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Role of Cargo Owner in Logistic Chain Sustainability

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Abstract: Understanding the factors and characteristics of the business and the influence of cargo owners on sustainable practices in maritime logistics chains is the main objective of this study. The sample consists of 141 valid responses from Portuguese companies that own cargo, freight forwarders and other maritime logistics service providers. Sustainable energy theory, green state theory, and shared value creation theory support the research. The SEM methodology was adopted. The sector's structure, management characteristics, type of transport contract and the size of the cargo characterize and condition the business of cargo owners and influence the choice of green transport, the use of green fuel and corporate social responsibility. It is important to increase the knowledge and practice of cargo owners in order to understand their business constraints.

Keywords: sustainable logistics chains; cargo owners; logistics service providers; maritime transport

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1. Introduction

Transport is responsible for around 25% of greenhouse gas emissions in the European Union, with significant environmental consequences for the planet. Despite the policies adopted by the United States and the use of technological innovations, maritime transport continues to use fossil fuels that emit carbon dioxide. Regulation of pollution from large industrial sources has reduced the environmental impact in several countries. However, this has not occurred with other agents and operators in the logistics chain [1]. However, growing environmental concerns have accelerated cargo owners' interest in sustainable practices in supply chains.

Although research has been conducted on the use of fossil fuels in passenger transport, there are few studies on freight transport [1]. These authors studied factors in freight transport and environmental strategies adopted by carriers, interaction with logistics service providers, and the role of transport service buyers in using renewable energies, green fuels, and different transport alternatives. Ref. [2] mentioned that the role played by the green agenda and sustainability in logistics services is relatively unexplored in the literature.

The role of cargo owners in promoting environmentally friendly transport is supported by several authors' theses. Refs. [3–5] argue that customer pressure can lead to a reduction in carbon emissions from carriers and encourage the use of more modern and less carbon-emitting vehicles, as well as favoring rail and road modes and intermodal transport.

Ref. [6] suggested that it is the buyers who influence the use of sustainable environmental factors in transportation, as they have the power to choose services based on factors such as company image, customer preferences, and government regulations. Ref. [1] noted that although environmental concerns are not always prioritized over costs, customers are increasingly demanding greener business practices. Meanwhile, Refs. [5,7] highlighted the benefits of logistics and transport companies adopting sustainable strategies for their brand image and reputation, as customers consider sustainability when selecting suppliers. The evidence points to the significant influence that cargo owners can have in driving a more environmentally friendly transportation industry, as they exert pressure on carriers to adopt more sustainable practices.

However, the role of cargo owners in sustainable practices in maritime logistics chains has not yet been sufficiently studied to understand how the drivers that characterize them are assessed by policymakers, end customers, and cargo owners themselves and how they influence those practices.

Sustainability theory is a multidisciplinary approach that seeks to understand how human societies can exist in a way that is compatible with the natural environment and with human systems in the long run. The concept of sustainability was popularized by the World Commission on Environment and Development (WCED) through the Brundtland Report, formally known as "Our Common Future". The commission, led by the former Prime Minister of Norway, Gro Harlem Brundtland, emphasized the need for a balance between economic growth, environmental protection, and social equity. This revolutionary approach to development set the stage for our understanding of sustainability today, focusing on coupling economy and ecology, and emphasizing the responsibility of the global community for both the causes and consequences of environmental damage [8], further explored sustainability practices and the necessity of ecological protection from an economic perspective, underscoring the importance of sustainable and ecological economics. In the realm of energy resources and technologies [9], discussed specific sustainability criteria for energy resources and technologies. The study drew on three complementary theories to support the analysis of cargo owners and sustainability in maritime logistics. These theories provide a theoretical framework and conceptual lens for understanding the dynamics and implications of sustainable practices in the context of cargo owners. Sustainable energy theory—this theory examines the decarbonization of the economy from a corporate social responsibility perspective. It encompasses the notion that businesses have a responsibility to reduce their carbon footprint and adopt sustainable practices to mitigate environmental impacts. This theory emphasizes the importance of incorporating sustainable energy sources, reducing emissions, and promoting environmentally friendly transportation [10–15]. Green state theory—the green state theory focuses on various aspects of state policies and institutions in the context of sustainability. It recognizes the need to address the limitations of the modern state, which often prioritizes economic imperatives over environmental concerns. This theory highlights the importance of transforming state policies and institutions to promote sustainable development and mitigate environmental damage [16]. Shared value creation theory—the shared value creation theory emphasizes the need for companies to integrate social, economic, and environmental benefits into their core business concepts. It advocates for companies to address sustainability across all three scopes, namely Scope 1 (direct emissions from company operations), Scope 2 (indirect emissions from purchased electricity, heat, or steam), and Scope 3 (indirect emissions from the value chain, including transportation of goods). For cargo owners in the maritime logistics context, this theory highlights the importance of influencing and promoting sustainable practices within the transportation of goods, particularly in the maritime mode. By actively engaging with and influencing transportation providers and supply chain partners, cargo owners can contribute to achieving sustainability goals across all three scopes and drive positive environmental impacts [17].

By incorporating these theories into the study, the authors adopt a comprehensive approach that considers the economic, social, and environmental dimensions of cargo owners' roles in sustainability within maritime logistics. These theories provide a solid foundation for understanding the motivations, challenges, and opportunities associated with sustainable practices in this context. By aligning their research with these theories, the authors aim to contribute to the existing literature by shedding light on the key factors influencing cargo owners' adoption of sustainable practices in maritime logistics chains. Furthermore, the theories provide a broader perspective on the implications for business strategies, public policies, and societal well-being in the pursuit of sustainable transportation and logistics.

This study aims to comprehensively understand the characteristics of cargo owners that influence sustainable practices in these logistics chains. By addressing this aspect, the study fills an existing gap in the literature and provides valuable insights into the key players and their impact on sustainability. The study goes beyond the citied previous research by identifying and exploring the various elements that describe cargo owners in the context of sustainable practices within maritime-based logistics networks. This identification enhances our understanding of the specific factors and attributes associated with cargo owners' involvement in sustainable initiatives. Moreover, the study successfully identifies and characterizes the factors that contribute to sustainable practices within maritime-based logistics networks. By elucidating these factors, the study offers practical guidance for implementing sustainable measures in the industry, thereby facilitating environmentally friendly transportation, pollution prevention, and corporate social responsibility.

The research aims to understand how cargo owners contribute to sustainable practices in maritime-based logistics chains. The objectives are as follows: (1) to identify the factors characterizing cargo owners; (2) to identify the factors characterizing sustainable practices in maritime-based logistics chains; (3) to understand the characteristics of cargo owners that influence sustainable practices in maritime-based logistics chains. The research question is: which characteristics of cargo owners play an important role in adopting sustainability measures in maritime-based logistics chains? The structural equation modeling (SEM) methodology was used to analyze the 141 valid responses obtained from Portuguese companies.

The results confirm different influences of cargo owners' business characteristics on sustainable practices in maritime-based logistics chains, with a greater focus on green transport, pollution prevention, and corporate social responsibility.

This study demonstrates the importance of cargo owners' business characteristics for the sustainability of maritime-based logistics chains and contributes to practice by suggesting that cargo owners and policymakers have better conditions to decide on the sustainability of maritime-based logistics chains.

After the introduction, the literature review and method sections follow, where the research model, constructs, and variables, and samples and measures are highlighted. The analysis and results and the discussion follow. Finally, conclusions and contributions are presented.

2. Literature Review

Through a thorough review of the literature and empirical analysis, the study identifies and investigates various factors that influence cargo owners' sustainable practices. Cargo owners' business characteristics encompass the size of shipments, the relationship with transport service providers, the sector framework with sector-specific environmental regulations, green taxes, and the weight of transport costs. These characteristics have been found to influence cargo owners' commitment and alignment with sustainable practices in transportation. The study examines the influence of management characteristics on cargo owners' sustainable practices. This includes the level of commitment to sustainable initiatives, the use of green associative models, and the adoption of sustainability indicators to meet higher environmental requirements. These management characteristics are vital in driving and promoting sustainable practices within the business. The study explores the impact of different types of transport contracts on cargo owners' sustainable practices. Long-term contracts and the utilization of full ships and containers are considered in relation to their influence on sustainable transportation practices. By examining these key factors, the authors aim to provide insights into the determinants of cargo owners' sustainable practices in maritime logistics chains. The findings of this research contribute to a better understanding of the factors that shape cargo owners' decision-making processes and their ability to adopt and implement sustainable measures within their business operations.

2.1. Sector Framework

The adoption of sustainable practices in the supply chain is influenced by factors related to the business of cargo owners. The sector framework in terms of regulation, both industrial and environmental, determines the performance of cargo owners in all aspects of the business, including the contracting of transport. Ref. [5] highlighted the transport sector as responsible for almost a quarter of carbon emissions, intelligent public transport regulation systems limiting traffic congestion and CO_2 emissions, and managers and cargo owners being influenced by regulatory environmental regulations and government policies. Ref. [18] emphasized legal requirements in the relationship between the shipper and logistics service providers. Ref. [19] emphasizes the important participation of companies in government initiatives to improve environmental performance. Refs. [20–22] mention the influence of regulations and laws on transport, while Ref. [23] concludes that green taxes define greener transport. Ref. [24] refers to the need for an efficient sector framework to improve the efficiency and sustainability of the supply chain. Furthermore, Refs. [25,26] discuss the use of new technologies, such as electric vehicles and drones, to improve cargo transport efficiency, reduce operating costs, and achieve more sustainable logistics.

2.2. Management Characteristics

Pressure from customers reduces carbon emissions from carriers, favoring rail and road modes and intermodal transport using more modern and less carbon-emitting vehicles [3–5]. For [6], it is the buyers who influence the use of sustainable environmental factors, as the purchase of services depends on managers, the company's image, customers (cargo owners), carriers, government, and other authorities.

Customers increasingly demand a green business model, although environmental aspects are less prioritized than costs [1]. Most small and medium-sized companies adopt sustainable strategies to achieve greener supply chains. Logistics and transport companies benefit their brand image with a reputation for sustainability [5,7], also knowing that customers consider sustainability as a criterion for selecting suppliers.

Transport sustainability actions and cargo owner criteria in transport selection result more from the internal dynamics of employees and top management than the obligation to calculate CO_2 emissions, justifying measures to reduce costs [7,27]. Cargo owners and carriers lack effective tools and standard methods for sharing real benefits to strengthen the environment and sustainable practices [7].

Ref. [27] refers to the importance of cooperation among various actors in the logistics chain, highlighting the role of the cargo owner in influencing the level of carbon emissions from the maritime-based logistics chain. Ref. [28] studied collaboration mechanisms between cargo owners and logistics service providers in sustainable transport practices. Ref. [6] highlights simpler practices such as ISO 14001 accreditation and the adoption of specific technologies in vehicles. Cargo owner cooperatives encourage joint sustainability measures in transport chains [29].

The awareness of top and middle managers [23] facilitates greater normality in the choice of suppliers, based on environmental and social criteria [21]. Shippers consider the green agenda and environmental sustainability important for their business [2]. Being environmentally conscious should be an integral part of the shipper's corporate culture [22] to invest in sustainable practices and social responsibility policies [30].

Ref. [29] finds that shippers are willing to pay extra for sustainable logistics services. However, Refs. [6,20,23] point out differences between the stated intentions of shippers and their behavior in acquiring green logistics services, due to costs, adopting traditional performance goals in practice, based on price, quality, and delivery time, despite the importance of visibility of individual ecological actions, as mentioned by [20]. The sustainability goals of shippers have a positive influence on transport [31], but are limited by the financial objectives of shippers [32]

2.3. Type of Transport Contracts

Ref. [33] highlights contextual factors that do not always allow for successful modal shift to a greener mode. Green measures require efforts in the pre-contract phase, assigning intra-organizational objectives to them [34]. Ref. [35] mentions sustainable environmental practices as a competitive component in the selection of logistics service providers. The types of long-term direct contracts related to maritime transport lines and freight forwarders influence sustainable requirements in transport [19]. Management conditions and social responsibility lead shippers to demand environmental certifications from logistics service providers [1].

2.4. Shipment Size

Shippers focus more on sustainable practices than carriers, but the size of shipments influences the demand for sustainability in supply chains [31]. Those shippers with environmental concerns prefer smaller and newer carriers, as they are less resistant and more flexible [1,18]. On the other hand, the size of shippers has a positive influence on the demand for transparency in environmental performance [22]. Ref. [7] mentions the voluntary participation of companies in reducing their CO_2 emissions related to freight operations, regardless of the size of the company or its sector of activity.

The relationship between the size of shipments and sustainable practices in transport becomes easier to implement in less intense transport with greater flexibility to choose routes and more carbon-efficient carriers [36]. The size of companies is not always a decisive factor in adopting sustainable practices in transport. Ref. [37] shows that smaller companies can be more flexible and agile in implementing sustainable practices, while larger companies may have more difficulty changing their existing practices.

Based on the research objectives in the literature, the following working hypothesis was established:

Hypothesis 1 (H1). *The sector framework, management characteristics, transport contract typology, and size of shipments characterize the business of shippers.*

Sustainable practices encompass various aspects of environmentally friendly and socially responsible initiatives adopted by cargo owners and other stakeholders in the maritime logistics chain. Pollution prevention in transport involves measures to minimize and mitigate the environmental impact of maritime transport, such as recycling and reusing waste, recycling packaging materials, and implementing carbon capture and retention strategies. Green logistics chains refer to the integration of efficient technologies and transformation chains, collaboration for transport reduction, and the implementation of smart eco-driving practices to enhance the overall sustainability of the logistics operations. Social responsibility encompasses commitments to social responsibility, including fair wages, gender equality, and promoting justice and equality within the maritime logistics industry and the communities it operates in. Adoption of green fuels involves the utilization of sustainable and low-carbon fuels such as ammonia, methanol, hydrogen, liquefied natural gas (LNG), and hydrotreated vegetable oil (HVO) in maritime transport operations. Promotion of green modes of transport focuses on prioritizing and utilizing environmentally friendly modes of transport, such as rail and maritime transport with electric engines, to reduce emissions and improve overall sustainability.

2.5. Pollution Reduction

Various studies have analyzed ways to reduce pollution in the shipping industry by adopting more efficient propulsion technologies, such as hybrid electric engines, which reduce emissions of air pollutants with environmental impact [38]. Lower ship speeds reduce air pollutant emissions, particularly CO_2 [39]. It is also possible to reduce the environmental impact of maritime transport by using more efficient ships that consume less fuel and emit fewer air pollutants [32].

In road transport, pollution reduction is a growing concern, resorting to the use of electric or hybrid electric vehicles, which emit fewer air pollutants and have less environmental impact than fossil fuel-powered vehicles [40]. Moreover, the use of biofuels, such as biodiesel, reduces emissions of air pollutants such as carbon dioxide and particulate matter [18]. Another strategy is the adoption of more efficient propulsion technologies, such as natural gas vehicle (NGV) engines, which emit fewer air pollutants than fossil fuel engines [34]. It is also possible to reduce air pollutant emissions by using cleaner fuels, such as low-sulfur diesel [20].

Ref. [41] discuss ship recycling and highlight the importance of addressing the technical, economic, and regulatory challenges associated with the practice and emphasizes the importance of proper solid waste management generated during the ship recycling process. Ref. [42] discusses ship material recycling and highlights the importance of collaboration between companies, governments, and civil society organizations to promote the practice. International legislation has increased the requirements for reducing air and sea pollution in maritime-based logistics chains, gradually reducing the acceptable levels of polluting products in ship fuels, opting for electric power supply during a ship's stay in port and the obligation and incentive for the separation and treatment of ship and cargo waste, avoiding sea pollution [43]. Pollution prevention in transport is determined by cargo owners, with greater demands on recycling and reuse of solid and liquid waste and using transport packaging [1,27].

2.6. Green Logistics Networks

Cargo owners responsible for imports reported high levels of container consolidation and efficiency, although there are still opportunities to improve their use, avoiding the transport of empty space by shifting to a port-centered logistic model [19]. It is also essential to reduce empty space in trucks and empty trucks [2] and adopt eco-driving [28,35], as well as greater energy efficiency of transport services. Efficient design and cooperation to reduce empty transport is essential [30]. Green warehousing and eco-driving, green transport management, green logistics systems, and green packaging are essential for more sustainable transport [28].

2.7. Social Responsibility

Not using fossil fuels, using electricity, and avoiding noise are positive measures for public health and employee health [1]. Permanent improvements in working conditions and wages influence sustainable practices, especially in the social aspect [29].

One of the main social responsibilities of shipowners is to ensure fair wages and adequate working conditions for their employees. According to [29,44], permanent improvements in working conditions and wages are important for sustainable practices, particularly in the social dimension, and improve the retention of skilled workers in the maritime industry. According to Ref. [45], the use of fair state ships, considering the controversy of "flags of convenience", is essential to ensuring adequate working conditions and protecting the human rights of employees in the maritime industry. Gender equality and the presence of women are other significant social responsibility issues in the maritime industry [46]. Moreover, according to Ref. [47], it is crucial to promote a safe and inclusive work environment for women in the maritime industry to increase their participation and contribution.

2.8. Green Fuels

In many countries, renewable fuels such as biomethane, biodiesel, ethanol, and green electricity are used, and the general requirements and use of HVO and/or RME are being simplified [1]. Alternative engines [40] and alternative fuels [28,30] are vital.

The use of ammonia or methanol as low-carbon emission fuels has been considered a viable option for maritime transport. Studies show that ammonia can significantly reduce greenhouse gas emissions and that methanol can be produced from renewable sources, although technical and safety challenges are noted [48,49]. Hydrogen is seen as a promising energy source for low-carbon maritime transport, with safety issues of production and distribution infrastructure to be resolved [50,51]. Carbon capture and hydrogenation is another alternative to reduce greenhouse gas emissions in maritime transport. However, it is still an emerging technology, and challenges include hydrogen production infrastructure and high costs [52,53]. Liquefied Natural Gas (LNG) is another alternative to reduce greenhouse gas emissions in maritime transport. However, methane emissions during the production and transport of LNG are still a concern [54,55]. Hydrogenated biofuels, such as HVO and RME, are yet another alternative considered for reducing greenhouse gas emissions in maritime transport. However, limited availability and production challenges remain a concern [56,57].

2.9. Green Transport

Sustainability demands from cargo owners to logistics and transport service providers often boil down to using trucks with EURO VI emission levels [1,6]. It is also essential to require a shift towards intermodal transport, with increased use of railways and maritime transport [28,30,33,35]. The use of electric engines in maritime transport has been receiving increasing attention as a way to reduce greenhouse gas emissions [58]. The electrification of logistics and port operations can significantly reduce greenhouse gas emissions in maritime transport [59]. Using more efficient trucks can help reduce greenhouse gas emissions in land transport [60]. Turning to railways helps reduce greenhouse gas emissions in land transport [58]. Additionally, using maritime transport helps reduce greenhouse gas emissions in long-distance transport [61,62].

Based on the research objectives in the literature, the following working hypotheses were established:

Hypothesis 2 (H2). *Pollution prevention in transport, green supply chain, social responsibility, green fuels, and green transport characterize the sustainable practices of maritime-based logistics chains.*

Hypothesis 3 (H3). *The business characteristics of cargo owners influence the sustainable practices of maritime-based logistics chains.*

3. Method

The research model refers to the relationship between the business characteristics of the cargo owner, identified by the four constructs which are the sector framework, company management characteristics, type of transport contract, and size of shipments, and the sustainable practices of logistics chains identified by the five constructs which are pollution prevention mode, green logistics chains, social responsibility, green energy, and green transport modes (Figure 1). The working hypotheses (H1; H2; H3) are noted.

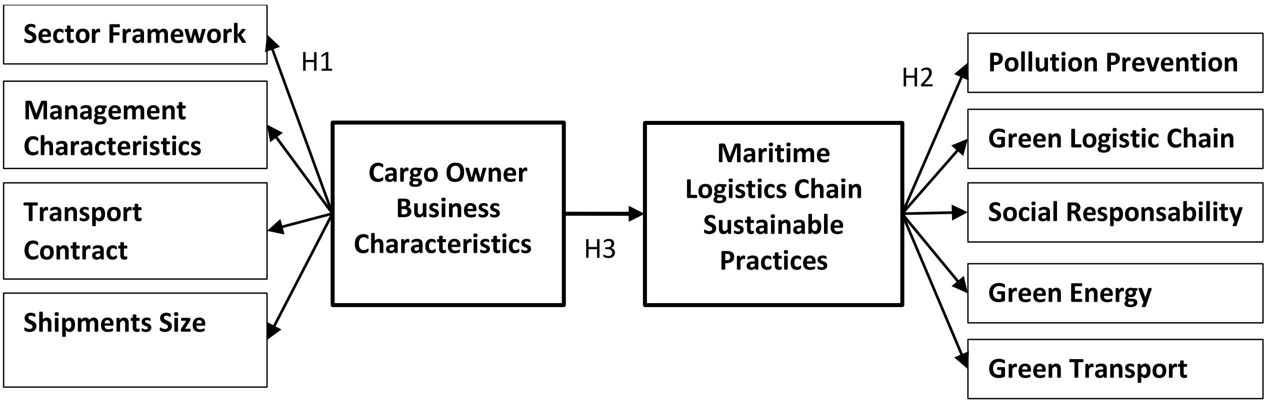

Figure 1. Research model and hypotheses.

3.1. Constructs and Variables

The sector framework construct is explained by the three identified variables: industrial and environmental regulation; green taxes; transport cost in the sector.

The management characteristics construct is explained by the ten identified variables: commitment to sustainability; focus on sustainable practices; social responsibility policy; alignment with carriers on sustainability; existence of a sustainability department; use of sustainability indicators; calculation of carbon in transport; higher environmental requirements; green business model; green associations.

The type of transport contract construct is explained by the three identified variables: long-term contracts; use of full ships; use of containers.

The size of the shipments construct is explained by the two identified variables: direct relationship between shipper and carrier or logistics service provider; size of regular shipments (Appendix A: Table A1).

The pollution prevention construct is explained by the five identified variables: recycling and reuse of solid waste; recycling and reuse of liquid waste; recycling of transport packaging; use of clean wind and solar energy; renewable and non-polluting energies; carbon retention in transport by catalysts and scramblers.

The green supply chains construct is explained by the six identified variables: green logistics networks; more efficient transport technologies; more efficient design of supply chains; syncromodality in transport; collaboration to reduce empty transport; smart eco-driving.

The social responsibility construct is explained by the three identified variables: use of ships with fair flag states; payment of fair wages; promotion of gender equality.

The green fuels construct is explained by the five identified variables: use of ammonia or methanol; use of hydrogen in transport; use of hydrogenated captured carbon in transport; use of LNG in transport; use of HVO and RME in transport (hydrogenated biofuels).

The green transport modes construct is explained by the five identified variables: use of electric engines in transport; logistics operations and ports with electricity; use of more efficient trucks; increased use of railways; increased use of maritime transport (Appendix A: Table A2).

3.2. Samples and Measures

The sample consists of Portuguese companies that are part of maritime-port logistics chains. The questionnaire was sent to 2000 specialists from industrial, commercial, freight forwarding, port, logistics, maritime transport, and land transport companies. Respondents answer with respect to the cargo owner in the logistics chain they are most familiar with. A total of 141 valid responses were obtained (7%).

A pre-test was carried out with a group of five specialists to ensure validity and reliability. The data obtained identify the main business characteristics of cargo owners and the sustainable practices of maritime-based logistics chains, as well as the influencing relationship. The survey evaluates the importance of each of the factors and variables that characterize the cargo owners' business (7-point Likert scale) and each of the factors that identify the sustainable practices of the maritime-based logistics chain (7-point Likert scale), allowing for a comparison between exogenous and endogenous variables, interpreting and measuring the specialists' perception of the relationship between factors and the relationship between variables.

The structural equation modeling (SEM) method [63] was used to test and confirm the structural model of relationships between latent variables obtained from factor analysis [64]. The Amos software from SPSS [65] was used.

The survey characterizes the cargo owners chosen by the respondents to the survey, with characteristics scored up to 100% (Appendix A: Table A3).

3.3. Pre-Assessment

The pre-assessment (and pre-test) involves specialists from five relevant companies—companies A, B, C, D, E—operating in maritime-based logistics chains in Portugal (Appendix B). Based on the respondents' evaluation, a graph was created showing the importance of each of the selected factors and variables for characterizing sustainable practices in the maritime-based logistics chain, which may be influenced by cargo owners (Appendix B: Table A4). This table refers to the average score assigned by specialists regarding the importance of each of the sustainable practices in the logistics chain that are most subject to the influence of cargo owners.

The highest-scoring factors are more efficient transport technology, recycling and reuse of waste, collaboration to reduce empty transport, intelligent eco-driving, recycling of transport packaging, use of electric motors in transport means, and the use of more efficient trucks. These can be considered the practices most subject to influence by cargo owners in the short and medium term to increase the sustainability of maritime-based supply chains, which cargo owners should better consider when outsourcing transport.

4. Analysis and Results

It was observed that 56.0% of respondents were over 50 years old, 36.9% were between 31 and 50 years old, and 7.1% were under 30 years old. A total of 27% work in the industry, 24.1% in ports and logistics platforms, 12.1% in freight forwarding companies, 7.1% as logistics service providers, 2.1% in commercial and distribution companies, 5.0% as transport providers, and 22.7% in other activities. The variables used in the survey show an average score higher than 4.5 points on the 7-point Likert scale.

Structural Model

The authors used Structural Equation Modeling (SEM) in this study because it offers several advantages when dealing with surveys using a long 7-point Likert scale to gather expert opinions on various variables. Firstly, SEM allows for a quantitative analysis of the relationships and comparisons between variables. It enables the researchers to assess the strength and significance of the connections between different constructs, providing a rigorous statistical framework for evaluating the relationships. Secondly, SEM accommodates the subjective nature of the Likert scale responses. While Likert scales capture subjective opinions, SEM enables the researchers to model and quantify these subjective assessments. By treating the Likert scale responses as observed indicators of latent variables, SEM allows for the estimation of underlying constructs and their interrelationships.

The benefits of using Structural Equation Modeling (SEM) to understand the relationship between latent variables have been explored in various recent studies. For instance, Ref. [66] utilized SEM to investigate the effect of green intellectual capital on green performance in the Spanish wine industry. In a similar vein, Ref. [67] employed SEM to scrutinize the role of green innovation and green supply chain management on the sustainability of the performance of SMEs. Ref. [68] also implemented SEM to analyze the structural relationships of a firm's green strategies for environmental performance, emphasizing the roles of green supply chain management and green marketing innovation. Ref. [69] used SEM to explore the technical and behavioral dimensions of green supply chain management. SEM allowed them to construct a roadmap towards environmental sustainability, thus demonstrating its utility in facilitating understanding of complex relationships between latent variables in the context of environmental sustainability.

Moreover, SEM offers the capability to incorporate measurement error in the analysis. Likert scales may have inherent measurement error due to subjective interpretation or response biases. SEM accounts for this measurement error and provides more accurate estimates of the relationships between variables. Furthermore, SEM facilitates the visual examination of complex models with multiple dependent and independent variables. It allows for the simultaneous assessment of both direct and indirect effects, enabling a comprehensive understanding of the relationships among the variables. The choice of SEM in this study with a Likert scale of seven points was driven by its ability to provide a quantitative analysis of expert opinions, allowing for comparisons and relationships between variables. Despite relying on subjective opinions, SEM enables the researchers to obtain meaningful insights and draw robust conclusions from the data.

In developing the structural model, multiple steps were taken to ensure a high level of goodness-of-fit. These steps involved assessing the internal consistency, convergent validity, and unidimensionality of the models, as outlined by Ref. [70]. One specific model employed in this study considered 'Cargo Owners Business Characteristics' as a second-order construct. This construct served as a mediator between the independent first-order constructs characterizing the cargo owner's business (on the left side of the model) and the dependent first-order constructs characterizing the sustainable practices in the maritime logistics chain (on the right side of the model). Each first-order construct was derived from observed variables that were associated in the SEM model. The selection of these observed variables was based on a literature review and took into consideration their significant coefficients, as described in Tables A1 and A2. The goodness-of-fit results of the model were assessed using various indices. These indices included a Chi-square value of 2654.618 ($p \leq 0.01$), a Chi-square to degrees of freedom ratio of 2.897, a Goodness-of-Fit Index (GFI) of 0.90, and a Root Mean Square Error of Approximation (RMSEA) of 0.118. These goodness-of-fit indices provide evidence of how well the proposed model fits the data. The obtained values indicate an acceptable fit between the model and the observed data, suggesting that the structural model adequately represents the relationships among the variables. By following these steps and obtaining satisfactory goodness-of-fit results, the study ensures the robustness and validity of the structural model in examining the relationships between cargo owners' business characteristics and sustainable practices in the maritime logistics chain.

Cargo owners' business characteristics are especially identified (Figure 2) by the size of shipments and the relationship they have with transport service providers ($\beta = 0.87$), by the sector framework with evidence of sector and environmental regulation, green taxes, and the weight of transport costs in the sector ($\beta = 0.42$), and also by the management characteristics of the companies, which contribute to the commitment and alignment of sustainable practices with transport, green associative models, and the use of sustainability indicators for higher environmental requirements ($\beta = 0.25$). The type of transport contract, which includes long-term contracts and the use of full ships and containers, contributes very little as a business characteristic of cargo owners ($\beta = 0.09$).

The sustainable practices of maritime-port logistics chains adopted by cargo owners' businesses differently influence the five factors of sustainable practices: (1) pollution prevention in transport ($\beta = 0.91$; $R2 = 0.83$), involving pollution prevention care by recycling and reusing waste, recycling packaging, and carbon retention; (2) green logistics chains ($\beta = 0.67$; $R2 = 0.45$), explained by the use of green logistics chains that integrate efficient technologies and transformation chains, collaboration for transport reduction, and smart eco-driving; (3) social responsibility ($\beta = 0.54$; $R2 = 0.29$), explained by the commitment to social responsibility focused on countries with a strong sense of justice, fair wages, and gender equality; (4) green fuels (β = 0.79; R2 = 0.62), which considers the care for adopting green fuels, using ammonia or methanol, hydrogen utilization, and captured carbon, LNG, and HVO; and (5) green modes of transport (β = 0.97; R2 = 0.95), identified by green transport modes, rail, and maritime, by using electric engines, efficient transport, and green port logistics operations. Each factor represents specific actions and considerations related to sustainability in maritime-port logistics chains, such as recycling and reusing waste, utilizing efficient technologies and collaboration for transport reduction, promoting social responsibility and fair wages, adopting green fuels, and using environmentally friendly transport modes. In a Structural Equation Modeling (SEM) model, β (beta) and R2 (R-squared) are statistical measures used to assess the relationships and explained variance in the model. β (beta): β represents the standardized path coefficients or standardized regression weights in an SEM model. It indicates the strength and direction of the relationships between the variables in the model. Each β coefficient corresponds to the effect of one variable on another variable. A positive β coefficient indicates a positive relationship, a negative β coefficient indicates a negative relationship, and the magnitude of the coefficient represents the strength of the relationship. R2 (R-squared): R2 measures the amount of variance explained in a particular endogenous variable (dependent variable) by its predictors (independent variables) in an SEM model. It represents the proportion of variance in the dependent variable that is accounted for by the independent variables. R2 values range from 0 to 1, with higher values indicating a greater proportion of variance explained. R2 can be interpreted as the goodness of fit of the model for the specific endogenous variable, reflecting how well the predictors capture the variability in that variable. It's important to note that β coefficients and R2 values are standardized in SEM, meaning they are scaled to have a mean of zero and a standard deviation of one. This standardization allows for easier comparison and interpretation of the coefficients and explained variance across different variables in the model.

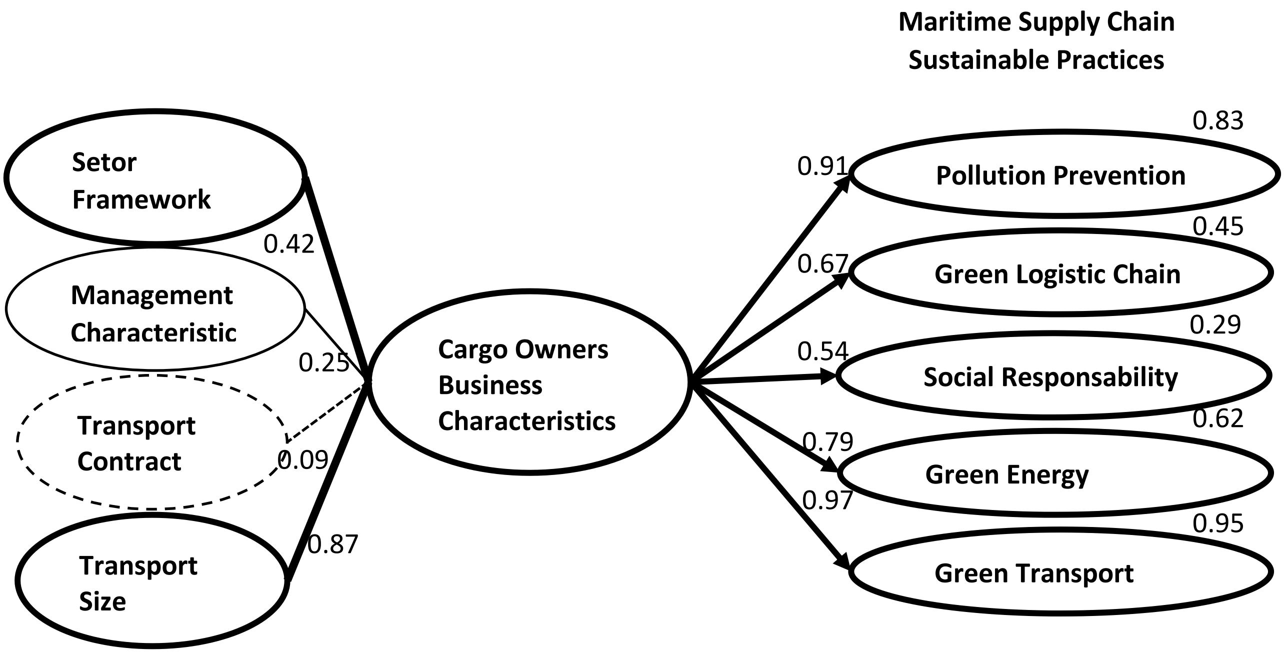

Figure 2. Results of SEM Research, based on Cargo Owners Business Characteristics (first level construct).

The second model relates the four constructs that make up cargo owners' business characteristics direct influence on the five constructs that identify maritime logistics chain sustainable practices (Figure 3), without using a second level construct. This model did not utilize a second-level construct, but explored direct relations. The goodness-of-fit results of the model are confirmed (χ^2 = 94.363, $p \leq 0.01$; χ^2/df = 2.621; GFI = 0.883; NFI = 0.976; RFI = 0.913; RAMSEA = 0.108).

Second-order constructs, also known as higher-order constructs or latent variables, play an important role in Structural Equation Modeling (SEM) as they provide a way to capture complex relationships and summarize the underlying dimensions of multiple observed variables. The importance of second-order constructs in SEM stems from several reasons: reduction in complexity, conceptual clarity and theoretical grounding, exploratory and confirmatory analysis and model parsimony and efficiency. However, it is recommended to test both the simpler (without second-order construct) and more complex (with second-order construct) models and compare their fit indices, interpretability, and theoretical coherence. This model comparison allows researchers to evaluate the added value of the second-order construct and make an informed decision about its inclusion in the final model.

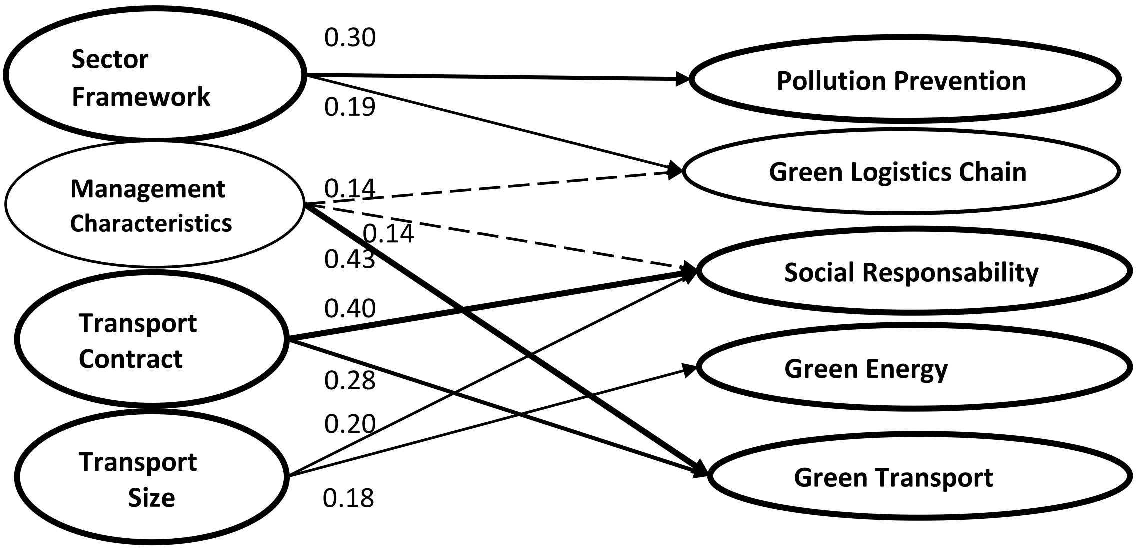

Figure 3. Results of SEM Research (without second level construct).

This study shows that management characteristics have a strong relationship with green transport (β = 0.43) and transport contracts have a strong relationship with social responsibility (β = 0.40). Additionally, the regulatory framework has a strong influence on pollution prevention (β = 0.30) and green logistics chains (β = 0.19). There are three groups of relevant effects in the influence relationships. On the one hand, management characteristics and transport contracts have a strong relationship with social responsibility (β = 0.40; β = 0.20), and management and transport contracts have a strong relationship with green transport (β = 0.43; β = 0.28). On the other hand, the sector framework has a strong relationship with pollution and green logistics chains (β = 0.30; β = 0.19). Finally, the transport size is related to social responsibility (β = 0.20) and green energy (β = 0.18), influencing the use of green fuels such as methanol, hydrogen, LNG, HVO, and RME.

5. Discussion

This research examines the relationship between cargo owners' business and sustainable practices in maritime-port logistics chains. Four factors characterize the cargo owners' business with the characteristics of management, transport contract, and sector framework standing out. The study confirms Hypothesis 1.

The sector framework [5,18] regarding the regulation of sector activities and environmental regulation determines the cargo owner's performance in the business. Green and carbon taxes also determine cargo owners' actions in transport contracting. Transport costs affected by sustainable transport contracting associated with the sector of activity and the load strongly influence the cargo owner's business. Ref. [1] confirm the importance of legislative requirements in the relationship between shippers and transport and logistics service providers, as well as [19] concluding that government initiatives and industry-led initiatives are essential for improving the environmental performance of freight transport. Similarly, Ref. [23] states that green taxes enable greener transport.

In turn, management characteristics distinguish the cargo owner's company [18,34], to which sustainable management practices and business concerns, social responsibility policy, the use of sustainability and carbon emission indicators in transport, clients' environmental and sustainability demands, among others, contribute. Ref. [21] verified the importance of prices in the relationship with carriers [6,23] and the green demand from clients with implications in determining transport requirements. The importance of cargo owner cooperatives in implementing sustainability measures in transport [20,29], is confirmed, and that top management awareness is crucial for influencing sustainable transport [23].

Similarly, the type of services and contracts used by the cargo owner [19] depends on the duration, the use of full ships, and the use of containers. It is confirmed that cargo owners with long-term contracts with maritime transport lines have more power to demand sustainable requirements in transport [19] and that explicit sustainability targets have a positive influence on transport, as argued by [31].

Additionally, the size of the shipments [1,31] depends on the relationship between shippers and carriers. Ref. [7] considers that environmental issues are not yet a decisive criterion in selecting the carrier, and it is necessary to measure CO_2 emissions.

This research also verifies that sustainable practices in maritime-port logistics chains include pollution prevention in transport, green logistics chains, social responsibility, green fuels, and green transport modes. The study confirms Hypothesis 2.

Pollution prevention in transport [1,19] is strongly associated with cargo owners, who have greater demands for recycling and reusing solid and liquid waste and transport packaging. The use of renewable energy to reduce pollution and carbon-neutral energy, as well as the use of catalysts in road transport or scramblers on ships, are increasingly demanded by cargo owners. Green logistics networks [2,35] ensure more efficient and less carbon-emitting organization, means, and energy, synchronicity, reduction in empty space transport, as well as eco-driving and more efficient artificial intelligence applied to motors and transport, which are sustainable practices that the cargo owner can influence. Social responsibility [29] contributes to sustainability in the context of sustainable development goals (UN), especially fair wages, fair labor laws, and promotion of gender equality policies, avoiding social dumping and discriminatory practices. The importance of improving working conditions and wages as sustainable practices, as referred to by Ref. [29], is confirmed.

The use of green fuels [1,28] that do not emit carbon with carbon neutrality contributes to sustainability. The importance of phasing out fossil fuels and using electricity or neutral fuels, such as gas trucks, electric trucks, or other neutral fuels, as referred by Refs. [1,28,30], is confirmed. Green transport [1,20,35] contributes to sustainability for cargo owners with logistics and transport service providers using EURO VI emission level trucks, and as advocated by Ref. [33], the increased use of intermodal transport, such as rail and sea modes. The importance of avoiding empty space transport by changing logistics models and greater collaboration between companies, as referred to by Refs. [2,19], as well as the importance of eco-driving [28], is confirmed.

The study confirms that the characteristics of cargo owners' business influences sustainable practices in maritime-port logistics chains. Hypothesis 3 is verified. Environmental regulation, green taxes, and especially the use of larger cargo volumes benefit cargo owners in choosing sustainable modes of transport, such as rail and sea, regarding the use of green fuels, as well as the efficiency of electric road and quality of port logistics operations. The management choices made by cargo owners to use sustainability indicators, carbon calculations, and green associativism also reflect their concern to ensure conditions of social responsibility.

6. Conclusions and Contributions

The main conclusion considers that the different characteristics of cargo owners influences sustainable practices in maritime-port logistics chains in diverse ways, with evidence for pollution prevention and the use of green transport. The results indicate that the business characteristics of cargo owners strongly influence the choice of green transport and pollution prevention. In other words, cargo owners have a strong opportunity to clearly influence pollution control through recycling and reuse, the use of electric energy and carbon retention in transport, and the choice of green transport modes, such as using less polluting trains and ships, electric and more efficient trucks, and choosing ports that emit less carbon.

Furthermore, management characteristics and the size of the shipments have a strong influence on social responsibility and green transport. Sustainable management of cargo owners' companies is essential for demanding respect for social responsibility by ships, ports, and other greener transport modes.

Sector and environmental regulations strongly influence pollution prevention and green logistics chains. In fact, controlling pollution and reducing the carbon footprint in the maritime-based logistics chain largely depends on national and European legislation and defined carbon taxes, with effects still present in regulations adopted by green logistics chains.

The size of shipments in relation to their sustainable transport characterizes the business of cargo owners and strongly influences green energy and social responsibility. Only with large shipments is it possible to influence the shipowner in using greener fuels and adopting fair practices with the crew.

All of these four factors are relevant in the context of the literature, as they provide a better understanding of the sustainability of the maritime-based logistics chain and the relevant role of the cargo owner.

The primary contributions of the study to the literature and practice include understanding the role of cargo owners in the adoption of sustainable practices in maritime-based logistics chains: The study aims to comprehensively understand the characteristics of cargo owners that influence sustainable practices in such logistics chains. By examining this aspect, the study fills a gap in the existing literature and provides valuable insights into the key players and their impact on sustainability. The study identifies and explores the various elements that describe cargo owners in the context of sustainable practices in maritime-based logistics networks. This identification enhances our understanding of the specific factors and attributes associated with cargo owners' involvement in sustainable initiatives. The study identifies and characterizes the factors that contribute to sustainable practices in maritime-based logistics networks. By elucidating these factors, the study offers practical guidance for implementing sustainable measures in the industry, thereby facilitating environmentally friendly transportation, pollution prevention, and corporate social responsibility.

The importance of understanding the role of cargo owners and shippers in the sustainability of transportation on the demand for maritime transportation can be a "silver bullet" for emissions reduction, potentially outweighing the significance of sustainable maritime fuels. This insight indicates that cargo owners and shippers, as major emitters of greenhouse gas emissions and significant users of maritime transportation, have the power to drive sustainable change. Industries with high energy-intensive and carbon-intensive raw material processing, such as the steel industry, can play a crucial role in reducing emissions and lead to a structural shift in maritime transportation demand and a simultaneous reduction in CO_2 emissions. The significance of these insights lies in the need for various actors, including cargo owners, shippers, industries, and governments, to recognize the importance of their roles in shaping sustainable transportation practices. It is important to recalibrate global trade, favoring pioneers in the maritime transportation industry who establish partnerships with clients and secure long-term and high volume contracts for green shipping. This underscores the importance of collaboration and forward-thinking approaches in driving sustainability.

This research emphasizes the need for stakeholders to align their actions and collectively contribute to achieving sustainable transportation goals. By understanding their roles and making informed decisions, cargo owners and shippers can have a significant impact on reducing emissions and driving sustainable practices in the transportation sector. These contributions to the literature and practice offer valuable insights for researchers, practitioners, and policymakers in the field of maritime-based logistics and sustainable practices.

This work has limitations regarding sample size and limited geographic context. Another limitation involves results due to the lack of quantified indicators on the reduction in emissions and increased green practices in maritime-based logistics chains over time in concrete cases of different sectors with diverse characteristics.

Future research can support different characteristics of cargo owners to verify other implications for sustainable practices in logistics chains. It will also be important to analyze each adopted characteristic and evaluate its implications for sustainable practices, extending the study to different geographic contexts.

Other topics for future research, for example, may involve the interaction between key organizational actors, the company's environmental strategy, economic–financial factors and green actions, technological barriers, measuring CO_2 emissions from logistics activities, efficiency of green logistics service offerings, and measuring environmental performance.

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Appendix A

Table A1. Exogenous variables (Cargo Owner Business Characteristics).

First-Order Construct	Observed Variable	Coeff.
Sector Framework Authors [5,18–26,71]	Sector and environmental regulations	0.70
	Green taxes	0.69
	Transport cost in the sector	0.77
Management Characteristics Authors [3–7,22,23,27–32]	Commitment to sustainable practices	0.91
	Investment in sustainable practices	0.91
	Social responsibility policy	0.93
	Alignment with sustainable transporters	0.59
	Sustainability department	0.81
	Use of sustainability indicators	0.89
	Carbon calculation in transportation	0.79
	Higher environmental demands	0.73
	Green business model	0.89
	Green partnerships	0.70
Transport Contract Authors [1,19,33–35]	Long-term contracts	0.75
	Use of full ships	0.73
	Use of containers	0.55
Transport Dimension [1,31,36,38]	Relationship between cargo owners and transporters	0.92
	Shipment size	0.54

Table A2. Endogenous variables (Maritime Supply Chain Sustainable Practices).

First-Order Construct	Observed Variable	Coeff.
Pollution Prevention Authors [1,27,32,34,37–42]	Recycling and reuse of solid waste	0.94
	Recycling and reuse of liquid waste	0.92
	Recycling of transport packaging	0.87
	Renewable and non-polluting energy	0.85
	Carbon retention in transport	0.83

Table A2. *Cont.*

First-Order Construct	Observed Variable	Coeff.
Green Logistic Chain Authors [2,27,28,39]	Green logistics networks	0.96
	More efficient transport technologies	0.80
	More efficient chain design	0.51
	Synchronized transport	0.92
	Collaboration to reduce empty transport Intelligent	0.82
	eco-driving	0.85
Social Responsability Authors [29,43–46]	Fair wages	0.99
	Fair state ships	0.61
	Gender equality	0.87
Green Energy	Use of ammonia or methanol	0.60
	Use of hydrogen in transport	0.89
Authors [47–56]	Use of hydrogenated captured carbon in transport	0.93
	Use of LNG in transport	0.57
	Use of HVO and RME in transport (hydrogenated biofuels)	0.58
Green Transport Authors [57–61]	Use of electric motors in transport	0.95
	Logistics operation and ports with electricity	0.90
	Use of more efficient trucks	0.56
	More use of rail transport	0.71
	More use of maritime transport	0.50

Table A3. Characterization of cargo owners chosen by experts.

Characteristic of Cargo Owner	Variable Weight (Maximum 100%)
Direct relationship with transporters	87.8%
Customers with environmental demands	85.4%
High weight of transport costs	82.9%
Investment in sustainable practices	80.5%
Sector with high environmental regulation	80.5%
Corporate Social Responsibility policy	78.0%
Handles raw materials	78.0%
Handles consumer products	75.6%
Commitment to sustainable practices	73.2%
Handles containers	70.7%
Exports	70.7%
Engages in commercial activities	68.3%
Large company	68.3%
Imports	68.3%
Engages in industrial activities	65.9%
Handles small shipments	61.0%
Has a green business model	61.0%
Aligns sustainable practices with transporters	56.1%
Has long-term transport contracts	53.7%
Pays environmental taxes	53.7%
Has a sustainability department	53.7%
Calculates carbon emissions in transport	51.2%
Uses sustainability indicators in transport	48.8%
Has sustainability requirements in transport	43.9%
Negotiates full ships	41.5%
CEO is over 50 years old.	34.1%

Appendix B

Pre-assessment

The sustainable practices influenced by cargo owners resulted from the pre-assessment conducted through a survey of experts from five relevant companies—companies A, B, C, D, E—operating in maritime-based logistics chains in Portugal.

Company A is a large Portuguese logistics company that considers green legislation and taxes, as well as cargo size and greater concern for sustainable practices, as fundamental business characteristics that can influence more sustainable transport. The use of wind and solar as energy sources is crucial in the supply chain, with electricity and ammonia as future fuels. Catalysts, pollution prevention, and social responsibility are crucial for a more sustainable maritime-based logistics chain.

Company B is a Portuguese mineral export company that considers environmental legislation and increasing customer demand for sustainability as fundamental to sustainable transport. Larger shipments, full ships, environmental alignment with transporters, practical indicators, and long-term contracts are drivers for cargo owners to influence sustainable practices in the maritime-based logistics chain.

Company C is a large Portuguese bulk export industry in the Lisbon region. The business is highly regulated and subject to green taxes. It uses full ships in its direct relationship with transporters. It is investing in sustainable practices, but currently does not have indicators of carbon emissions in transport. More investment by cargo owners is needed in the future to change transport with more sustainable parameters, relying more on maritime transport. More efficient transport technologies, greater use of electricity, and greater reuse of waste are the future focus for maritime-based logistics chains.

Company D is a Portuguese industrial exporter of consumer products. It has a direct relationship with transporters and considers customers increasingly demand sustainable conditions in the logistics chain. It aligns with transporters in sustainable practices and calculates carbon emissions. The future of sustainable transport is based on rail and maritime transport, with hydrogen, ammonia, and carbon capture assumed.

Company E exports minerals, subject to heavy regulation and high transport costs for the exported product, with a direct relationship with transporters, using containers. It has no environmental alignment or transport requirements. It considers that larger shipments and sustainability partnerships are crucial for a sustainable maritime-based logistics chain. Other important issues for the future include measuring emissions in transport, greater environmental concern by cargo owners, relying more on maritime transport, wind, solar, electricity, newer trucks, and recycling of packaging. Collaboration to reduce empty transport, eco-driving, fairer wages, and gender equality are also considered important for the future.

Table A4. Sustainable practices influenced by cargo owners (7-point Likert scale).

Variable	Average
More efficient transport technologies	6.11
Recycling and reusing solid waste	5.99
Collaboration to reduce empty transport	5.98
Intelligent eco-driving	5.93
More efficient truck unitization	5.92
Use of electric motors in transport	5.91
Recycling of transport packaging	5.90
Fair wages	5.87
Recycling and reusing liquid waste	5.87
Logistic operations and ports with electricity	5.87
Green logistics networks	5.83
Use of wind and solar as energy sources	5.82
Gender equality	5.81
More efficient supply chain design	5.79

Table A4. *Cont.*

Variable	Average
Increased use of rail transport	5.73
Synchronicity in transport	5.72
Increased use of maritime transport	5.70
Use of catalysts and scramblers to retain carbon in transport	5.68
Use of HVO and RME in transport (hydrogenated biofuels)	5.50
Use of hydrogen in transport	5.48
Fair state ships	5.48
Use of ammonia or methanol	5.43
Use of hydrogenated captured carbon in transport	5.39
Use of LNG in transport	5.27

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