2 concerns economic and cost performance and relates to objective 2. In this theme, freight costs, fuel efficiency, and transport mode decisions are the primary focus. By exploring the cost differences and factors that lead to the modal decision, this theme supports objective 2 by identifying the differences and strengths of each mode across the entire transportation operation. All the insights provide a high-level view of each mode to improve utilization.

Theme 3 is logistical and infrastructure constraints. In this theme, typical financial and operational constraints, such as port capacity, congestion, and strategic scheduling, are discussed. Therefore, this theme directly contributes to objective 3 of the research.

Theme 4 is customer and business behavior. These are the new findings from the interviews, in which most participants mentioned preferences and perceptions from both the customer and business sides regarding inland waterways transport and the transition to green logistics. Therefore, this theme is connected to objectives 2 and 3 by identifying the current limitations of internal operations or the customer working mindset. When the current challenges and customer needs are properly addressed, the business can provide suitable solutions.

Theme 5 is future opportunities, in which the government's investment effort and roadmap are mentioned. Specifically, these future opportunities play a critical role in driving the national supply chain toward a sustainable, positive direction.

Finally, theme 6 presents recommendations from interviewees to improve the current situation of inland waterways transport. As stated at the beginning, this study focuses on the operational level rather than the national level. Therefore, the strategic recommendations include a plan for electrification, driving business motivation, and customer segmentation. Business motivation and customer segmentation are directly related to aligning business value with customer needs.

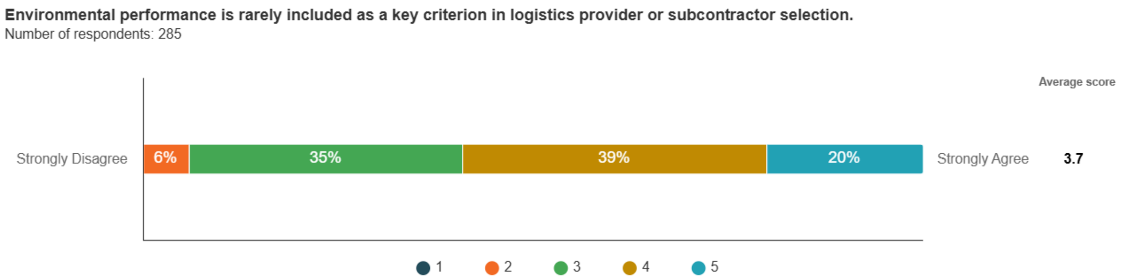
From the logistics perspective, all participants agreed on the environmental benefits of waterways shipping, particularly inland waterways transport, which results in lower energy and emissions. Inland waterways can be a viable solution for integrating into multimodal transportation. When asked about the environmental benefits of waterways transport, all participants gave similar answers about the cost and emissions reductions compared to road freight. This similarity highlights the potential for future development of inland waterways transport to leverage those advantages for economic and environmental benefits and to reduce the overuse of road freight in domestic transport, especially in southern regions. This region has witnessed a significant growth in urbanization and industrialization in recent years, particularly in Ho Chi Minh City and Binh Duong Province (Huyen et al., 2024). They also highlighted that the use of inland waterway transport in Vietnam continues to face many challenges. In general, most multinational logistics companies with Foreign Direct Investment (FDI) have already acknowledged the high environmental emissions from road freight and implemented many initiatives to reduce truck emissions, such as investing in EURO IV and EURO V trucks, electric vehicles, and waterway shipping. However, for small and medium logistics enterprises, sustainable investment is a significant challenge. The main reasons for these small companies are financial constraints and operational preferences (Pham Van et al., 2023). Carbon emissions and environmental protection are not top priorities for these domestic companies, as they rely on road freight to compete with multinational enterprises on cost and delivery speed. This modal choice is also related to end-customers' behavior, which has been shown to favor low-cost, fast delivery (Phuong, 2025).

The existing studies and interview findings highlight the importance of ideas and direction in shaping the strategies of the entire business. The business strategy is identified based on the customer demands, business capability, and market competition. This explains why small logistics companies prioritize economic growth over sustainable development, while large firms balance operational excellence with environmental protection. Based on the business strategy and internal resources, appropriate solutions are implemented to reduce emissions. One participant also highlighted the importance of business direction in waterways shipping to reduce unit costs and emissions, using examples from the Zara and H&M fashion industries. In the interview, different strategies from Zara and H&M were discussed, with Zara focusing on fast in-store fulfillment and low inventory and using airfreight as the primary transportation mode.

On the other hand, H&M focused on the sustainability of its products. This company used ocean freight as its primary mode to reduce unit costs and emissions. The interviewee also stated that air freight has the highest emissions, and waterways shipping is the most environmentally friendly shipping mode. In another interview with the head of VLI, the case study of using inland waterways transport during the COVID-19 pandemic was shared. Because of lockdowns and road restrictions, trucks could not operate normally at that time, so logistics companies had to shift the volume to another mode: inland waterways. Initially, inland waterways received little attention from either customers or logistics companies. Through many pilots, customers gradually accepted this mode as an alternative to road freight and realized greater economic and environmental benefits from inland waterways. This finding supports the previous work by Dang et al. (2022) on the development of the waterways system during the COVID-19 pandemic in Vietnam. In this study, the author noted that waterways transport had the least impact during the pandemic, which maintained a high resilience level. This is due to the less human interaction and fewer road traffic restrictions. The case example and findings about the performance of inland waterways during the COVID-19 pandemic highlight two points. First, customer requirements are important for every transport decision. Second, while customers require fast delivery (Phuong, 2025), that behavior is changeable if they see the benefits from the solution. Consequently, customer acceptance of the transportation mode is a key driver of future inland waterways development.

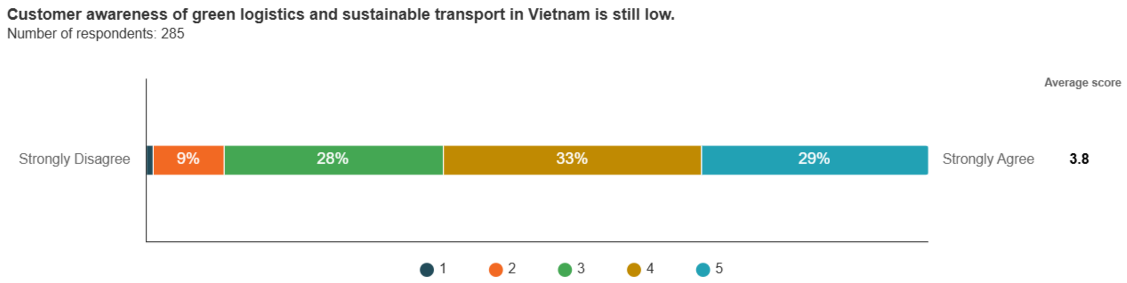
As stated above, customers’ requirements are crucial to every logistics enterprise. From a business perspective, they provide all transport solutions for customers and then follow the customer’s decision. However, due to local customers' limited awareness of sustainability, it remains low, leading to underutilization of other modes such as rail or inland waterways transport to reduce road freight emissions. From the local customer’s perspective, environmental shipping modes are not considered a high priority, customers prefer a fast, flexible delivery mode that uses road freight to leverage highway infrastructure and strong connectivity. In terms of sustainable initiatives, customers’ awareness is limited to the use of recycled materials or one-time-use packaging. This is because Vietnam is still a developing country, where environmental awareness is lower than in other developed countries and regions, such as European countries and Singapore. Consequently, more campaigns could be conducted in the future to raise customer awareness.

The insight into customer behavior is strengthened by survey results showing that customer awareness of sustainability in Vietnam remains low. Specifically, there are questions addressing the customer awareness of environmental protection. Figures 9 and 10 below show the average score of 3.7–3.8, with around 59% of respondents agreeing that low customer awareness leads to the neglect of environmental performance in selecting logistics service providers. Customer decisions are directly connected to business motivation and transport mode decisions. According to Kotlars & Skribans (2025), logistics companies face pressure from government and customers in their operational strategies. In section 4.3 about the practical solution theme, the suitable approach for customers' needs is discussed to increase awareness of sustainable transport in Vietnam.



	1	2	3	4	5		Total	Average	Median
Strongly Disagree	1	17	101	110	56	Strongly Agree	285	3.7	4.0
	0.4%	6.0%	35.4%	38.6%	19.6%				
Total	**1**	**17**	**101**	**110**	**56**		**285**	**3.7**	**4.0**

Figure 9. Perception of environmental performance as a criterion in logistics service selection



	1	2	3	4	5		Total	Average	Median
Strongly Disagree	3	25	81	93	83	Strongly Agree	285	3.8	4.0
	1.1%	8.8%	28.4%	32.6%	29.1%				
Total	**3**	**25**	**81**	**93**	**83**		**285**	**3.8**	**4.0**

Figure 10. Perception of customer awareness of sustainable transport in Vietnam

Lead time, freight rates, and flexibility are also consensus points in the interview results. The empirical route used in this thesis, which is the route from Can Tho to Ho Chi Minh City, was also raised in the interview. In general, it takes about 5 hours from Can Tho to Ho Chi Minh City by road, while the lead time can be up to 15 hours via waterways systems. Despite congestion, the overall lead time for road freight is still higher than that for inland waterways transport. As a result, road freight often receives higher priority in last-mile delivery due to its high flexibility. At the same time, inland waterways are better suited for long-haul, non-time-sensitive shipments. In addition, waterway transport offers substantial advantages in shipment consolidation, where one barge can replace more than 10 container trucks, reducing transportation costs per unit. The interviewees also highlight that, in some cases, finding tractors for more than 10 containers at once is difficult and costly, and that barge transport is the most optimal solution. For instance, the agricultural supplier located in Can Tho wants to transport a bulk shipment to Cat Lai port in Ho Chi Minh City for exporting, they will prefer choosing a barge to utilize waterways via the Tien and Hau Rivers to Cat Lai port (refer to figures 6 and 7 for the routing) rather than finding many containers. Besides cost reduction, another reason leading to this behavior is the complexity and quality of the documentation process. Due to poor documentation in some developing ports, such as the Cai Cui port in Can Tho, some suppliers may prefer all activities to be performed at Cat Lai port in Ho Chi Minh City, which has professional staff to handle export documents and container loading. While barge transportation reduces transportation costs per unit, transportation planners need to account for the handling fee at each transshipment. In road transportation, there are only two loading and unloading points, whereas there can be more than four if transported by barge. The increase in handling activities can raise total transportation costs by increasing resource and equipment expenses at each handling point.

The qualitative analysis of the interviews clearly presents the characteristics of each mode under appropriate conditions, such as shipment characteristics, distance, and cost-saving opportunities. To understand the preferences of logistics operators who handle transportation operations every day regarding the choice of inland waterways transport, some common conditions are preset in the survey, and respondents need to choose which conditions they prefer for inland waterways transport over road freight.

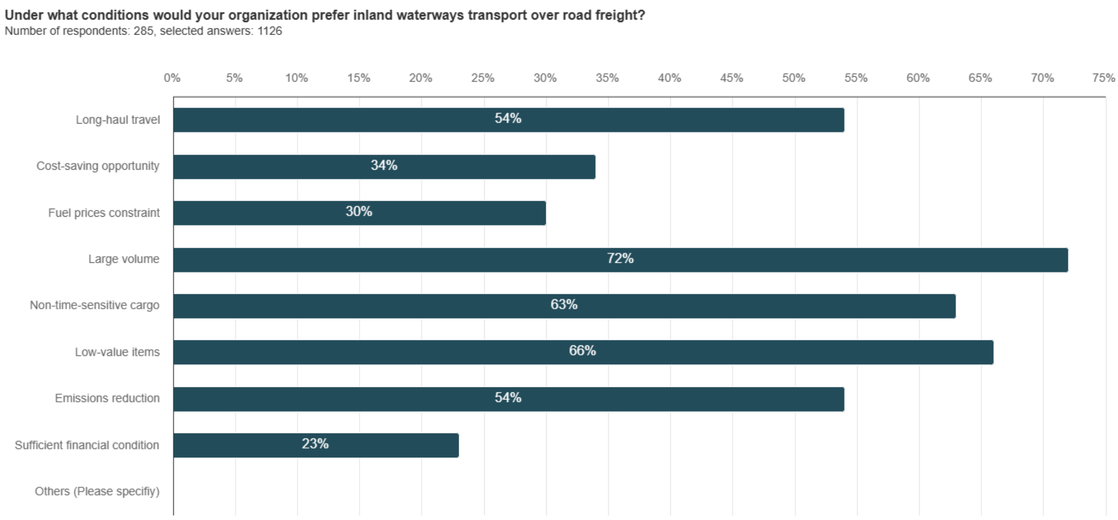


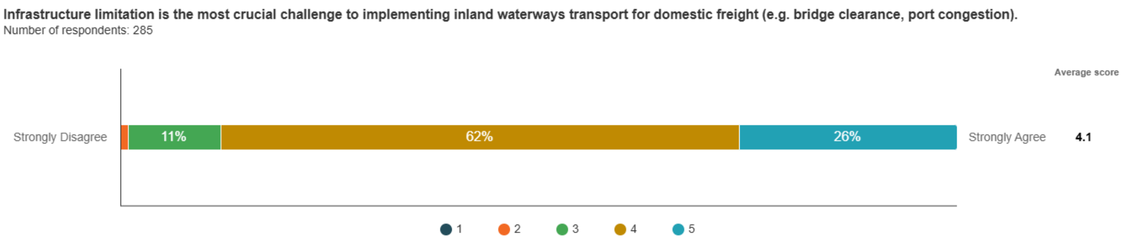
Figure 11. Conditions of choosing inland waterways transport

Figure 11 shows the survey results, in which most choose large-volume, low-value items and non-time-sensitive cargo, with 72%, 66%, and 63%, respectively. This result indicates that the key drivers come from operational matters rather than environmental or financial concerns, reflecting the practical preference in the logistics industry. Indeed, when considering the transportation mode for a specific type of shipment, the mode must first be suitable for the shipment's characteristics. In this case, bulky, low-value items are ideal for inland waterway transport because they can leverage the large capacity of a barge to consolidate shipments. Transit time is also important for meeting customers requested delivery dates. This is why non-time-sensitive conditions receive high priority when choosing inland waterways. Following the emissions reduction factor, long-haul travel at 54% shows moderate awareness among logistics operators of the environmental benefits of inland waterways transport over long distances in reducing environmental impacts.

In conclusion, inland waterways have their own strengths and can coordinate with road freight to create the optimal transport solution for customers, in which waterways transport can be used for large shipments over long distances to reduce costs, and trucks are used for last-mile delivery to maximize flexibility and connectivity.

4.2 Challenges and opportunities for inland waterways in Vietnam's southern region

Infrastructural, natural, behavioral, and internal challenges are discussed in the interviews to identify the most common obstacles to businesses adopting inland waterways transport in Vietnam's southern region. First, the capacity and modernization of inland waterways depots are very limited, leading to congestion when many barges arrive at once. This is due to resource limitations, working equipment such as forklifts and cranes, and a poor documentation process. To be more specific, one participant highlighted that inadequate port facilities at some small ports in the south, such as My Thoi port in An Giang and Cai Cui port in Can Tho, are a significant bottleneck for inland waterways management. At each port, the slow administrative procedures also prolong the lead time for waterway transport. For example, the administrative staff at small ports can handle only about 20–30 sets of documents per hour, resulting in long wait times at the port. The poor connectivity between the road and the waterways port also causes a delay in lead time. As shared by the Sustainable and Quality Manager at Maersk, the route connecting the highway with ports in Ho Chi Minh City often faces severe congestion every day. So even if the barge arrives on time and all documentation processes go smoothly, logistics still cannot meet the delivery time to customers due to congestion.

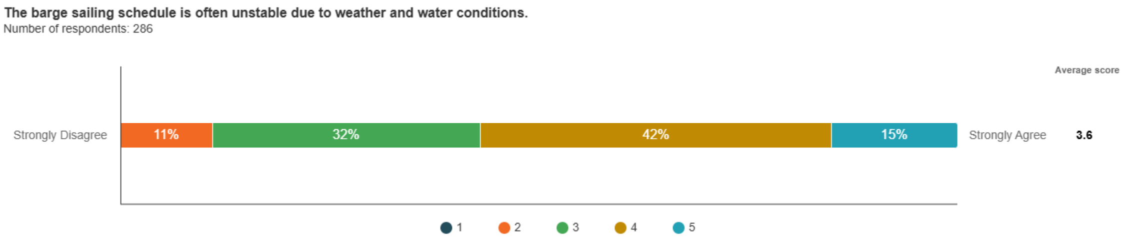


	1	2	3	4	5		Total	Average	Median
Strongly Disagree	0	3	31	176	75	Strongly Agree	285	4.1	4.0
	0.0%	1.0%	10.9%	61.8%	26.3%				
Total	**0**	**3**	**31**	**176**	**75**		**285**	**4.1**	**4.0**

Figure 12. Infrastructure challenges of inland waterways transport

Figure 12 highlights the same results with qualitative insights that about 88% of respondents agree on the infrastructure challenges of inland waterways. These challenges have been mentioned in many existing studies of inland waterways transport in Vietnam. Specifically, T. V. Nguyen & Nguyen (2020) mentioned the importance of port facility development to improve connectivity for import and export operations. Poor port facility causes severe delays in waiting time for loading and unloading, leading to late delivery to customers.

Weather constraints are another factor that prolongs delivery time because weather conditions and water level fluctuations directly impact barge operations in the waterway system (Cang et al., 2021). Although many attempts have been made to dredge canals, they still experience alluvial deposition every year due to natural weather conditions in Vietnam. Taking the Cho Gao canal as an example, because this is the critical canal for inland waterways transport in the south to connect the Mekong Delta region with Ho Chi Minh City, this canal is sedimented every year. Vietnam Inland Waterways Administration (VIWA) needs to have an outsourced operator to dredge the canal so that barges can operate as usual in this canal. The Cho Gao canal also experiences congestion during the peak season, when multiple barges and vessels operate simultaneously, resulting in significant transportation delays. Besides sedimentation and congestion, tides are the other natural challenges to inland waterways transport in Vietnam. The tide cannot be too low or too high because when the tide is too low, barges cannot pass the canals, but when the tide is too high, the maximum height of shipment on a barge can reach the minimum height of bridge clearance, creating a high risk of collision. Therefore, tides are a critical factor in the schedule of the inland waterways in Vietnam.



	1	2	3	4	5		Total	Average	Median
Strongly Disagree	0	32	90	120	44	Strongly Agree	286	3.6	4.0
	0.0%	11.2%	31.5%	41.9%	15.4%				
Total	**0**	**32**	**90**	**120**	**44**		**286**	**3.6**	**4.0**

Figure 13. Impact of weather and water conditions on barge sailing schedule

The survey results in Figure 13 highlight that more than 57% of logistics operators agree on the instability of the sailing schedule due to water fluctuations, with an average score of 3.6. This finding from surveys and interviews presents a significant operational vulnerability of inland waterways transport in Vietnam. Although the advantages of canal networks support the waterways systems of canal networks (Huy et al., 2023), natural risks such as rainfall, sedimentation, and tidal variations are still present. Such fluctuations can result in the rescheduling of barge operations and potential delays in cargo delivery. To reduce the risk of delays, companies can anticipate delays in advance and maintain buffer inventory or adjust transit times to customers.

These infrastructural and natural challenges lead to the reluctance to change in some small to medium logistics enterprises (SMEs) in which road freight is their primary transport solution. One reason is that they are familiar with their road freight operations and tend to avoid adopting new inland waterways solutions due to the many risks and complexities involved in the procedures. From the viewpoint of SMEs, cost and lead time are their two main competitive advantages over other logistics giants, such as Maersk, DHL Supply Chain, or DB Schenker. Therefore, even with the risks of delay from canal congestion and water fluctuations remaining, most SMEs are hesitant to use inland waterways transport as an alternative.

Finally, from the internal companies' perspective, financial and resource challenges are the main constraints for SMEs to adopt green logistics transition. These SMEs face financial challenges, such as initial investment, piloting fee, and additional transshipment expenses, when implementing the new inland waterways services (Santén et al., 2021). Vietnam's economy is in a developing process and in the early global integration phase, in which most SMEs choose to prioritize economic growth rather than concentrating on environmental concerns. Additionally, due to a lack of investment, most logistics service providers face difficulty funding green technologies such as electric vehicles, EURO trucks, or cleaner transport modes. Consequently, domestic logistics providers are limited by financial conditions and economic competition. Once the revenue and business growth of logistics companies are stable and secure, environmental awareness will improve accordingly. This is why only global enterprises are adopting environmental standards, such as emissions reductions through mode transition or green energy, because these companies need to comply with their global emissions standards. Taking Maersk as an example, Maersk has its own strategy for sustainable strategy in Vietnam to reduce the emissions target for scope 1 & 2 by 96% and scope three by 90% by 2040, which is 10 years before Vietnam's national strategy to reach net-zero in 2050. As shared in the interview, Maersk is focusing on electrification in the Vietnamese market, including electric vehicles for road freight and electric barges for inland waterways transport. However, the interviewee highlighted that the electric infrastructure is a significant challenge for electrification in Vietnam, including battery storage and charging stations. Therefore, a diesel barge is the primary mode of inland waterway transport in Vietnam.

Regarding resource capability, SMEs are lacking the professional expertise to implement sustainable transport and inland waterways operations in Vietnam's southern region. Indeed, sustainable awareness has increased slightly from the past, so the ability of transport planners to plan, design, and develop multimodal transport between roads and inland waterways remains limited. This is linked to the reluctance to change in the majority of SMEs stated above, where staff are familiar with trucking and hesitate to explore new inland waterways solutions, which require managing barge schedules, collaborating with barge operators, and managing emissions.

The existing constraints on infrastructure and logistical efficiency reflect that Vietnam's sustainable development is still in the developing phase. However, Vietnam is making significant progress toward sustainable development and economic growth through government policies and investments. These factors reflect the ESG framework from a sustainable perspective, which includes environment, social, and governance dimensions. Currently, environmental protection is limited by the overuse of road freight on highways, resulting in high atmospheric emissions. However, the social awareness from customers and small logistics companies is still low. From the national policy perspective, the government has already set the target to reduce the overall greenhouse gas emissions from domestic transport and invest in waterways infrastructure, such as digitalization and bridge clearance (World Bank, 2025). These fundings and investments highlight the efforts from governments to balance three pillars in ESG to achieve long-term development.

Overall, while inland waterways face many internal and external challenges from infrastructure, nature, and the company's resources, the environmental and economic benefits of this mode are being recognized in Vietnam's logistics community. With that potential, the government is encouraging inland waterways through a development roadmap for waterways corridors to improve connectivity and bridge clearance, thereby increasing the volume of shipments on waterways.

4.3 Potential strategies to improve inland waterways into operations

This section examines the recommendations and practices of the interviewees and logistics operators regarding their current and future business direction. The participants were asked about recommendations based on their expertise and experience to increase the utilization of inland waterways transport in Vietnam's southern region.

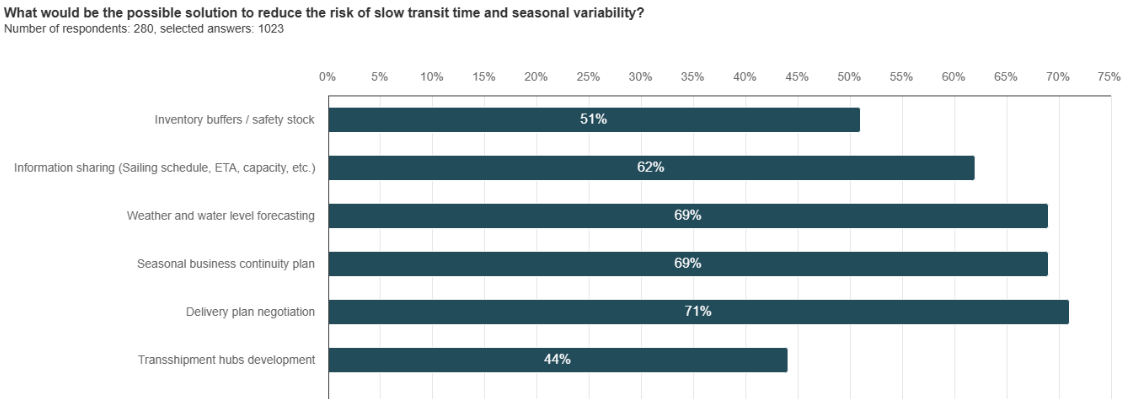


Figure 14. Possible solutions to reduce the risk of slow transit time and seasonal variability

Firstly, the survey asked for possible solutions to mitigate the delay risks of slow transit times and seasonal variability; the results are shown in Figure 14. From the logistics operators' perspective, the respondents gave more attributes to delivery plan negotiation, weather and water level forecasting, and seasonal business continuity plan, with the average percentage of 71%, 69%, and 69%, respectively. The results highlight respondents' proactivity in preventing delays in inland waterways transport before they occur. Delivery plan negotiation is a practical solution in daily operations when communication and data sharing are important for maintaining a high service level for customers. Through negotiation, logistics operators inform customers of the risks in advance and discuss a suitable delivery plan with a buffer lead time. For example, due to the risks of port congestion or rainfall, logistics companies inform customers that this shipment might be delayed by 1 or 2 days if they choose inland waterway transport. If the buffer delivery time is still in the acceptable range, the customers will take the risk, otherwise, other modes such as road freight are chosen. Weather forecasting and seasonal continuity plans are also practical solutions in predictive analytics to predict the risk before it happens. By collecting data on weather forecasts and variations, logistics planners can identify patterns in weather fluctuations and develop a suitable plan. In addition, during the interview, the participants highlighted the need for a backup plan in transportation planning. This is the continuity plan mentioned in the surveys to keep the business running in the event of disruptions.

Second, with the gradual shift towards sustainable development from the Vietnamese government, logistics companies are forced to consider inland waterways transport in the future instead of focusing only on the traditional road freight. Due to the low volume, domestic logistics enterprises can collaborate to optimize barge consolidation to provide more schedules for customers. As discussed during the interview, the strength of barge transport is its ability to handle high volumes, reducing emissions and costs per unit. Consolidating volume from different logistics companies can reduce overall costs accordingly. As a result, customers will have more flexibility in choosing the mode and schedule. Customer satisfaction is the end goal of every supply chain and logistics operation. Therefore, it is necessary to view road freight and inland waterways as complementary elements that support each other with their own strengths to offer customers the optimal transport solution. Once customer satisfaction is achieved, the next step is to raise awareness among customers about green transportation by showing the long-term benefits of inland waterways transport to the environment and logistics costs

Customers and the government are two key drivers that strongly influence business operations. With highly demanding customers in sustainability, logistics companies must demonstrate their sustainable practices across logistics operations, including transportation modes, contractor selection, and carrier management. These customers are generally willing to pay more to have sustainable solutions. At the same time, other small customers with limited budgets tend to choose the cheapest and fastest solution and have no high requirements for sustainable measurement. During the interviews, it is admitted that domestic companies rarely consider emissions and environmental protection unless customers require it. Consequently, one potential approach is customer segmentation. The participants emphasize the importance of understanding customer behavior and requirements before designing solutions. In the sustainable context, customer segmentation will be based on customers' environmental awareness. As one interviewee explained, the customers are categorized into four main groups from one to four based on the maturity of environmental awareness, from low to high. Level 4 customers have a high level of understanding and sustainable strategies in their operations, while levels 1 and 2 are developing clients. For these customers in levels 1 or 2, it is necessary to understand their challenges towards sustainability to provide a suitable solution. Customer segmentation not only allows logistics companies to improve solution design and communication but also matches the appropriate price and value to each customer group. Ultimately, this approach strengthens stakeholder relationships and widens the potential of inland waterways transport for sustainable logistics.

Finally, effective communication campaigns are also important for raising awareness among customers and domestic logistics providers about environmental protection and sustainability. The interviews reveal that some small companies and customers in the Mekong Delta region remain unaware of the practical and environmental benefits of inland waterways. The communication campaigns approach can help the government and logistics association in Vietnam accelerate awareness and the multimodal solutions between road and inland waterways transport. In addition, collaborative communication from stakeholders such as governments, logistics associations, and logistics services providers is essential to create the long-term impact of sustainable logistics solutions to align with national development goals towards global sustainable standards. In conclusion, to create effective communication awareness, multi-level collaboration is critical to raise awareness, reshape the current perception of traditional transport, and foster the modal shift towards sustainable inland waterways transport.

5 Comparative performance analysis

This chapter analyzes the results of a survey to compare the performance of road freight and inland waterways in terms of environmental and economic performance. The survey was developed using a 5-point Likert scale to allow respondents to rate their perceptions of the given statement and comparison matrix. The survey was sent to logistics, transportation, and supply chain executives to ensure they had sufficient knowledge to provide answers. The results for 286 respondents were generated on the Webropol survey platform after data collection. In the following sections, the environmental performance section focuses on opinions regarding emissions and energy consumption, while the economic performance section focuses on ratings of cost elements to support better decision-making.

5.1 Environmental performance

5.1.1 Emissions analysis

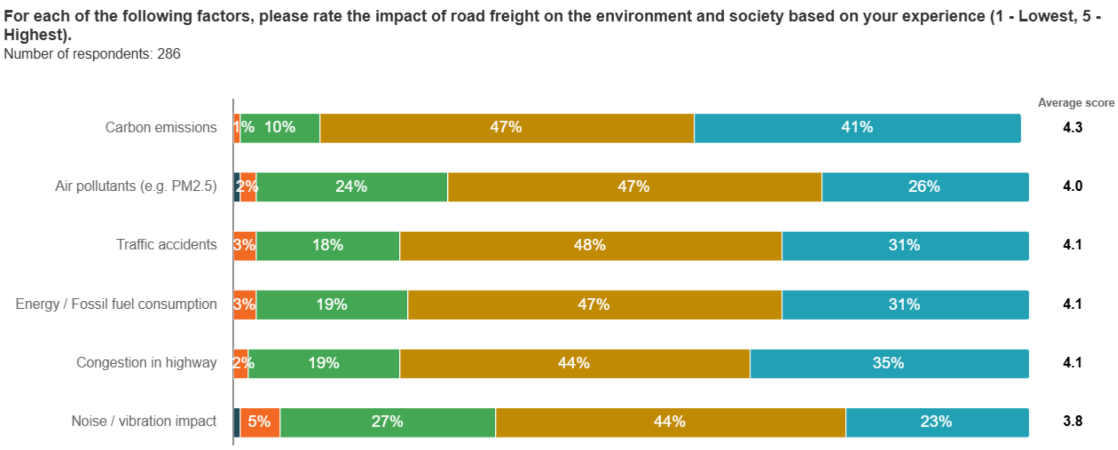


Figure 15. Impact of road freight on the environment and society

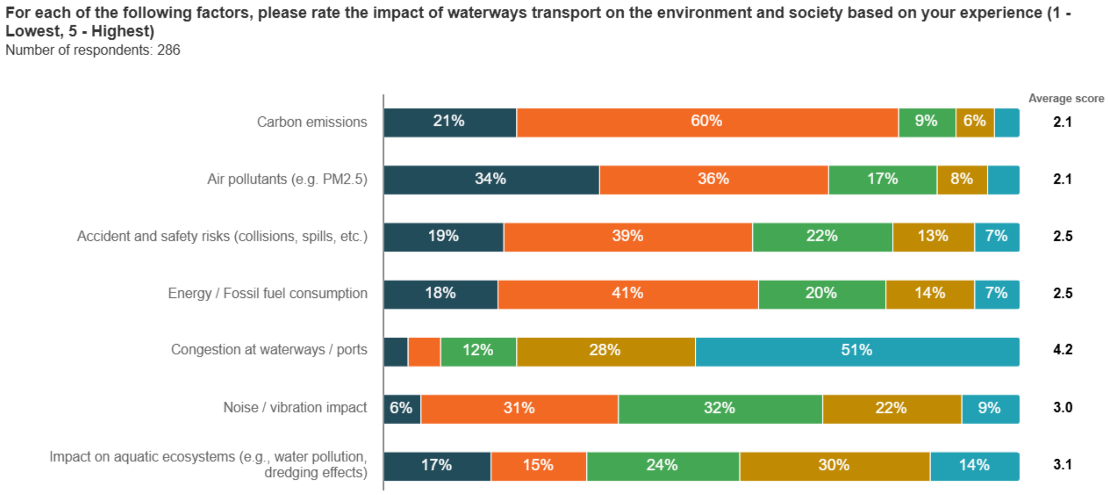
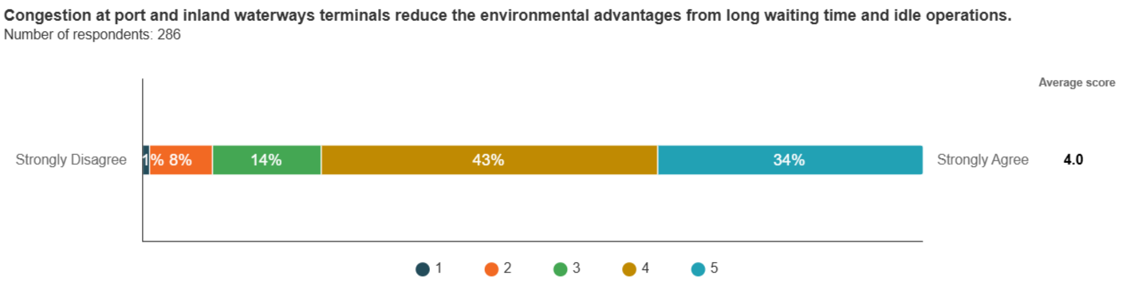


Figure 16. Impact of inland waterways transport on the environment and society

Figures 15 and 16 show the environmental impacts of road freight and inland waterways. When respondents were asked to rate the impact on a 5-point Likert scale from lowest to highest, the results show that road freight has the highest carbon emissions and air pollution, with average scores of 4.3 and 4.0, respectively. On the other hand, the scores for these factors of inland waterways are only 2.1 points on average. The lower emissions of inland waterways align with existing research by Bu and Nachtmann (2023), who reported that inland waterway transport in Asia has strong potential to reduce overall emissions by 40–60% compared to truck operations. Wang et al. (2020) also pointed out that the environmental dimension is a significant strength of inland waterways. This result aligns well with the interview findings that road freight has higher emissions than inland waterways. This high emissions level comes from the extensive use of road freight for domestic transportation in Vietnam. The higher emissions from road freight reflect Vietnam's dependence on diesel trucks and lack of alternative solutions. This is due to the green transformation in transportation infrastructure in Vietnam being slower than the boost of international trade and agreements from Vietnam's government in recent years to boost economic growth, leading to the dominance of road freight as of now (Thang & Tuan, 2025). In the Vietnam transportation sector, about 60-70% freight volume is handled by trucks, and most trucks used are diesel-powered with the EURO II standard only, which are aging and poorly maintained (Thi & Thi Thu, 2020). These trucks produce higher emissions, according to surveys and qualitative insights.

In addition to direct emissions from vehicle engines, the survey also asked respondents to rate their perceptions of environmental efficiency, including congestion, noise, and idle waiting time. Specifically, the results for road freight on traffic accidents, highway congestion, and noise impact are 4.1, 4.1, and 3.8, respectively. As shown on the bar chart, the majority of respondents rate the impact of these factors at 4 and 5 points, indicating the high impact of road freight on society.

Regarding inland waterways transport, while this mode shows lower rates of traffic accidents (Mean = 2.5) and vibration impact, the respondents highlight the challenge of congestion at waterway ports, with an average of 4.2. Additionally, more than 70% respondents agree with the statement: "Congestion at port and inland waterways terminals reduces the environmental advantages from long waiting time and idle operations", as shown in Figure 17.



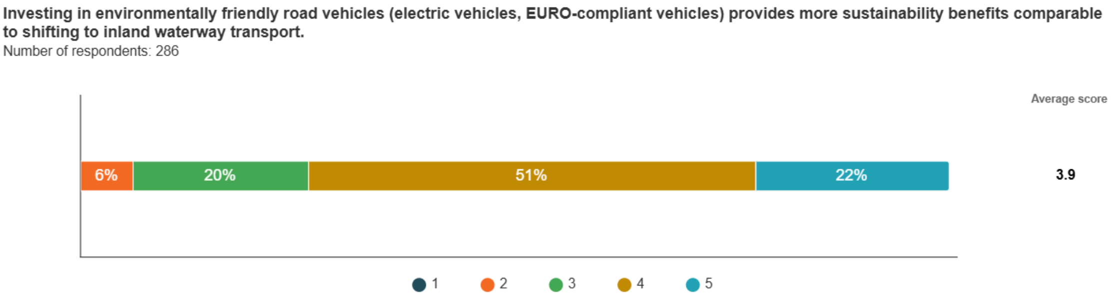
	1	2	3	4	5		Total	Average	Median
Strongly Disagree	2	22	39	124	99	Strongly Agree	286	4.0	4.0
	0.7%	7.7%	13.6%	43.4%	34.6%				
Total	2	22	39	124	99		286	4.0	4.0

Figure 17. Results of congestion at port and terminal impact on waiting time and idle operation

The results suggest that the current congestion issue at Vietnam's ports is serious and widely recognized by all logistics operators. This is explained by the semi-structured interviews, which indicate that there is significant congestion and long queues at some terminals in the south, such as Cat Lai port in Ho Chi Minh City. In conclusion, while the reduction in emissions, pollutants, and accidents can be seen as significant advantages of waterway transport, the survey shows localized concerns about waterway operations at the port, which reduce the attractiveness of this mode. These unstable operations and congestion reduce the environmental efficiency. Moreover, barges in Vietnam still rely on conventional diesel power, resulting in the underutilization of the full environmental benefits of this mode. Through the lens of three pillars: Environment, Economic, and social dimensions in the Triple Bottom Line framework (Stefaniec et al., 2020). Inland waterways transport performs well from an environmental perspective, but its development potential is constrained by economic and social factors. Specifically, the lack of awareness of customer transport behavior and the underdeveloped port infrastructure hinder the adoption of inland waterways transport. Consequently, the collaboration among governments, institutions, and logistics enterprises, as presented in the previous chapter, is important for reinforcing and promoting the inland waterways system.

5.1.2 Energy consumption analysis

Energy consumption is another important dimension to measure environmental performance and operational costs. According to figures 9 and 10, the survey results indicate a significant difference in energy and fossil fuel efficiency between the two modes. The average score for road freight on energy and fossil fuel consumption is 4.1, which is much higher than that for inland waterways transport (2.5). This is because the majority of trucks operating in Vietnam only meet EURO II standards, while the adoption of electric freight vehicles remains limited due to financial constraints. In inland waterways transport, using higher tonnage per liter of fuel reduces overall energy consumption. This is consistent with the interview results, which indicate that one barge can replace up to 10 or 20 trucks.



	1	2	3	4	5		Total	Average	Median
	1	18	58	146	63		286	3.9	4.0
	0.4%	6.3%	20.3%	51.0%	22.0%				
Total	1	18	58	146	63		286	3.9	4.0

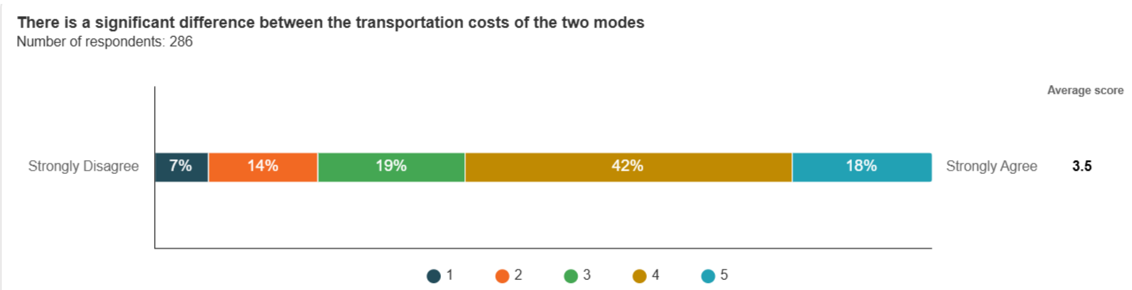
Figure 18. Respondents' perceptions of road freight investment and modal shift to inland waterways

However, when asked about the preference between investing in road vehicles and shifting to inland waterways to reduce energy consumption. Figure 18 indicates that about 70% of respondents agree that environmentally friendly trucks provide more sustainable benefits than inland waterways, with an average score of 3.9. This is because of the existing behavior of choosing the familiar transport mode by the majority of logistics operators. The behavior is explained during the interviews, which indicate that they are more reluctant to change to another mode if the risks of slow delivery, port congestion, and complicated procedure still remain for inland waterways. These results suggest that Vietnam's logistics industry is still in the traditional and developing phase, with little to moderate investment in a sustainable supply chain. While inland waterways are perceived as an energy-efficient mode, road freight continues to dominate due to the current limitations and infrastructure challenges in the waterways system. In the short term, investment in energy efficiency trucks such as EURO III and EURO IV can reduce energy consumption and emissions. However, the high upfront investment in these trucks is also a significant financial challenge for small companies. Therefore, the modal shift to inland waterways transport presents the potential long-term solution to achieve sustainability in the future. This direction is aligned with the current investment and effort from governments, such as the Green Transport Development Roadmap (Decision 876/QĐ-TTg, 2022), to increase the utilization of inland waterways.

5.2 Economic performance

5.2.1 Cost-effectiveness analysis

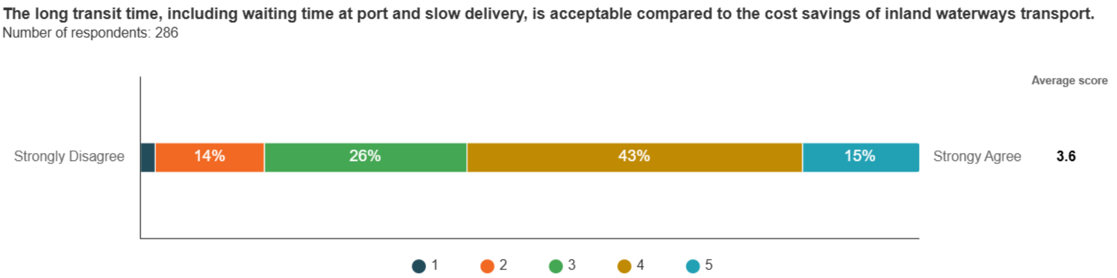
In the Vietnam logistics market, cost is one of the critical factors for customers and logistics companies to decide on transportation modes. In this qualitative study, there are two statements about the cost difference and the acceptance level of cost reduction with long waiting time at the port, which were asked in the survey. First, both surveys and interviews gave the same evidence that there is a difference between the costs of the two modes.



	1	2	3	4	5		Total	Average	Median
Strongly Disagree	19	41	55	120	51	Strongly Agree	286	3.5	4.0
	6.7%	14.3%	19.2%	42.0%	17.8%				
Total	19	41	55	120	51		286	3.5	4.0

Figure 19. Respondents' perceptions of differences in costs between two modes

Figure 19 shows the result of the first statement. The mean score is about 3.5, indicating moderate to strong agreement from respondents. This is because of the current infrastructure challenges remaining in waterways operation, which may increase the hidden costs, such as documentation and procedures. In addition, the transportation costs also depend on the context, distance, and goods characteristics. As analyzed in the interview results, the cost for inland waterways is significantly lower than road freight in the case of bulk transportation and long distances. Otherwise, the cost-saving from modal shift is minimal or even higher. However, the cost-saving initiative from inland waterways is gradually receiving attention in Vietnam's logistics network.



	1	2	3	4	5		Total	Average	Median
Strongly Disagree	4	41	75	124	42	Strongy Agree	286	3.6	4.0
	1.4%	14.3%	26.2%	43.4%	14.7%				
Total	**4**	**41**	**75**	**124**	**42**		**286**	**3.6**	**4.0**

Figure 20. Respondents' perceptions of trade-off between cost and speed of delivery

In Figure 20, more than 60% of respondents, with a mean score of 3.6, are willing to accept the longer transit time to achieve cost savings from inland waterways transport. Although this is not a high value, the score is still positive when showing that more than half of respondents perceive inland waterways transport as an economical solution despite delays.

The cost structure is broken down into more components: freight rate, fuel cost, labor cost, special handling cost, maintenance cost, and investment in infrastructure. The respondents need to rate each cost structure on a 5-point Likert scale from lowest to highest. The raw results are shown in Figures 21 and 22 below.

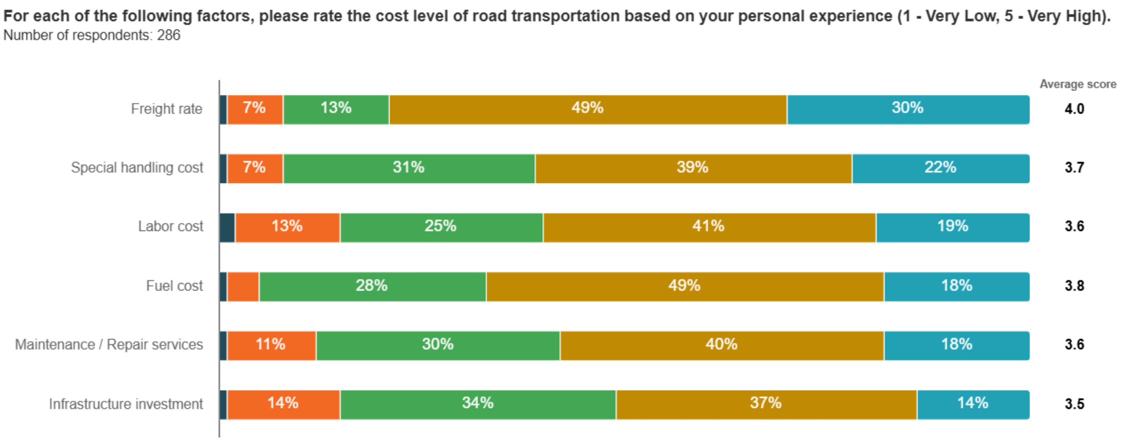


Figure 21. Cost level of road transport by categories

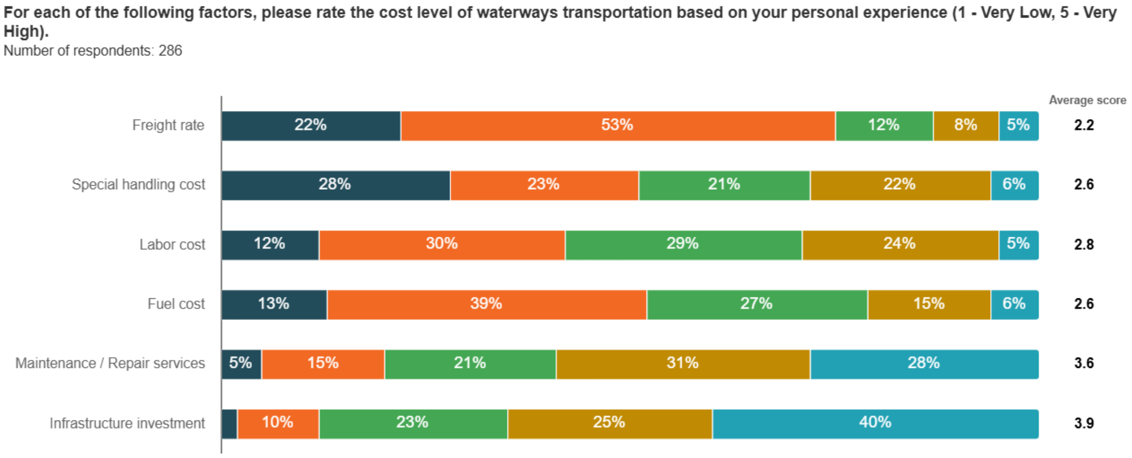


Figure 22. Cost level of inland waterways transport by categories

Table 13. Summary of cost difference between road and inland waterways transport

Cost component	Road transport	Inland waterways transport
Freight rate	4.0	2.2
Special handling cost	3.7	2.6
Labor cost	3.6	2.8
Fuel cost	3.8	2.6
Maintenance / repair services	3.6	3.6
Infrastructure investment	3.5	3.9

Table 13 summarizes the difference in cost components between the two modes for convenient comparison. It is shown that the freight cost of road freight is much higher than that of inland waterways transport. This is obvious when the company considers the cost per unit of shipment. In this scenario, inland waterways transport has more advantages in shipment consolidation to reduce the cost. These results align with the previous research by Le and Tran (2025) to present the significant reduction in costs for bulk shipment compared with road transport due to the lower energy consumption, labor costs, and freight rate. Regarding variable costs such as special handling, labor cost, and fuel cost, inland waterways transport is perceived as more economical with the lower average score. This is true in normal cases when inland waterways are utilized to transport bulk, heavy, and non-time-sensitive shipments over long distances. Indeed, the special handling cost of a typical shipment may include extra protection, labor, or special lashing for a sensitive shipment. Therefore, in practical operations, such special shipments are normally transported via container trucks for better protection and lead time. This behavior leads to higher costs in special handling and labor costs. Taking sensitive manufacturing equipment as an example, this kind of shipment needs special handling with sensitive vibration control and secure protection. Waterways transport is not suitable in this case because the vibration control can be compromised during multiple loading and unloading processes. Consequently, container trucks with an air-ride tractor are chosen to provide the best security of shipment. For fixed costs such as maintenance and investment costs, the up-front investment for waterways is higher than for road transport. This is also mentioned in the interviews that due to the enormous initial investment for inland waterways transport, the process is still ongoing with support from the government and foreign funding, such as a World Bank project. While for road freight, the company can choose to invest in its trucks, such as upgrading from EURO II to EURO III trucks or investing in electric vehicles.

In conclusion, the survey results confirm that waterway transport is more cost-efficient than road transport overall. This is a suitable choice for non-urgent and large shipments over long distances. Next, the modal choice between two modes depends more on the strategic decision of logistics companies and final decisions from customers, based on the evaluation of cargo characteristics, reliability, or flexibility of the mode. In the next section, the analysis of the performance of road and inland waterways transport is presented to support this trade-off decision.

5.2.2 Trade-offs analysis

There are many factors leading to transportation mode decisions. This survey outlines common factors, including transit time, reliability, flexibility, capacity, accessibility, quality, schedule consistency, and freight rate fluctuations. Similar to cost structure, all these factors were rated from lowest to highest on a 5-point Likert scale.

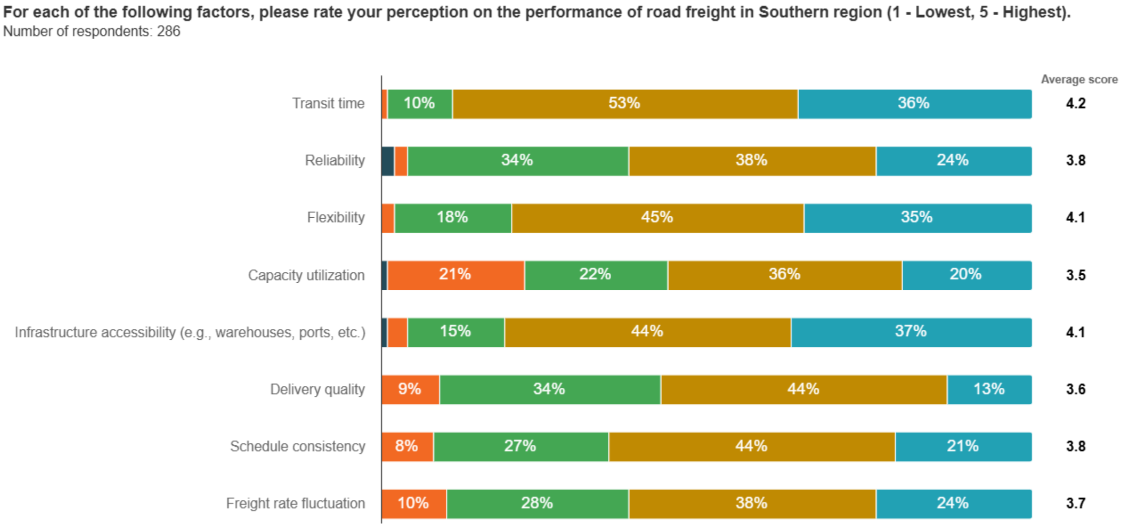


Figure 23. Performance of road transport by factors

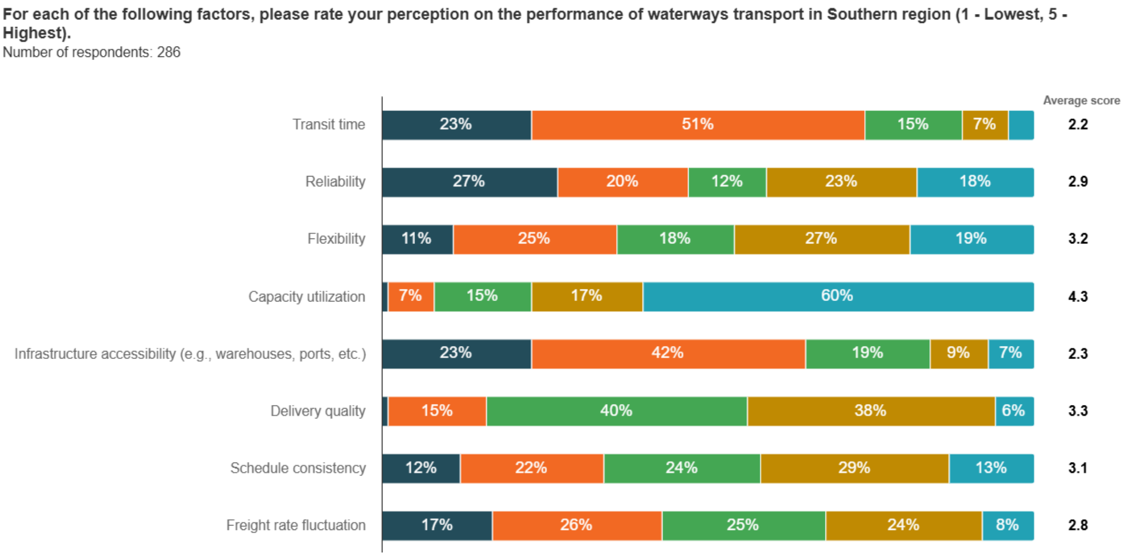


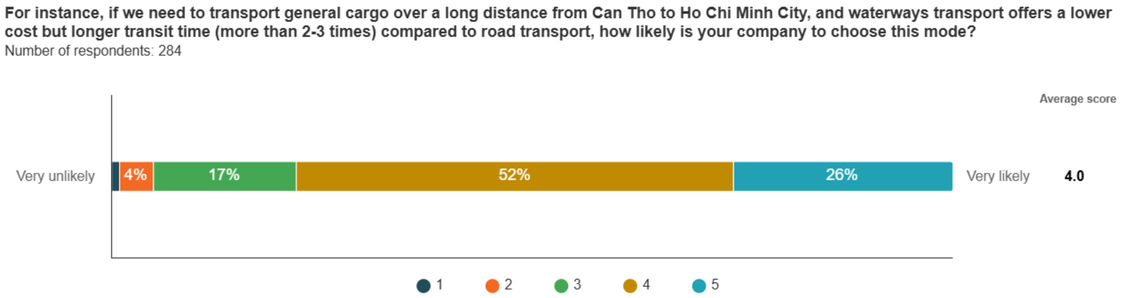
Figure 24. Performance of inland waterways transport by factors

Table 14. Summary of performance difference between road and inland waterways transport

Factor	Road transport	Inland waterways transport
Transit time	4.2	2.2
Reliability	3.8	2.9
Flexibility	4.1	3.2
Capacity utilization	3.5	4.3
Infrastructure connectivity	4.1	2.3
Delivery quality	3.6	3.3
Schedule consistency	3.8	3.1
Freight rate fluctuation	3.7	2.8

Figures 23 and 24 show the full results of performance level between road and inland waterways transport. The results are summarized in Table 14 based on the average point of the two modes. It is clear that inland waterways transport has more advantages in terms of capacity utilization on a barge, with 4.3 points, while road freight has only 3.5 points. However, the trade-off for high capacity is slower lead time, reliability, flexibility, and infrastructure connectivity. The performance of road freight is at the upper scale with an average score of 3.8 for reliability, 4.1 for flexibility, and 4.1 for infrastructure connectivity, while that of inland waterways transport is 2.9 for reliability, 3.2 for flexibility, and 2.3 for infrastructure connectivity. This is due to the remaining challenges that cause significant delays in waterways operations, resulting in a lower level of reliability and flexibility. The challenges that cause delay include port procedures and canal congestion. In practice, road performs well in terms of delivery lead time, high flexibility, and ability to connect to infrastructure such as ports or customers' warehouses. Therefore, road freight is often chosen when the customers need fast and door-to-door delivery, as it is impossible to choose water transport. Nevertheless, the two modes have a minimal difference in delivery quality, which shows the potential of waterways transport to secure shipment quality. The presented results for inland waterways in Vietnam's Southern region are consistent with the conclusion from previous research that the strength of inland waterways is environmental and cost efficiency. Bu and Nachtmann (2023) indicated that barge transport achieves a lower carbon footprint but has the limitation of long transit time, and Binsfeld et al. (2024) demonstrated that inland waterways should be assigned to long-haul segments. At the same time, road freight is utilized for first and last-mile delivery to optimize transportation costs and greenhouse gas emissions in multimodal freight networks.

The survey also questioned respondents about the empirical operational decision of routing from Can Tho City to Ho Chi Minh City, in which waterways have a lower cost but a 2-3 3-times longer lead time.



	1	2	3	4	5		Total	Average	Median
Very unlikely	4	10	49	148	73	Very likely	284	4.0	4.0
	1.4%	3.5%	17.3%	52.1%	25.7%				
Total	4	10	49	148	73		284	4.0	4.0

Figure 25. Respondent's likelihood to choose inland waterways for empirical route

Figure 25 shows the result of the question. The average score of 4.0 indicates that respondents are more likely to choose water transport in the case of general and non-urgent cargo to achieve economic savings. Moreover, the interviews support this point by adding the cargo characteristics and customer requirements into the modal choice. Particularly, if the cargo is insensitive and time is not a critical factor, logistics companies can offer customers a waterways option to reduce the total transportation costs. On the contrary, for sensitive goods such as fresh vegetables or electronic equipment, speed and reliability have more priority than cost. The trade-off analysis between road and inland waterways transport is not only technically based on data-driven decisions but also behavioral and institutional. As analyzed in the customer and business behavior theme, the interviews highlight that many firms and customers are reluctant to adopt inland waterways due to the foreseen risks of slow delivery, port congestion, and complicated procedures at the port. Even though more than 60% of respondents acknowledged the environmental benefits of inland waterways transport, the behavioral challenges remain in daily practices. Consequently, the trade-off analysis presents that Vietnam's logistics transformation should be framed as the complementary integration of road and inland waterways to form the road–inland waterways-road multimodal network, especially for long-haul shipment. Specifically, shippers use trucks to transport shipments from the shipper's location to the port. Barge or container vessels are used for long-distance transportation, while trucks handle the last-mile delivery to end customers. Road transportation remains indispensable for high flexibility and reliability, while inland waterways transport provides customers with a scalable and low-emissions solution. Consequently, multimodal synchronization presents the most economical and environmentally friendly strategy to maximize the transport operation performance. In this integration of multimodal transport, both modes share the scheduling information and coordinate on the time window to provide transparency.

Finally, the key message for the trade-off analysis is the multimodal supply chain integration mindset. It is essential to choose the most suitable mode for business purposes instead of focusing on only one factor. Each mode has its own function and associated impact on the environment and operation. This integration approach is the optimal balance between cost and performance in transportation design.

6 Conclusion

This chapter will conclude the whole study by summarizing the key research findings and results interpretation, which reflect the research aims and research questions stated from the beginning. Next, the value and contributions of this thesis are discussed to identify its practical application areas, particularly in logistics and transportation management. Finally, the last section reviews the study's shortcomings and proposes opportunities for future research.

6.1 Summary of research findings and discussion

This study aims to investigate the environmental and sustainability aspects of inland waterway transport in Vietnam's southern region to reduce road freight emissions. The criteria evaluated in this thesis include environmental performance, economic feasibility, and logistical efficiency of inland waterways transport, to understand under what circumstances this mode can be utilized as a green alternative. Lastly, the study identifies the current challenges of inland waterways transport from a business perspective.

From the qualitative analysis of semi-structured interviews and surveys, the results conclude that while inland waterways transport is having some infrastructural challenges, financial constraints, and customer behavior, this mode has the potential to support sustainable transport system in the future. Taking some quotes from the interview as an example, the interviewees mentioned: "From an environmental perspective, inland waterway transport is cleaner and more sustainable," or "Vietnam, particularly the Mekong Delta region, possesses natural advantages with its dense river network. If waterway transport is used for long-haul shipment, the country can reduce logistics costs while minimizing environmental impacts. These statements align with the survey scoring data, which show that road freight has an average emissions rate of 4.3, while inland waterways have an average rate of only 2.1. The data collected highlights the environmental benefits of inland waterways compared to road freight. Indeed, inland waterway transport in Vietnam is supported by various factors, including the natural characteristics of canal systems, government investment in infrastructure, and business-led innovation.

While the environmental and economic advantages have been confirmed through the qualitative results, the transport mode selection is a strategic decision-making process that considers all factors related to transportation, such as transit time, flexibility, or accessibility. The findings suggest that road freight is more suitable for last-mile delivery. In addition, this mode is often used for high sensitive shipment such as electronics or semiconductors or fresh products that need to be delivered in the shortest time window. On the contrary, inland waterways offer large-capacity barges and a natural river system for bulk and large shipments, which are not sensitive to time or security. By using inland waterways transport, shippers can wait for consolidation with other shipments until the barge is full, thereby significantly reducing the total transportation costs, emissions, and energy consumption per unit. The most important trade-offs between the two modes are time and accessibility to infrastructure. Consequently, logistics companies need to clearly identify shipment characteristics and integrate all available transport modes to provide customers with the most appropriate and unique transport solutions that balance time, cost, resources, and sustainability.

The findings suggest that understanding customer requirements and behaviors is important before promoting inland waterways transport in Vietnam. Because of not being in logistics industry, customers have little attention and understanding about sustainable transportation, which leads to the preference of fastest delivery mode. This finding support the existing research about customer demand (refer table 6), which only shows that customers have high requirement for fast delivery and do not consider behavioral preferences due to low environmental awareness in logistics operations (Phuong, 2025). While it is true that customers often require fast delivery, this behavior can be changed to a more sustainable way to consider other factors, such as carbon emissions, as the average awareness increases. The current logistics industry in Vietnam is changing to seek a balance between operational efficiency and sustainability, in which logistics

companies and customers cannot remain in their status quo for long. As changing customer habits over a short period are challenging, logistics companies need to gradually educate and promote inland waterways transport through transport solution design for suitable customers. Specifically, this study highlights the importance of segmentation in customer relationship management.
By analyzing customer's insights from surveys or communication, logistics companies can understand each customer's preferences, challenges, and resources availability to match business value with customer's needs. In operational practices, shipment quality, requested delivery date, and costs are three critical pillars that every solution must satisfy. Once the core requirements are met, through communication and negotiation, logistics companies can raise awareness and persuade customers to pilot shipment via the inland waterways system. Hence, the proposed transport solutions must be detailed and clearly highlight the cost reduction and environmental contribution.

Finally, inland waterways can be a sustainable mode of transportation if used for the right purpose by the right customers. For SMEs, collaboration within logistics networks and compliance with government direction on waterways development are crucial to improving the quality of waterways transport and to realizing the environmental benefits this mode offers. Turning back to the research question, the findings answer it by identifying the strengths and implications of using inland waterways to foster sustainable transportation, reduce costs, and reduce emissions from road freight. In particular, road freight cannot be totally replaced by inland waterways transport due to its high efficiency and flexibility in last-mile and domestic delivery, and waterways transport becomes the ideal and sustainable mode, a complementary mode of transportation in middle-mile logistics. In addition, the findings highlight behavioral challenges in transportation awareness in Vietnam's domestic market, which need to be addressed through communication and segmentation to strengthen the adoption of inland waterways solutions.

6.2 Contribution of research

This study contributes to the academic world by filling the identified knowledge, geographical, and methodological gaps at the beginning of this thesis. Specifically, this research approach examines the operation of inland waterways in Vietnam's southern region from a business-oriented perspective, focusing on the voices of business professionals to investigate the current challenges of inland waterways logistics. While current research in Vietnam's transportation market primarily focuses on multi-criteria decision models to identify the most optimal dry-port and barge service providers or to determine national-level financial policy and development, this study employs a qualitative research approach through semi-structured interviews and surveys to collect practical opinions. Consequently, this research is valuable by adding a practical viewpoint to the existing theory.

From the business viewpoint, this research targets small and medium logistics enterprises on the adoption level of inland waterways transport in Vietnam. By summarizing the current challenges and potential approaches, this study can serve as a benchmark for enterprises seeking to transform their conventional operations into a sustainable supply chain through inland waterway transport, including strategic collaboration among small companies, an awareness campaign, and customer value segmentation. In addition, this study provides a broader view of the economic and logistical performance of road and inland waterways transport, along with associated attribution scores, which are useful for trade-off analysis and strategic decision-making before choosing a transportation mode. Finally, this study highlights the potential of inland waterways transport. It raises awareness of the current government funding and investment, which promise to create a more integrated and sustainable transportation system in Vietnam in the future.

6.3 Limitation and future development of research

This study still has some limitations due to the qualitative research approach. The results would be more reliable if quantitative analysis were conducted, such as testing hypotheses and analyzing correlations between variables. For example, quantitative analysis may examine the correlation between the environmental awareness score and the preference for adopting inland waterways or test the dependence of each performance criterion on the likelihood of choosing inland waterways transport.

In addition, because this study considers only qualitative insights from interviews, there is a lack of quantitative analysis of detailed emissions data, such as energy consumption per ton/kilometer or CO_2 equivalent, which can only be obtained from internal business systems. Finally, the sample size in this research considers only the business perspective. The viewpoints of shipment owners or customers who use transportation services from logistics companies and have the final decision on the transportation mode can be collected to generate a more comprehensive view of the situation of the inland waterways in Vietnam. However, this approach requires significant time due to the fragmentation of customer types and shipments. Therefore, future research would be more approachable if it focused only on key industries and customers, such as agricultural products or fast-moving consumer goods, to yield concise results.

For future research, the mixed approach of qualitative and quantitative research can be used to quantify the environmental benefits of inland waterways transportation through a framework such as ISO 14083 and to support a data-driven decision. More operational data can be collected from shipment owners and port operators to create a holistic view of the waterways system in Vietnam. Integrating statistical, cost analysis, and stakeholders' perspectives would enable future research to validate and strengthen the environmental benefits of inland waterways. Moreover, the specific approach to industry can improve the analysis by focusing on the specific needs and requirements of key industries in Vietnam. Because each industry has its own requirements for transportation modes, future research on specific industries can provide a more targeted evaluation and framework to support transport mode decisions toward efficient and sustainable strategies.

Appendices

Appendix 1. The interview questions

Part I: General information

1. Can you briefly describe your title, role, and responsibilities, and your experience in logistics/transportation?
2. Can you share the current transportation services offered by your company?

Part II: Environmental awareness

3. In your view, what are the environmental advantages or disadvantages of using inland waterways for freight compared to road transport?
    - Besides carbon emissions, do you think noise pollution, accidents, and road congestion are the main challenges for road freight?
4. Do you regularly consider sustainability and environmental factors as a top priority when designing transport solutions or choosing transport modes? Or do cost, time, and human resource issues still receive more priority?
5. Are companies aware of the negative impact of road freight on the environment?
    - If yes, does the company have any solutions?
    - If no, do you think the lack of awareness of environmental impact is a challenge for logistics companies to achieve sustainable logistics?
6. Do you have any environmental concerns with transporting goods via inland waterways in Southern Vietnam?

Part III: Economic performance between road and IWT

7. What are the major differences in cost factors between two modes, such as in fuel, labor, or handling?
8. Do you think the cost savings from modal shift are strong enough to encourage the shift of freight from road to inland waterways? Why?
9. How do we calculate cost by using road freight and inland waterways?
10. For instance, for transportation from Can Tho to Ho Chi Minh city, we have two different routes for waterways and highway, so if the cost and emissions is lower by barge, but the transit time is longer, how would you evaluate the trade off? For example: If using IWT reduced CO_2 emissions by 30% compared to road but added 2 extra days in transit, would you still consider IWT for transportation?

11. In your experience, under what circumstances is inland waterways transport more economically than road transport?
    - Are there any specific types of goods or routes that are more cost-effective when using barges instead of trucks?
    - And conversely, when is road freight preferable? Under what conditions?
    - So, do you often split the volume and maximize the capacity of two modes? How do you balance all the factors such as volume, cost, and lead time?

Part V: Logistical efficiencies of road and inland waterways transport?

12. According to your experience, how do delivery times and reliability of shipments by waterways system compared to those by road, given the same routing.
    - Do you think road traffic congestion is the main limitation for flexibility and predictability of road freight? How does it impact the planning schedule of shipment by road?
    - Similarly, how does canal traffic and weather impact the operation of waterways system? Is it the main limitation?
13. What are the main transportation modes your company primarily utilize? And why?

Part IV: Key challenges to adopt inland waterways transport

14. What barriers or obstacles have you seen that prevent greater use of IWT for sustainability reasons (e.g. limited green infrastructure, lack of company support, customer's requirements, etc.)?
    - Customers prefer fast delivery, so most logistics companies, especially small to medium companies, still stick to road freight. Do you think this is a challenge for company?
    - Are you experiencing any pressure from customers or regulators to adopt greener transport options? If yes, how does that affect your preference for IWT over road or vice versa?
15. What are the main financial or economic challenges that discourage you from using IWT more frequently?
16. Do some issues such as longer transit time, additional handling, or infrastructure fee affect the cost-competitiveness of waterways transport?
17. Are inland waterways and environmental solutions in transportation only suitable for big and multinational companies? What do you think about this statement?

Part V: Opportunities and future trends of transportation

18. Do you see the potential opportunities to reduce costs and gain environmental benefits with waterways? Or do we have other effective solutions?
19. With the recent focus on sustainability and green supply chain, how do you think it will affect the company's strategies in the future?

Part VI: Additional sharing

20. Is there anything else you'd like to add about inland waterway transport or sustainable transportation that we haven't covered? Any advice or final thoughts?

Appendix 2. The thematic coding results

Theme	Sub-code	Quotes from interviewees
Environmental awareness	Emissions	- "Most trucks used diesel fuel, which remains the dominant energy source in freight transport." - **Interviewee #1** - "First mile and last mile delivery release the highest emissions" - **Interviewee #1** - "Waiting time at ICD due to congestion also causes energy consumption and waste time" - **Interviewee #2** - "EURO 2 and 3 trucks are common, and they still release emissions" - **Interviewee #3** - "Barge is using diesel power" - **Interviewee #3**
	Environmental benefits of inland waterways	- "In practice, waterway transport is the most environmentally friendly mode." - **Interviewee #2** - "From an environmental perspective, inland waterway transport is cleaner and more sustainable" - **Interviewee #2** - "Customer tried it due to road lockdowns during COVID-19, they found it worked well and environmentally friendly and they want to continue using inland waterways transport after COVID" **- Interviewee #3** - "Vietnam, particularly the Mekong Delta region, possesses natural advantages with its dense river network. If waterway transport is used for long-haul shipment, the country can reduce logistics costs while minimizing environmental impacts." **- Interviewee #4** - "Inland waterway transport causes less environmental pollution compared to road freight, as it consumes less fuel per ton-kilometer." **- Interviewee #5** - "It has lower accident risks and reduces road congestion" - "A single barge can carry the equivalent volume of several trucks, highlighting a consolidation advantage to reduce cost and emissions" **- Interviewee #6**

Economic and cost performance	Freight comparison	- “From an economic perspective, they are also more cost-efficient because freight rates are consistently the lowest.”” - **Interviewee #2** - “Inland waterways transport offers lower freight cost than road.” **- Interviewee #3** - “In container shipping, dry containers are cheaper, but refrigerated containers have higher cost due to power supply” **- Interviewee #3** - “In some cases, inland waterway freight rates are higher than road transport, especially for small shipment volumes or short distances” **- Interviewee #4** - “Cost reduction happens when the containers are full and loaded on barges” **- Interviewee #6** - “The total transportation depends on total freight rate and handling fee at both sides, origin and destination” **- Interviewee #7**
	Handling and transshipment costs	- “Road freight involves 2 handling steps, while inland waterways need at least four.” **- Interviewee #3** - “Inland waterways raise concerns about handling costs, labor intensity, and cargo safety” **- Interviewee #4** - “Multiple handling operations and limited port access increase the total logistics cost.” **- Interviewee #4** - “Delays at port due to congestion and long queue incur more fixed costs on waiting” **- Interviewee #6** - “Low equipment productivity at port increase hidden costs for smooth operation” **- Interviewee #6**
	Fuel efficiency	- “Some companies are concerned about fuel consumption, so they often switch to waterways, rail, or invest in euro 3 or euro 4 trucks” **- Interviewee #1** - “Regular equipment is important to avoid waste fuel during operation” **- Interviewee #1** - “Consolidate reduces the fuel consumption per unit” **- Interviewee #2** - “Integrate rail and inland waterways transport with road freight brings more benefits to costs and fuel consumption” **- Interviewee #4**
	Transport mode decision	- “When transporting large volumes, waterway transport becomes extremely cost-effective. However, the trade-off lies in slower transit times compared to other modes.” **- Interviewee #2** - “For domestic distribution, road transport is the most practical and flexible option, especially for last-mile delivery**.” - Interviewee #2** - “From Cần Thơ to Ho Chi Minh City takes about 5 hours by truck, but around 15 hours by barge” **- Interviewee #3** - “Currently, inland waterways are primarily used for bulk agricultural commodities” **- Interviewee #3** - “Fresh or perishable goods are unsuitable for waterway transport due to long lead time” **- Interviewee #3**

		- "Customers make decision based on shipment characteristics and scale" **- Interviewee #3** - "Inland waterway transport is most suitable for bulk and non-urgent commodities such as construction materials, cement, coal, rice, fertilizer, and large container shipments." **- Interviewee #4** - "For large shipment volumes (5–10 containers or more), road transport becomes less economical, and barges are more suitable" **- Interviewee #5** - "Waterway transport is suitable for standardized packaging shipment that can be loaded into containers**" - Interviewee #6** - "Barges are more efficient for bulk transport." **- Interviewee #6**
Logistical and infrastructure constraints	Financial investment and infrastructure constraints	- "Another challenge is that government policies and financial support are still incomplete, lacking a synchronized framework and implementation strategy." **- Interviewee #1** - "One of the major constraints of Vietnam's inland waterway system is its limited modernization in infrastructure**" - Interviewee #3** - "The current inland waterway corridor and port infrastructure remain fragmented and underdeveloped." **- Interviewee #4** - "Low bridge clearance prevents large barges from passing through many key routes." **- Interviewee #5** - "Given their limited financial capacity and competitiveness, many Vietnamese enterprises currently find it challenging to adopt low-carbon logistics solutions across their supply chains." **- Interviewee #7** - "Currently, charging stations in Vietnam are designed mainly for small vehicles, with battery capacity around 20 kWh or less." **- Interviewee #7** - "Many small and medium-sized enterprises (SMEs) lack the financial capacity to invest in green transformation." **- Interviewee #7** - "One of the main barriers to adopting electric trucks and barges is the high initial investment cost compared with conventional diesel vehicles." **- Interviewee #7**
	Port capacity and congestion	- "Waterways terminals and facilities are underdeveloped" - **Interviewee #3** - "Inland waterway transport faces limitations in port availability and door-to-door connectivity" **- Interviewee #4** - "Many inland ports remain underdeveloped and poorly equipped, lacking cranes and standardized handling systems, which results in longer loading times and hidden operational costs." **- Interviewee #5** - "There is a lack of modern river ports and nearby ICD facilities, which limits logistics efficiency." **- Interviewee #5**

		- "One challenge is limited customs processing capacity at waterways port. The capacity is only about 20 to 30 declarations per hour, causing congestion and delays" **- Interviewee #6** - "Forklifts also have limited handling capacity" **- Interviewee #6** - "Port congestion remains a critical concern because it reduces the efficiency of intermodal connection between road and waterway transport and increases total logistics costs." **- Interviewee #6**
	Waterways conditions and scheduling bottle necks	- "Inland waterways face operational bottlenecks and congestion, especially at Chợ Gạo Canal" **- Interviewee #3** - "Tidal fluctuations affect navigation, causing vessels to wait for water levels before departure." **- Interviewee #3** - "Unstable barge schedule affects planning" **- Interviewee #3** - "Terminal often prioritize large vessel such as container vessels, and small barges need to wait" **- Interviewee #3** - "Scheduling and trip consolidation is limited due to lack of digital technology" **- Interviewee #4** - "Shallow navigation channels during the dry season often cause grounding issues and operational delays." **- Interviewee #5** - "Bridge clearance and tides affect the schedule" **- Interviewee #6** - "Inland waterways have more risk in delays more than road transport, for example, a shipment is planned to deliver with 2 days lead time, but congestion and queue prolong more than 1 day" **- Interviewee #6**
Customer and business behavior	Customer preference	- "Factors such as environmental protection, CO_2 emissions, ESG, and green logistics are not key decision criteria when customers select transport service providers." **- Interviewee #1** - "Customers make decision based on shipment characteristics and scale" **- Interviewee #3** - "Customers are accustomed to using trucks because they are fast, flexible, and easy to control" **- Interviewee #5** - "The domestic market has almost no sustainability requirements." **- Interviewee #6** - "Long delivery time discourages customers from choosing waterway transport, especially when shipments are urgent or time sensitive." **- Interviewee #7**
	Business behavior and attention	- "For small companies, environmental issues are less prioritized compared with operational efficiency." **- Interviewee #1** - "Logistics companies are familiar with existing transport routines, shifting from road to waterways is not easy." **- Interviewee #3**

		- "Firms often prioritize a balance between cost, speed, and reliability. Therefore, while modal shift can foster cost savings, these benefits are not strong enough" **- Interviewee #4** - "There is a lack of collaboration among waterway transport companies, limiting the strong and connected logistics network." **- Interviewee #4** - "From my observation, only a few Vietnamese companies actually consider sustainability in their logistics operations." **- Interviewee #6** - "They are accustomed to traditional flows and routines**." - Interviewee #6** - "Global companies follow sustainability direction, such as reducing CO_2 emissions and pollution" **- Interviewee #6** - "Another issue is that some firms maintain a reactive rather than proactive mindset, they react to environmental issues instead of developing strategic planning" **- Interviewee #7**
	Lack of environmental awareness	- "In terms of sustainability awareness, public knowledge remains limited, most people only know about recyclable packaging or biodegradable materials such as paper or leaf-based products." **- Interviewee #2** - "Only foreign customers such as EU cares about environmental concerns, while domestic customers don't" **- Interviewee #3** - "Customers and shippers have not aware of environmental benefits of inland waterways transport yet" **- Interviewee #3** - "Customer awareness remains low, and many shippers still lack confidence in the reliability of inland waterway logistics." **- Interviewee #4** - "Most of domestic companies and customers cares more about economic growth" **- Interviewee #6**
Future opportunities	Government investment and policy	- "Many projects have been raised for funding, such as World Bank project to improve inland waterways corridors, I was in the core team from 2017 to plan for the project" **- Interviewee #3** - "In the context of both Vietnam and the global community pursuing emission reduction and green logistics, inland waterway transport is expected to receive more policy and market support." **- Interviewee #4** - "Projects such as World Bank's Mekong Delta Transport Improvement Program focus on dredging navigation channels and increasing bridge clearance to improve the region's inland waterway network." **- Interviewee #5** - "Recently, the government has focused on infrastructure development to improve connectivity and logistics performance." **- Interviewee #6**

		- "The government also plans to electrify port operations, including electric cranes, forklifts, and container-handling vehicles. This is a significant step towards green port development." **- Interviewee #7**
	Sustainability roadmap	- "The Ministry of Transport's 2030 inland waterway development strategy includes incentives for clean energy and electric-powered vessels, such as hydrogen fuel." **- Interviewee #3** - "National Development Program for Inland Waterway Logistics, aiming to attract investment in river ports, inland container depots (ICDs), and supporting logistics infrastructure." **- Interviewee #5** - "The government recognizes the importance of investment in transport and port system, and have plan to invest in seaports and North-South land routes" - Interviewee #6 - "Vietnam has committed to achieving net-zero emissions by 2025." **- Interviewee #6** - "In the future, more green logistics projects are expected, especially among state-owned enterprises with sufficient resources" **- Interviewee #7**
Potential practices and solution recommendation	Electrification initiatives	- "Electric trucks and euro 5 vehicles are not yet widely used" **- Interviewee #1** - "Electric trucks are not yet available, and most vehicles still operate under Euro 2 or Euro 3 emission standards." **- Interviewee #2** - "Several multinational logistics companies have started exploring and piloting the use of electric barges for short-distance transport, mainly between Ho Chi Minh City, Bình Dương, and Long An." **- Interviewee #5** - "In the inland waterway sector, we are also planning to develop and deploy electric barges to enhance environmental performance." **- Interviewee #7**
	Business motivation	- "Market pressure, social awareness, and overall societal development level play key roles in shaping the entire supply chain, with government policy acting as a critical driver" **- Interviewee #2** - "Customer and market pressure are the key drivers for companies to change" **- Interviewee #3** - "Companies need to evaluate customer profile and preference to define a proper strategic direction." **- Interviewee #7**
	Customer awareness and segmentation	- "Most shippers are not logistics experts, and they prefer road transport because trucks are fast and convenient" **- Interviewee #3** - "Communication initiatives are important to raise awareness on the environmental benefits of inland waterway logistics." **- Interviewee #3** - "To convince customers, it is crucial to demonstrate the clear benefits of inland waterway transport in terms of cost

		efficiency, transit time, and risk reduction." **- Interviewee #4** - "We regularly conduct a Customer Maturity Assessment on sustainability to classify customers into levels 1 to 4, based on their environmental awareness and readiness for green logistics." **- Interviewee #7**

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