

Rail freight development and modal shift from road transport: an empirical analysis of economic, energy and environmental perceptions in Morocco

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Abstract

Purpose – The purpose of this study is to examine the determinants of modal shift intention from road freight transport to rail freight in Morocco, focusing on the perceived economic, energy and environmental performance of rail freight.

Design/methodology/approach – A quantitative survey was conducted among key freight transport stakeholders, including road carriers, industrial shippers, logistics operators and experts. A total of 483 valid questionnaires were collected. Measurement scales were derived from the literature and adapted to the Moroccan context. Data were analyzed using SPSS through descriptive statistics, reliability analysis, correlation tests and multiple linear regression.

Findings – The results indicate generally positive perceptions of rail freight, particularly regarding energy efficiency and environmental performance. All three perceived performance dimensions have a positive and significant effect on modal shift intention. Perceived energy performance emerges as the strongest predictor, followed by environmental impact, while economic performance shows a significant but more moderate influence. The model demonstrates strong explanatory power.

Research limitations/implications – The study relies on perceptual data and a non-probabilistic sampling approach, which may limit the generalizability of the findings. Future research could integrate objective cost, energy and emission data; apply longitudinal designs or extend the model by incorporating institutional, infrastructural and policy-related variables to further explain rail freight adoption.

Practical implications – The findings provide valuable insights for policymakers, rail operators and logistics managers by highlighting the key levers for promoting rail freight development. Strengthening rail energy efficiency, improving service reliability and enhancing intermodal integration can significantly increase stakeholders' willingness to shift freight from road to rail.

Social implications – By encouraging modal shift toward rail freight, the study supports broader societal objectives related to environmental protection, energy security and sustainable development. Increased use of rail freight can contribute to reduced greenhouse gas emissions, lower road congestion and improved quality of life in urban and industrial areas.

Originality/value – This study provides one of the first empirical investigations of rail freight modal shift determinants in Morocco, offering an integrated analysis of economic, energy and environmental factors within a single conceptual framework.

Keywords Rail freight transport, Modal shift, Energy efficiency, Environmental performance

Paper type Research article

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1. Introduction

Rail freight transport occupies a strategic position within contemporary transport systems, particularly in a context characterized by sustained growth in trade, the globalization of value chains, and the need to reduce the environmental footprint of logistics activities (Hu *et al.*, 2020). At the international level, rail freight is widely recognized as a structuring mode of transport capable of moving large volumes over long distances, with significantly lower levels of energy consumption and greenhouse gas (GHG) emissions than heavy road transport (da Fonseca-Soares, Eliziário, Galvinctio, & Ramos-Ridao, 2024). This recognition has led many countries to place rail freight at the core of their sustainable mobility and energy transition policies.

In Morocco, freight transport plays a decisive role in economic and territorial development dynamics (Salhi, Benhsain, & Boujrouf, 2024). The expansion of major port and industrial platforms—such as Tanger Med, Casablanca, Kénitra Atlantic, and Nador West Med—has substantially intensified freight flows, thereby increasing the demand for efficient, reliable, and competitive transport solutions (Bencardino & Esposito, 2020). In this context, the national railway network, operated by the Moroccan National Railways Office/Office National des Chemins de Fer (ONCF), represents a major asset by connecting the country's main economic and logistics hubs and offering significant potential for the development of rail freight (Mohamed, 2020; Hoummirat & Blayac, 2025). Nevertheless, despite these structural advantages and the substantial investments made in railway infrastructure, the share of rail in freight transport remains limited, to the benefit of a largely dominant road transport sector.

The predominance of road freight transport in Morocco can be explained by its high operational flexibility and its ability to provide door-to-door services. However, this dominance is accompanied by considerable economic, energy, and environmental costs. Growing congestion along strategic road corridors, accelerated deterioration of infrastructure, strong dependence on imported fossil fuels, and rising GHG emissions highlight the structural limitations of a transport model largely based on road haulage (Ferrer & Thome, 2023). In an international context marked by climate urgency, energy market volatility, and the strengthening of environmental commitments by states, these limitations raise critical questions about the long-term sustainability of Morocco's freight transport system.

In this perspective, the development of rail freight and the modal shift of heavy road transport toward rail emerge as strategic levers for improving the overall performance of the transport system. Rail transport offers well-established comparative advantages in terms of energy efficiency per tonne-kilometer, the reduction of environmental externalities, and its capacity to accommodate the future growth of freight transport demand (El Moussaoui *et al.*, 2025a, El Moussaoui, Loqman, & El Moussaoui, 2025b; Tookey & Dhawan, 2025). However, the competitiveness of rail cannot be taken for granted; it depends on multiple factors, including investment and operating costs, the organization of rail services, intermodality with other transport modes, and the institutional and regulatory framework (Knorr & Eisenkopf, 2022; Abu-Aisha, Audy, & Ouhimmou, 2024).

In the Moroccan context, the issue of rail freight therefore requires a rigorous evaluation grounded in realistic operational and economic assumptions. Rather than projecting long-term horizons based on speculative assumptions, this study adopts a scenario-based analytical framework to examine the economic, energy, and environmental implications of a gradual modal shift from heavy road transport to rail under plausible development conditions. This approach allows for a structured comparison between transport modes while avoiding overextension of forecast horizons.

It is within this framework that this article is situated. Its main objective is to assess the costs and benefits associated with an expanded development of rail freight transport in Morocco through a modal shift scenario from heavy road transport to rail. The study emphasizes comparative evaluation rather than predictive certainty, focusing on discounted economic costs, energy performance indicators, and estimated environmental externalities under defined scenarios. The originality of this research lies in its empirical application to the Moroccan

context and in its integrated approach combining economic, energy, and environmental dimensions. While the existing literature on rail freight is largely dominated by studies conducted in industrialized countries, this article contributes to addressing a gap in applied research focusing on emerging economies, particularly in North Africa.

More specifically, the study aims to estimate the freight volumes that could potentially be accommodated by rail under defined modal shift scenarios, to identify the investments required in railway infrastructure and rolling stock, to compare the overall costs of rail freight and heavy road transport, and to analyze potential gains in terms of energy consumption and reductions in GHG emissions. By articulating these objectives, the study seeks to answer the following research questions: (1) Under what economic conditions can rail freight become competitive relative to heavy road transport in Morocco? (2) What levels of investment are required to support a structured modal shift? (3) What are the expected energy and environmental implications of such a transition?

To achieve these objectives, the article is structured into six sections. Following this introduction, the second section provides an in-depth review of the literature on rail freight, modal shift, and the economic and environmental evaluation of transport modes. The third section outlines the research methodology and the analytical framework adopted. The fourth section is devoted to the presentation and discussion of the empirical results. The fifth section presents the theoretical, methodological, and managerial implications of the findings. Finally, the last section concludes by synthesizing the main findings of the study, highlighting its limitations, and suggesting avenues for future research related to the development of rail freight transport.

2. Literature review and conceptual framework

2.1 Literature review

The literature on freight transport assigns a central role to rail freight in the analysis of sustainable transport systems, particularly in contexts characterized by sustained growth in traffic flows, increasing pressure on road infrastructure, and progressively stricter environmental requirements (Milewicz *et al.*, 2023). Approaches grounded in transport economics highlight that rail freight is characterized by a specific cost structure, dominated by high fixed costs related to infrastructure, rolling stock, and operating systems, but offset by low unit costs as transported volumes increase (Marcucci, Gatta, Simoni, & Maltese, 2023; White, 2025). This configuration provides rail transport with significant economies of scale and density, which explain its competitiveness for the movement of bulk, regular freight over medium and long distances. By contrast, road transport, although more flexible and better suited to fragmented flows and door-to-door services, relies on high variable costs that are highly sensitive to energy prices, congestion, and infrastructure wear (Zhu, 2024).

Within this perspective, numerous studies mobilize the concept of generalized transport cost to explain shippers' modal choices. This concept goes beyond a simple comparison of direct monetary costs by incorporating dimensions such as transit time, reliability, punctuality, cargo safety, and service quality (Izadi, Nabipour, & Titidezh, 2019; Muñoz, Soza-Parra, & Raveau, 2020). Daramola (2022) thus shows that rail freight offers a comparative advantage when flows are predictable and sufficiently large, whereas road transport retains a relative advantage in situations requiring a high degree of operational flexibility. These theoretical frameworks provide an essential foundation for the analysis of modal shift, as they make it possible to identify market segments in which rail can capture an increased share of freight transport.

Moreover, studies rooted in welfare economics and environmental economics emphasize that the dominance of road transport does not necessarily reflect an optimal allocation of resources, due to the existence of significant negative externalities (Varghese & Pradhan, 2025; El Moussaoui *et al.*, 2025a, b). Heavy road freight generates high social costs related to congestion, accidents, air pollution, noise nuisance, and greenhouse gas

emissions, which are rarely fully internalized in transport prices (Čižiūnienė, Bureika, & Matijošius, 2022). By contrast, rail freight stands out for its superior energy performance, measured in terms of energy consumption per tonne-kilometer, and for significantly lower CO₂ emissions, particularly when the network is electrified (Rosenberg *et al.*, 2023; El Moussaoui, 2025). Life-cycle analyses confirm that, despite the initial impacts associated with the construction of railway infrastructure, rail remains more efficient than road over its entire operating cycle, provided that transported volumes are sufficient to amortize these investments (Hausberger, Cordes, & Gschösser, 2023). These evidence reinforce the idea that the development of rail freight constitutes a central lever in strategies aimed at decarbonizing freight transport.

Applied to the Moroccan context, the literature highlights a structural paradox between, on the one hand, the existence of a relatively well-developed national railway network, operated by the Moroccan National Railways Office, connecting the country's main port, industrial, and urban hubs, and, on the other hand, the still marginal role of rail in domestic freight transport. Imhof and Mayer (2025) point out that road transport remains largely dominant due to its flexibility, its ability to provide door-to-door services, and an institutional framework historically favorable to road transport. This situation, however, is accompanied by high economic, energy, and environmental costs, notably in terms of dependence on imported fossil fuels, congestion along key corridors, and rising greenhouse gas emissions (Lin, Qin, Wu, & Xu, 2021; El Moussaoui *et al.*, 2023; Avesh, Hossain, & Sharma, 2024).

In a country committed to an ambitious strategy of energy transition and logistics development, several studies highlight the strategic potential of rail freight to support the growth of goods flows, particularly those generated by ports, industrial zones, and logistics platforms. Rail is thus perceived as a mode capable of enhancing national economic competitiveness while reducing the environmental footprint of the transport system (Niu, Li, Zhang, Deng, & Chang, 2023; Liu, Ali, Chen, & She, 2023). Nevertheless, most studies focusing on Morocco adopt a largely descriptive or sectoral approach, concentrating either on railway infrastructure or on the overall performance of the transport sector, without offering an integrated and forward-looking analysis of the modal shift from heavy road transport to rail (Chengaou, El Yassini, & Oufaska, 2024; Salhi *et al.*, 2024; Hoummirat & Blayac, 2025).

The literature review therefore reveals a significant scientific gap. On the one hand, the theoretical and empirical frameworks demonstrating the economic, energy, and environmental advantages of rail freight have been predominantly developed in industrialized countries, characterized by mature rail freight markets and high levels of investment. Findings derived from these contexts cannot be directly transposed to Morocco without adaptation to national realities in terms of demand structure, cost conditions, railway capacity, and sector governance. On the other hand, existing studies applied to Morocco rarely address economic, energy, and environmental dimensions jointly within a long-term perspective based on explicit scenarios of demand growth and modal shift.

This lack of integrated and forward-looking analyses limits the ability of public decision-makers to rigorously assess the actual benefits of developing rail freight and to make informed trade-offs between road and rail investments. It is precisely this gap that the present study seeks to address by developing an integrated methodological analysis applied to the Moroccan context, aimed at comparing, over a long-term horizon, the economic, energy, and environmental performance of heavy road transport and rail freight. To this end, the study is grounded in a structured conceptual framework drawing on key insights from transport economics, energy economics, and environmental economics, which clarifies the relationships between freight demand growth, modal choice, economic costs, energy consumption, and environmental impacts. This framework also allows the formulation of empirically testable research hypotheses regarding the expected effects of a modal shift from heavy road transport to rail, providing a solid foundation for the scenario-based empirical analysis presented in the remainder of the article.

2.2 Conceptual framework and research hypotheses

Based on the literature review, the present research is grounded in a conceptual framework according to which modal choice decisions by freight transport stakeholders are primarily influenced by their perceptions of the performance of different transport modes. From this perspective, rail freight transport is examined through three key dimensions derived from transport economics and environmental economics: perceived economic performance, perceived energy performance, and perceived environmental impact (Figure 1).

Perceived economic performance refers to stakeholders' assessment of transport costs, long-term control of logistics costs, and the competitiveness of rail freight for consolidated flows over medium and long distances (Derse & Van Woensel, 2024; Sumbal, Agha, Nisar, & Chan, 2024). Perceived energy performance relates to the energy efficiency of rail transport, particularly in terms of energy consumption per tonne-kilometer and the reduction of dependence on fossil fuels (Ozeranska, 2022). Finally, perceived environmental impact refers to greenhouse gas emissions, air pollution, and, more broadly, the contribution of rail freight to a more sustainable transport system (Bilgili, 2023; Pan, 2024).

These three dimensions—economic, energy, and environmental—are expected to influence stakeholders' intention to shift to rail freight, which is defined as their willingness to increase rail usage in place of heavy road transport. Specifically, perceived economic performance is likely to affect decisions by highlighting potential cost savings, efficiency gains, and predictability in logistics operations. Perceived energy performance emphasizes the strategic advantage of rail in reducing energy consumption and reliance on fossil fuels, which may be particularly salient for stakeholders operating in sectors sensitive to energy costs. Perceived environmental impact underscores the broader social and regulatory benefits of rail adoption, including compliance with emission reduction targets, corporate sustainability objectives, and enhanced public image. By considering these dimensions together, the framework captures the multifaceted nature of stakeholders' decision-making processes. It recognizes that the intention to shift to rail is not determined by cost alone but results from an interplay of financial, operational, and environmental considerations. In the Moroccan context, where rail infrastructure exists but road transport dominates, integrating these determinants provides a nuanced understanding of the conditions under which rail freight can become a viable alternative. Ultimately, this approach allows for the formulation of empirically testable hypotheses linking perceived performance in these three domains to the expected modal shift, providing a structured basis for both quantitative and scenario-based analysis.

Based on the developed conceptual framework, the following hypotheses are formulated:

- H1. The perceived economic performance of rail freight transport has a positive and significant influence on the intention to shift from heavy road transport to rail freight transport.
- H2. The perceived energy performance of rail freight transport has a positive and significant influence on the intention to shift from heavy road transport to rail freight transport.

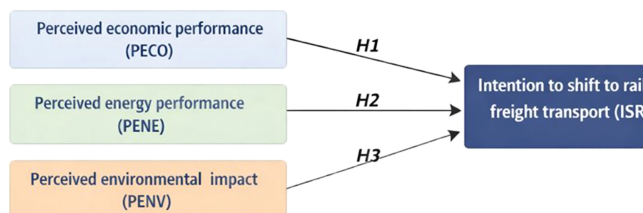


Figure 1. Conceptual framework. Source: Authors' own work

H3. The perceived environmental impact of rail freight transport has a positive and significant influence on the intention to shift from heavy road transport to rail freight transport.

3. Research methodology

The choice of this study is part of an effort to provide an in-depth empirical assessment of the comparative performance of heavy road transport and rail freight transport in a context marked by the continuous growth of logistics flows, the progressive saturation of transport infrastructure, and the increasing need to reduce the energy and environmental footprint of the sector. Although rail freight transport is widely recognized in the scientific literature as a particularly efficient mode for carrying large volumes over medium and long distances, its level of use remains relatively limited in many countries, especially in emerging economies. This discrepancy between theoretical advantages and actual practices underscores the importance of empirically examining the factors influencing modal choice. The methodology adopted in this research is specifically designed to analyze this gap by drawing on field data that allow for a quantitative and structured evaluation of the economic, energy, and environmental performance associated with different freight transport modes. By combining survey-based data with established measurement constructs, the approach ensures methodological rigor and contextual relevance. This methodological orientation ensures a strong coherence between the research objectives, the data collected, the analytical methods employed, and the empirical results that will be presented and discussed in [Section 4](#).

3.1 Data collection

Data collection is based on the implementation of an in-depth quantitative survey conducted using a structured questionnaire administered to actors directly involved in freight transport and logistics. The survey design follows best practices in transport research, ensuring content validity and minimizing measurement bias. The use of this data collection method is justified by the need to gather standardized and comparable information from a large number of respondents, while covering a wide range of analytical dimensions related to modal choice. The questionnaire makes it possible to capture not only actual transport practices, but also stakeholders' perceptions regarding costs, energy efficiency, environmental impacts, and organizational constraints associated with heavy road transport and rail freight transport. This dual focus on objective practices and subjective perceptions enables a more comprehensive understanding of modal shift drivers.

The questionnaire was developed on the basis of an extensive review of the literature on transport economics, rail freight, and modal shift, and was then adapted to the specific characteristics of the Moroccan context in order to accurately reflect the operational realities of the national freight transport system. Particular attention was paid to the wording of the questions, with the aim of clearly distinguishing the characteristics specific to heavy road transport from those of rail freight transport and avoiding any ambiguity that could affect the quality of responses. A pre-test of the questionnaire with a small group of stakeholders was conducted to refine question clarity and ensure contextual relevance. The target population includes road transport companies, industrial and commercial shippers, logistics operators, supply chain managers, as well as experts from the rail sector. These categories of stakeholders are directly involved in modal choice decisions and possess in-depth operational knowledge of the performance of different transport modes.

The sampling strategy adopted is a non-probability purposive sampling method, based on the selection of respondents with proven professional experience in the field of freight transport. This approach, while not aiming for statistical representativeness, prioritizes data quality and relevance, which is particularly suitable for studies focusing on expert perceptions. In total, 483 usable questionnaires were retained for analysis. A larger number of questionnaires were

initially collected, but a rigorous data quality control phase led to the elimination of incomplete, partially completed, or internally inconsistent responses. Such rigorous data cleaning strengthens the validity of subsequent analyses and reduces response biases.

The questionnaire is structured into five complementary sections, each corresponding to a key analytical dimension of the research. The questionnaire was administered in French, a choice justified by the fact that French is the second most widely used language in Morocco after Arabic, particularly in the transport, logistics, industrial, and administrative sectors. The use of French ensures a precise understanding of technical concepts related to rail freight transport, reduces the risk of misinterpretation, and improves the overall quality of the collected data. Responses were measured using five-point Likert-type scales, ranging from “strongly disagree” to “strongly agree.”

In order to operationalize the research model, latent constructs were defined based on the literature and tailored to the Moroccan context. [Table 1](#) presents the constructs and the corresponding survey items.

3.2 Data analysis

Data analysis follows a structured and progressive statistical approach implemented using SPSS software, which is widely recognized in empirical research in economics, management

Table 1. Measurement constructs and items

Construct	Code	Item
Perceived Economic Performance of Rail Freight Transport	PECO1	Rail freight transport helps reduce unit transport costs compared to heavy road transport
	PECO2	The use of rail freight contributes to better long-term control of logistics costs
	PECO3	Rail freight transport is economically competitive for the transport of large volumes over medium and long distances
	PECO4	Rail freight transport helps reduce costs related to road congestion and delays
Perceived Energy Performance of Rail Freight Transport	PENE1	Rail freight transport consumes less energy per tonne-kilometer than heavy road transport
	PENE2	Rail freight transport is more energy-efficient for long-distance transport
	PENE3	The development of rail transport helps reduce dependence on fossil fuels
	PENE4	Rail freight transport improves the overall energy efficiency of the freight transport system
Perceived Environmental Impact of Rail Freight Transport	PENV1	Rail freight transport emits fewer greenhouse gases than heavy road transport
	PENV2	Rail freight transport helps reduce the carbon footprint of logistics chains
	PENV3	Rail freight transport contributes to reducing air pollution
	PENV4	The development of rail transport promotes a more environmentally friendly transport system
Intention to Shift to Rail Freight Transport	ISR1	Our company plans to increase the use of rail freight transport in the future
	ISR2	Rail freight transport represents a credible alternative to heavy road transport
	ISR3	We would be willing to shift part of our freight flows to rail if conditions are favorable
	ISR4	The development of rail freight services would strengthen our intention to reduce road transport use

Source(s): Authors' own work

sciences, and transport studies. SPSS was selected for its robustness, versatility, and ability to perform both descriptive and inferential statistical analyses efficiently. The use of SPSS is justified by its ability to handle large datasets, ensure analytical reliability, and provide a broad range of statistical tests suited to the objectives of the research. The analysis was designed to ensure a coherent alignment between the collected data, the conceptual framework derived from the literature review, and the formulated research hypotheses. This alignment ensures that the results directly address the study's objectives and research questions. It thus aims to generate robust empirical results that make it possible to identify the determinants of rail freight transport development and to explain the underlying mechanisms driving the modal shift from heavy road transport.

In a first step, an in-depth descriptive statistical analysis was conducted in order to characterize the sample and gain a better understanding of the profile of the surveyed actors as well as their freight transport practices. This step also provides insights into prevailing perceptions and highlights areas of potential intervention for rail development. Descriptive analysis thus constitutes an indispensable analytical foundation for interpreting subsequent results and for empirically situating the role of rail transport within the logistics chains under study.

In a second step, the data analysis focused on assessing the quality of the measurement instruments used in the questionnaire. Reliability tests were performed to verify the internal consistency of the latent constructs measuring perceived rail freight performance and the intention to shift modes. Cronbach's alpha values exceeding the recommended threshold confirmed the reliability of the constructs, providing confidence in subsequent regression analyses.

In a third step, correlation analyses were carried out to examine the relationships among the different variables in the research model. These analyses also allowed for preliminary detection of multicollinearity and ensured that each independent variable contributed unique explanatory power. Correlation analysis thus provides an initial reading of the interactions among variables and lays the groundwork for more in-depth explanatory analyses.

Finally, the data analysis relied on regression analyses conducted using SPSS in order to assess the relative influence of the different dimensions of perceived performance on the intention to shift toward rail freight transport. Hierarchical regression was employed to sequentially assess economic, energy, and environmental predictors, allowing for a nuanced understanding of their respective impacts. The results derived from these analyses constitute the empirical core of the research and provide essential inputs for the discussion presented in [Section 4](#). In particular, they make it possible to highlight the central role of the energy and environmental performance of rail freight transport, while also underlining the importance of economic considerations in modal choice decisions.

3.3 Study area

The study area of this research corresponds to the freight transport system in Morocco, analyzed at the national scale through its main logistics corridors linking ports, industrial zones, logistics platforms, and consumption centers. The choice of this study area is justified by the profound transformations experienced by the Moroccan transport system over recent decades, driven by economic openness, the expansion of trade flows, and the implementation of national strategies aimed at strengthening the country's logistics competitiveness. This national-scale approach ensures comprehensive coverage of key freight flows while capturing regional disparities in infrastructure and modal use.

Morocco's freight transport system is characterized by a strong predominance of heavy road transport, which handles the majority of domestic freight flows due to its operational flexibility and its ability to provide door-to-door services. However, this dominance is accompanied by high economic, energy, and environmental costs, particularly in terms of fossil fuel consumption, congestion along major corridors, and greenhouse gas emissions. The

Moroccan railway network, despite significant investments, remains underutilized for freight, making the modal shift a highly relevant policy and research question.

The analysis of the study area highlights that certain logistics corridors offer particularly favorable conditions for the development of rail freight transport. These include routes linking major ports to industrial and logistics zones, where flows are relatively regular, consolidated, and cover distances sufficient to make rail transport competitive. Identification of these corridors allows for a targeted analysis of modal shift potential and informs policy recommendations regarding infrastructure investment and service development. The empirical results presented in [Section 4](#) confirm that these corridors concentrate the most significant opportunities for modal shift, thereby reinforcing the relevance of the chosen study area.

Finally, the choice of the Moroccan context allows this research to be situated within a broader reflection on the development of rail freight in emerging economies. The Moroccan case provides an empirical setting with both high infrastructure potential and persistent institutional constraints, offering lessons applicable to other emerging economies. The analysis of this study area thus contributes to enriching the existing literature by providing empirical findings applied to a still underexplored context, while also offering useful insights for public decision-makers and stakeholders in the rail sector.

4. Results and discussion

4.1 Descriptive analysis of the results

Descriptive analysis constitutes an essential step in any empirical research based on survey data, as it makes it possible to contextualize subsequent statistical results and to anchor their interpretation in the observed realities of the field. In the present case, this analysis aims to empirically situate rail freight transport within the Moroccan logistics system, taking into account both stakeholders' actual practices and their subjective perceptions of rail performance. Through the analysis of the 483 usable questionnaires, this initial analytical phase highlights the structural characteristics of the freight transport market in Morocco, which is marked by a persistent dominance of heavy road transport, but also by the gradual emergence of growing interest in more sustainable transport solutions.

This descriptive stage is of particular importance in the Moroccan context, where modal choice decisions have historically been shaped by institutional, organizational, and economic factors favorable to road transport. In this respect, descriptive analysis not only provides an accurate overview of current practices, but also helps identify early signals pointing to a potential future reconfiguration of the freight transport system, notably through the development of rail freight and multimodal transport solutions.

It is important to note that the study relies on purposive, non-probabilistic sampling, which is methodologically appropriate for exploratory research targeting key decision-makers in the freight sector. However, this approach has implications for representativeness. The predominance of road transport operators in the sample may influence the overall perception of rail freight performance, either through competitive bias or through strategic positioning toward regulatory developments. Consequently, while the findings provide valuable insights into stakeholder perceptions, they should be interpreted as analytically informative rather than statistically generalizable to the entire Moroccan freight transport population. This clarification enhances methodological transparency and situates the results within their proper interpretative scope.

4.1.1 Respondent profile and transport practices. The results relating to the respondents' profile ([Table 2](#)) show that the sample is mainly composed of actors directly involved in decision-making and in the operational management of freight transport, which lends strong credibility to the collected data. The predominance of road transport operators (41.2%) and industrial shippers (28.6%) accurately reflects the current structure of the Moroccan freight market, in which these two categories of stakeholders play a central role in the organization of

Table 2. Respondent profile

Characteristic	Category	%
Respondent	Road transport operators	41.2
	Industrial shippers	28.6
	Logistics operators	22.4
	Experts/institutional stakeholders	7.8
Main transport mode used	Road	76.5
	Rail	8.9
	Multimodal	14.6

Source(s): Authors' own work

logistics flows. The significant presence of logistics operators (22.4%) also highlights the growing importance of coordination, planning, and supply chain optimization functions.

The analysis of the main transport mode used confirms the overwhelming dominance of heavy road transport, which accounts for more than three quarters of freight flows. This result is consistent with the findings highlighted in the literature review and with available institutional data on the Moroccan transport system. However, the presence of 14.6% of actors already using multimodal solutions constitutes a particularly noteworthy finding. It suggests the existence of a core group of pioneering stakeholders who are already aware of the potential benefits of combining rail and road transport, especially along corridors linking ports with industrial and logistics zones.

Although still a minority, this proportion indicates that the modal shift toward rail freight transport is not merely a theoretical assumption, but rather a process that has already begun in certain market segments. It therefore represents a strategic lever on which public policies and rail operators could build to accelerate the development of rail freight transport in Morocco.

4.1.2 Descriptive statistics of the constructs. The analysis of the descriptive statistics of the constructs makes it possible to assess how stakeholders perceive the performance of rail freight transport and their willingness to consider a modal shift. The means and standard deviations reported in [Table 3](#) provide a concise yet informative overview of these perceptions.

The results reveal a very favorable assessment of the energy and environmental dimensions of rail freight transport. The high mean values for PENE (4.01) and PENV (4.18) indicate a clear and widely shared recognition of rail as an energy-efficient and environmentally friendly transport mode. This perception is fully consistent with prior studies showing that rail transport has significantly lower energy consumption per tonne-kilometer than heavy road transport, as well as lower greenhouse gas emissions, particularly when the network is electrified.

By contrast, perceived economic performance (PECO), with a mean value of 3.42, appears more nuanced. This result suggests that while stakeholders acknowledge the potential economic advantages of rail freight transport, these benefits are perceived as conditional upon specific factors, such as freight massification, regularity of transported volumes, and the

Table 3. Descriptive statistics of the constructs

Construct	Mean	Standard deviation
Perceived Economic Performance (PECO)	3.42	0.81
Perceived Energy Performance (PENE)	4.01	0.67
Perceived Environmental Impact (PENV)	4.18	0.62
Intention to Shift to Rail Freight Transport (ISR)	3.63	0.74

Source(s): Authors' own work

quality of interconnection with road transport. This intermediate perception reflects the persistent constraints of the Moroccan rail system, notably in terms of operational flexibility and territorial coverage.

Finally, the Intention to Shift to Rail Freight Transport (ISR) shows a relatively high mean value (3.63), which constitutes a particularly encouraging signal. This finding indicates that stakeholders are not fundamentally opposed to modal shift toward rail; rather, they condition such a decision on improvements in rail service provision and on the reduction of existing economic and organizational barriers.

4.2 Results of statistical analyses using SPSS

4.2.1 Reliability and validity of measurement scales. Assessing the reliability of measurement scales is an essential methodological step to ensure the robustness of empirical results. The Cronbach's alpha coefficients presented in Table 4 indicate an excellent level of internal consistency for all constructs.

These values, all above the threshold of 0.70 generally recommended in the literature, confirm that the selected items measure the theoretical constructs derived from the literature review in a homogeneous and reliable manner. This methodological robustness strengthens the credibility of the correlation and regression analyses conducted subsequently.

In addition to internal consistency, convergent and discriminant validity were assessed to ensure construct distinctiveness. Convergent validity was evaluated by calculating the Average Variance Extracted (AVE) for each construct, and discriminant validity was examined by comparing the square roots of AVE with inter-construct correlations. Table 5 summarizes these results.

The AVE values for all constructs exceed the recommended threshold of 0.50, indicating satisfactory convergent validity. The CR values are all above 0.70, confirming construct reliability. Discriminant validity is supported as the square root of each AVE ($\sqrt{\text{AVE}}$) is greater than the correlations of the construct with other constructs, demonstrating that each construct shares more variance with its own items than with other constructs. These results

Table 4. Reliability of constructs

Construct	Number of items	Cronbach's alpha
PECO	4	0.83
PENE	4	0.87
PENV	4	0.89
ISR	4	0.85
Source(s): Authors' own work		

Table 5. Convergent and discriminant validity of constructs

Construct	AVE	Composite reliability (CR)	$\sqrt{\text{AVE}}$
PECO	0.61	0.86	0.78
PENE	0.65	0.88	0.81
PENV	0.68	0.90	0.82
ISR	0.60	0.85	0.77
Source(s): Authors' own work			

strengthen confidence in the measurement model and confirm that the constructs are both empirically and conceptually distinct.

4.2.2 *Correlation analysis.* As illustrated in Table 6, the Pearson correlation analysis highlights positive, strong, and statistically significant relationships among the different variables of the model.

The positive and significant correlations observed between the perceived performance of rail freight transport and the Intention to Shift to Rail freight transport (ISR) empirically confirm the relationships postulated in the conceptual framework. These results suggest that the more actors perceive rail transport as economically, energetically, and environmentally efficient, the stronger their intention to shift freight flows from road to rail.

4.3 *Hypotheses testing and validated conceptual model*

4.3.1 *Multiple regression results.* To simultaneously test hypotheses H1, H2, and H3, a multiple linear regression analysis was conducted using SPSS, with the Intention to Shift to Rail freight transport (ISR) as the dependent variable (Table 7).

The model is statistically significant ($F = 112.6$; $p < 0.001$) and explains a substantial proportion of the variance in ISR ($R^2 = 0.58$). Thus, these different values make it possible to present the research model, in its validation version (Figure 2).

Beyond statistical significance, the magnitude of the standardized coefficients provides important insights into practical significance. A standardized β of 0.39 for perceived energy performance indicates that improvements in stakeholders' perception of rail energy efficiency are associated with a relatively strong increase in their intention to shift to rail. In managerial terms, this suggests that policies and communication strategies emphasizing measurable energy savings could substantially influence modal choice decisions. Similarly, the coefficient of 0.31 for environmental impact demonstrates that environmental considerations exert a meaningful and operational influence on decision-making, rather than representing merely symbolic commitments. By contrast, the more moderate coefficient of 0.21 for economic performance implies that cost considerations alone may not be sufficient to generate large-scale modal shift unless combined with strong energy and environmental advantages. This interpretation enhances the managerial and policy relevance of the regression findings.

Table 6. Correlation matrix

Variables	PECO	PENE	PENV	ISR
PECO	1			
PENE	0.48**	1		
PENV	0.44**	0.56**	1	
ISR	0.52**	0.64**	0.61**	1

Source(s): Authors' own work

Table 7. Multiple regression results (DV: ISR)

Hypothesis	Relationship	Standardized β	t	p
H1	PECO $\rightarrow$ ISR	0.21	5.34	<0.001
H2	PECO $\rightarrow$ ISR	0.39	9.12	<0.001
H3	PENV $\rightarrow$ ISR	0.31	7.48	<0.001

Source(s): Authors' own work

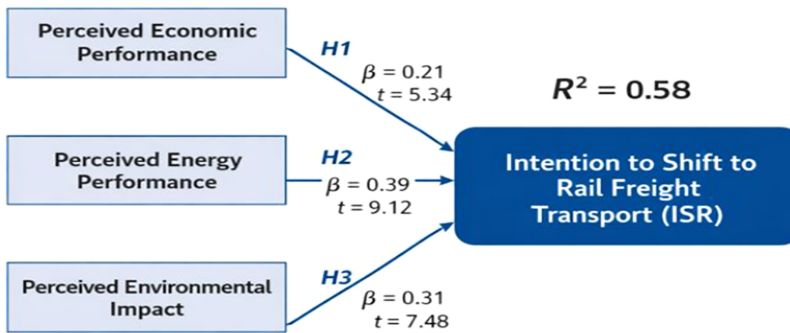


Figure 2. Validated empirical model. Source: Authors' own work

4.3.2 In-depth discussion of the results. The results of the multiple regression analysis provide clear and consistent empirical support for the hypotheses formulated on the basis of the literature review, thereby confirming the relevance of the proposed conceptual framework for analyzing the determinants of modal shift toward rail freight transport in the Moroccan context. All tested relationships are positive and statistically significant, indicating that perceptions of rail transport performance play a decisive role in shaping economic actors' Intention to Shift to Rail freight transport (ISR).

The validation of Hypothesis H1 highlights the existence of a positive and significant relationship between the perceived economic performance of rail freight transport and ISR. This result confirms insights from the transport economics literature, according to which modal choice decisions remain, at least partly, driven by cost considerations and economic competitiveness. Respondents thus recognize that rail freight offers potential economic advantages, particularly for the transport of massified volumes over medium and long distances, in line with the logic of economies of scale and density widely documented in previous studies.

However, the relatively moderate magnitude of the coefficient associated with perceived economic performance suggests that, in the Moroccan context, strictly economic factors alone are not sufficient to trigger a significant modal shift. This observation can be interpreted in light of the structural and organizational constraints that still characterize rail freight in Morocco. In particular, limited operational flexibility, incomplete territorial coverage of the rail network for certain industrial zones, and the need for road-based pre- and post-haulage operations tend to reduce the perceived economic advantage of rail transport. Thus, even when rail unit transport costs appear competitive, coordination costs, transshipment operations, and service reliability risks may weaken the impact of economic performance on actors' decisions.

Hypothesis H2 receives the strongest empirical support, with perceived energy performance emerging as the main determinant of ISR toward rail freight transport. This result is particularly revealing in the Moroccan macroeconomic and energy context. The country's strong dependence on imported energy products, combined with increasing volatility in fossil fuel prices on international markets, gives strategic importance to energy efficiency issues in firms' logistics decisions. In this context, rail transport is perceived as an intrinsically more energy-efficient mode, particularly in terms of energy consumption per tonne-kilometer, which enhances its attractiveness in the medium and long term.

This finding also reflects a gradual evolution in decision-making criteria among freight transport actors, who are no longer limited to a logic of minimizing immediate costs but increasingly integrate considerations related to energy sustainability and the management of energy supply risks. The energy performance of rail freight thus appears as a central lever of logistics competitiveness, capable of strengthening supply chain resilience in the face of energy shocks. This observation is fully consistent with recent studies emphasizing the role of rail as a key instrument in national strategies for energy transition and energy security.

The validation of Hypothesis H3 highlights the significant influence of the perceived environmental impact of rail freight transport on ISR. This result reflects the growing integration of environmental concerns into the economic decisions of Moroccan actors, even in a sector historically dominated by cost and time considerations. The perception of rail as a mode generating fewer greenhouse gas emissions and contributing to the reduction of air pollution now constitutes a distinct explanatory factor of actors' behavior.

The importance attributed to the environmental dimension can be interpreted as the result of several converging dynamics. On the one hand, Moroccan public policies increasingly emphasize decarbonization and sustainable development objectives, which gradually influence firms' strategies. On the other hand, Morocco's deeper integration into global value chains exposes economic actors to stronger environmental requirements, particularly regarding the carbon footprint of transport activities. In this context, rail freight appears as a lever enabling firms to improve their environmental performance and meet the growing expectations of international partners.

Taken together, the regression results reveal a clear hierarchy among the determinants of modal shift. While economic performance remains a significant factor, energy and environmental dimensions exert the strongest influence on ISR toward rail freight transport. This hierarchy suggests that the development of rail freight in Morocco cannot be addressed solely from a cost-competitiveness perspective, but must be analyzed within a broader framework integrating sustainability, energy security, and ecological transition issues.

Finally, the high value of R^2 (0.58) indicates that the proposed conceptual model has strong and substantial explanatory power. More than half of the variance in ISR is explained by the three perceived performance dimensions of rail freight transport, demonstrating the theoretical and empirical relevance of the adopted analytical framework. This result confirms that actors' perceptions constitute a central lever of modal change and that any policy aimed at promoting rail freight transport must simultaneously address economic, energy, and environmental dimensions in order to generate lasting effects on transport practices.

5. Research implications

The empirical results obtained in this study provide a set of major insights, both at the theoretical level and at the managerial and methodological levels. By highlighting the central role of perceived economic, energy, and environmental performance in shaping the intention to shift modal transport toward rail freight, this research contributes to a better understanding of the decision-making mechanisms of transport actors in an emerging economy context. The resulting implications not only enrich existing analytical frameworks but also help guide the strategies of economic actors and public decision-makers.

Beyond these general contributions, the empirical findings allow for the formulation of concrete and operational recommendations by explicitly linking the identified determinants to specific policy instruments. The relative importance of perceived energy and environmental performance suggests that targeted regulatory, fiscal, and informational tools can be mobilized to reinforce the structural attractiveness of rail freight transport.

5.1 Theoretical implications

From a theoretical perspective, this research makes several significant contributions to the literature on modal choice and rail freight transport. First, it empirically confirms the relevance of perception-based approaches for explaining modal shift behaviors. While many studies focus on objective comparisons of costs or technical performance, this study shows that it is primarily actors' representations and subjective evaluations of performance that guide firms' strategic decisions. In this sense, it aligns with behavioral theories applied to transport economics, emphasizing the importance of cognitive factors in logistics choices.

Second, the hierarchy of determinants revealed by the results constitutes a notable theoretical advancement. The predominance of perceived energy performance over perceived

economic performance suggests a gradual shift in traditional decision-making logics. This evolution partially challenges classical modal choice models based exclusively on cost minimization and calls for a more explicit integration of energy-related issues into existing conceptual frameworks. In the Moroccan context, characterized by strong energy dependence, this dimension appears to be a structuring factor in long-term decisions, opening new research avenues on the interconnections between transport, energy, and economic competitiveness.

Third, the significant influence of perceived environmental impact confirms the emergence of an expanded rationality in modal choice, incorporating sustainability and environmental responsibility considerations. This result enriches the literature on sustainable transport by showing that, even in emerging economies, environmental issues are no longer peripheral but are becoming central determinants of actors' behavior. Thus, this research helps fill a gap in the literature, which is still largely dominated by studies conducted in developed countries, by providing empirical evidence from a North African context.

Finally, the high explanatory power of the model ($R^2 = 0.58$) confirms the theoretical robustness of the proposed conceptual framework. This model can therefore be used as a relevant analytical basis for future comparative research, particularly in other emerging countries or in contexts characterized by a historical dominance of heavy road transport.

The results also suggest that public policy instruments play an indirect but structuring role in shaping modal choice through perception mechanisms. Instruments such as energy pricing schemes (e.g. progressive fuel taxation or carbon pricing), differentiated rail access charges reflecting environmental performance, or financial incentives supporting intermodal transport may significantly influence how economic actors evaluate the relative performance of rail versus road. By affecting cost visibility, energy risk exposure, and environmental accountability, these instruments contribute to reshaping the cognitive frameworks underlying modal decisions.

5.2 Managerial and operational implications

The managerial implications of this research are particularly significant for transport companies, shippers, logistics operators, and railway system managers. The results clearly show that the development of rail freight transport cannot be considered solely through a pricing-based logic. While economic competitiveness remains a necessary factor, it is not sufficient on its own to trigger a significant modal shift.

For railway operators and infrastructure managers, the findings highlight the importance of explicitly promoting the energy performance of rail in their commercial and communication strategies. Emphasizing clear indicators related to energy consumption per tonne-kilometer, the stability of energy costs, and resilience to fuel price volatility can represent a decisive argument for convincing shippers and industrial firms. This orientation also implies continuous investments in rolling stock modernization, operational optimization, and line electrification, in order to further strengthen the energy advantage of rail transport.

To translate these insights into operational levers, railway operators may advocate for stable and transparent rail access charging systems that reduce uncertainty for freight clients. In addition, targeted intermodal subsidies supporting combined rail–road solutions, particularly for first- and last-mile segments, can lower switching costs and make modal transfer economically viable. Such instruments directly reinforce the economic and energy-related perceptions identified as decisive in this study.

For industrial firms and shippers, the results encourage a stronger integration of energy criteria into logistics trade-offs and supply chain strategies. Increased reliance on rail freight can be perceived not only as a means of reducing long-term costs but also as a lever for energy security and risk management. In an uncertain economic environment, this strategic dimension can enhance the overall competitiveness of Moroccan firms.

Moreover, the importance attributed to perceived environmental impact suggests that rail freight transport can become a key tool for strategic differentiation for companies engaged in

corporate social and environmental responsibility initiatives. Using rail allows firms to reduce the carbon footprint of their logistics chains, which can strengthen brand image, facilitate access to certain international markets, and meet the growing requirements of clients and institutional partners.

Public authorities can reinforce this dynamic through concrete instruments such as carbon taxation mechanisms that internalize the external costs of road freight, eco-bonus schemes rewarding low-emission logistics solutions, and structured information campaigns highlighting the measurable environmental advantages of rail transport. Integrating low-carbon logistics criteria into public procurement policies can further strengthen the perceived environmental performance of rail and accelerate modal rebalancing.

Finally, for public decision-makers, this research highlights the need to adopt an integrated approach to the development of rail freight. Policies supporting rail transport should go beyond tariff subsidies and include measures aimed at improving service reliability, intermodality, and the visibility of energy and environmental gains. Better coordination between transport, energy, and sustainable development policies thus appears to be a key lever for fostering a lasting modal shift. More specifically, an effective policy mix could combine: (1) energy pricing reforms that gradually reduce distortions favoring road transport; (2) differentiated infrastructure charging reflecting environmental externalities; (3) strategic investment in multimodal logistics platforms and dry ports to improve rail accessibility; and (4) national awareness campaigns targeting logistics decision-makers. Aligning these instruments with the determinants empirically identified in this study enhances the operational relevance of modal shift strategies.

5.3 Methodological implications

From a methodological perspective, this research offers several important insights for future studies on freight transport and modal choice. First, the use of a quantitative survey based on a structured questionnaire administered to a large sample ($N = 483$) proved particularly relevant for capturing actors' perceptions and analyzing their behavioral intentions. This approach makes it possible to move beyond purely technical analyses and to better grasp the subjective dimensions of the decision-making process.

Second, the use of statistical analysis with SPSS, combining descriptive analyses, reliability tests, correlation analysis, and multiple regression, enabled a rigorous testing of the hypotheses derived from the literature review. This methodological approach, which is relatively accessible and widely used in management sciences and applied economics, has the advantage of being reproducible and adaptable to other geographical or sectoral contexts. It therefore provides a solid analytical framework for future comparative research.

Moreover, the structuring of the constructs around clearly defined dimensions (economic performance, energy performance, environmental impact, and intention to shift to rail freight transport) represents a methodological contribution in itself. The table of items developed in the methodology can be reused, adapted, or enriched in other studies, thereby contributing to the standardization of measurement instruments in the field of sustainable transport.

Finally, this research highlights the value of combining quantitative analyses with an in-depth contextual reflection. Interpreting the results in light of the institutional, economic, and energy-specific characteristics of Morocco strengthens the external validity of the conclusions and underscores the importance of territorial embeddedness in transport studies. This integrated methodological approach constitutes a promising avenue for future research, particularly in emerging economies where transport dynamics exhibit specific features.

6. Conclusion, limitations, and future research directions

This research aimed to analyze the determinants of the development of rail freight transport in Morocco by focusing on economic actors' perceptions of its economic, energy, and

environmental performance, as well as on their influence on the intention to shift freight flows from heavy road transport to rail. Based on a quantitative survey conducted among 483 actors in the transport and logistics sector, the study provides a structured empirical insight into an issue that remains insufficiently documented in the Moroccan context and, more broadly, in emerging economies.

The results show that rail freight transport is generally perceived positively, particularly in terms of energy and environmental performance. These two dimensions emerge as the most influential determinants of the intention to shift modes, confirming that issues related to energy consumption, dependence on fossil fuels, and the reduction of greenhouse gas emissions now occupy a central place in the logistics strategies of Moroccan actors. Perceived economic performance also exerts a significant, albeit more moderate, influence, suggesting that strictly financial considerations alone are not sufficient to trigger a large-scale modal shift toward rail. This situation reflects the persistence of structural and operational constraints, particularly with regard to flexibility, territorial coverage, and intermodal integration of rail transport.

The empirical validation of hypotheses H1, H2, and H3 confirms the relevance of the proposed conceptual framework and highlights the multidimensional nature of the modal choice process. The explanatory model estimated using SPSS exhibits a high explanatory power, with a coefficient of determination (R^2) of 0.58, indicating that perceived rail freight performance constitutes a key lever of the intention to shift modes. These findings are fully consistent with previous work on sustainable transport and modal shift, while making an original contribution through their application to the Moroccan context.

However, the results of this research should be interpreted in light of certain limitations. First, the study relies on self-reported data collected through a questionnaire, which means that the results primarily reflect perceptions and intentions rather than observed actual behaviors. Although intention to shift modes is widely used as a dependent variable in the literature, it does not necessarily guarantee the realization of an actual modal change. Moreover, the use of a non-probabilistic, purposive sampling approach, while appropriate given the exploratory and sector-specific nature of the research, limits the strict statistical generalization of the results to the entire population of freight transport actors in Morocco. Nevertheless, the large sample size and the diversity of respondent profiles help strengthen the credibility of the findings.

Another limitation lies in the scope of the conceptual model, which deliberately focuses on three key dimensions of rail freight performance. Other potentially influential factors—such as service reliability, delivery times, intermodal quality, regulatory constraints, or public incentives—were not included in the analysis. In addition, the cross-sectional approach adopted does not allow for capturing dynamic changes in actors' perceptions and intentions in a context characterized by progressive railway investments and rapid transformations in energy and environmental policies.

These limitations nevertheless open up particularly rich avenues for future research. Future studies could use longitudinal data to analyze changes in modal behavior over time and to assess the actual impact of public policies and railway investments on modal shift. Enriching the conceptual framework by integrating additional variables related to service quality, intermodality, or economic incentive mechanisms would also help refine the analysis. Furthermore, comparative studies conducted in other emerging countries or across different regional contexts would provide a better understanding of national specificities in the development of rail freight transport.

More specifically, given that perceived energy and environmental performance emerged as the strongest determinants of modal shift intention, future research could empirically test whether these dominant perceptions effectively translate into measurable modal reallocation in freight flows. Longitudinal designs based on panel data, freight statistics, or before–after evaluations of major railway investments would allow researchers to examine the stability and predictive validity of the intention–behavior relationship identified in this study. Such analyses would provide a more precise assessment of whether the high explanatory power of the model ($R^2 = 0.58$) is maintained when moving from declared intentions to observed transport practices.

Finally, the use of mixed approaches combining quantitative and qualitative analyses could offer complementary insights by enabling a more in-depth exploration of the institutional, organizational, and strategic constraints influencing modal choice decisions. From this perspective, the present research represents both an outcome and a starting point, providing a solid empirical foundation for further reflection on the conditions required for a sustainable transition of the freight transport system in Morocco.

Ethics statement

This research was conducted in accordance with ethical standards applicable to social science research. Participation in the survey was voluntary, and respondents were informed of the purpose of the study. Anonymity and confidentiality of the data were strictly ensured, and no personally identifiable information was collected.

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