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## **Competition and complementarity between road and rail transport**

**DORINELA COSTESCU<sup>1,2\*</sup>, ADINA CIOTE<sup>2</sup>**

<sup>1</sup>Technical Sciences Academy of Romania

<sup>2</sup>Doctoral School of Transport,

National University of Science and Technology Politehnica Bucharest, Romania

**Abstract.** At the international and national levels, a trend of increasing the share of road transport at the loss of rail transport is observed. This state results in a consensus that, for significant categories of demand, road transport does not meet the requirements of sustainable development. Road transport is a major consumer of non-renewable energy. It is also responsible for adverse effects on the social and natural environment in which it is carried out, including traffic congestion, pollution, and an increased risk of road accidents. For these reasons, there has been a growing interest in decreasing the share of road transport, supplemented by promoting intermodal and multimodal transport solutions that aim to complement the advantages offered by high-capacity transport (rail, maritime) and road transport. In this framework, the paper aims to analyse the relationships between competition and complementarity in road and rail transport. The examination is motivated by the fact that reducing energy consumption and mitigating polluting effects requires combined policies: promoting vehicles and transport technologies with increased energy efficiency and reduced external effects, regulating mobility needs in relation to the requirements of sustainable development, and expanding the share of trips using renewable energy sources.

**Keywords:** transport modes, transport performance, energy consumption, modal competition, intermodal transport, sustainable development.

### **1. Introduction**

Current concerns in the energy field are related to, on the one hand, meeting the growing global energy demand in a context of limited fossil fuel reserves. On the other hand, reducing the negative effects of energy consumption, especially that provided by fossil fuels (reducing greenhouse gas emissions and mitigating climate change). Furthermore, in recent years, these concerns have been emphasised by geopolitical tensions and the risks of fragmentation of fuel supply chains [1]. In these

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\* Corresponding author: dorinela.costescu@upb.ro

circumstances, given the significant share of energy consumption in the transport domain, operational, commercial and energy efficiency in this area must represent an essential component of the overall energy and environmental policies. The objectives of these policies aim to apply new technologies, mainly based on electricity [1,2] and the restructuring of the modal share in favour of solutions considered consistent with sustainable development [2–4].

In this regard, to manage current energy uncertainties and identify long-term solutions, independent and in-depth analyses are needed, in which databases with complex structures are essential [1,3].

Starting from a synthetic analysis of energy consumption in transportation, the paper aims to highlight the need for extensive research, which would allow for correct assessments of energy efficiency by transport modes, under different operating conditions and in meeting mobility demand. Only in this manner can correct comparisons be made on the advantages and disadvantages offered by different transport modes, especially in terms of energy efficiency. In addition, such a comprehensive analysis can be helpful in identifying and assessing the effects of various measures to introduce new technologies to satisfy mobility demand (from technologies for vehicle manufacturing to technologies for organising services, operating modal subsystems and the transport system as a whole).

Taking into consideration the increasing share of road transport at the loss of rail transport, the second part of the paper examines the competition and complementarity relationships between the transport modes. Appropriate and correlated policies promoting vehicles and transport technologies with increased energy efficiency and reduced external effects could support reducing the energy consumption and increasing the share of trips using renewable energy sources.

## **2. Energy consumption in transportation**

### **2.1. Overall circumstances**

Over the past decade, although the global energy demand has grown at an average annual rate of 1.4%, technological progress, improvements in energy efficiency, and changes in the structure of the worldwide economy have contributed to a decrease in energy consumption intensity (Figure 1). Gross domestic product (GDP) growth has been faster than the growth rate of energy demand, a result that can be interpreted as an improvement in specific energy consumption. The development of renewable energy sources and the expansion of end-user electrification play an essential role in increasing the efficiency of energy systems [1].

In 2022, at the European Union (EU) level, the analysis of final energy use shows three dominant categories, namely: transport (31.0%), households (26.9%) and industry (25.1%), followed by a category including services (13.4%) [5]. At the global level, the same categories (Figure 2) are used to analyse different trails that the energy sector could follow in terms of decision-making factors, implications for energy markets, energy security and emissions, as well as for quality of life [1].

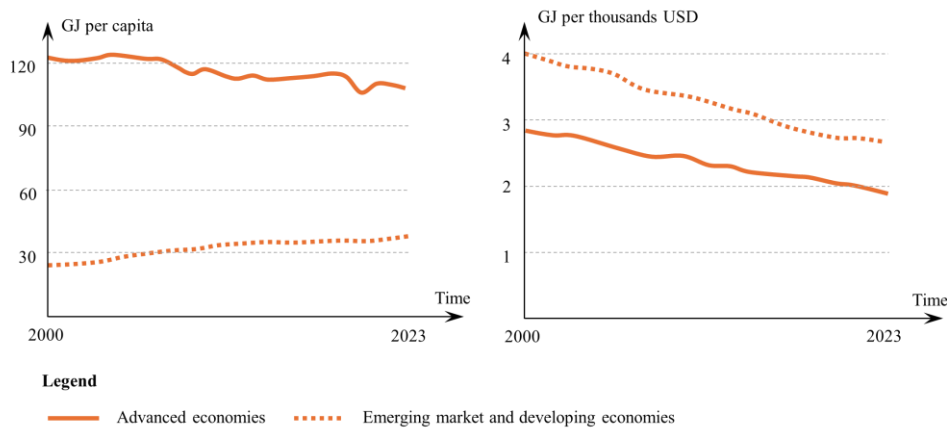


Fig. 1. The energy intensity of the global economy: total final energy consumption in gigajoules per capita and unit of gross domestic product (GDP) [1]

In the World Energy Outlook 2024 [1], three scenarios were proposed with a perspective on the year 2050:

- *Stated Policies Scenario* (STEPS) extrapolates current energy sector trends based on the latest market data, costs of energy production and industrial technologies, and an in-depth analysis of prevailing global policy objectives.
- *Announced Pledges Scenario* (APS) examines the evolution under the assumption that all energy and climate national targets set by governments would be fully met on time.
- *Net Zero Emissions by 2050 Scenario* (NZE) assesses the direction in which electricity and renewable energy sources will have significant shares, ensuring the limitation of net polluting emissions to zero by mid-century and ensuring the conditions considered necessary to limit global warming to 1.5 °C.

In any of the scenarios, it is noticed that the transport sector will rely heavily on fossil fuels (Figure 2). In addition, regardless of the scenario or evolution variant, it is recognised that the implementation of appropriate technologies in transport will be essential to achieve the objectives of increasing energy efficiency and reducing emissions [1,2].

## 2.2. Analysis of energy consumption in road and rail transport

In 2023, energy demand in the transport sector grew by almost 4%, a similar rate to that recorded in 2022. Much of this growth came from increased aviation activity, which returned to over 90% of the 2019 level, before the pandemic. Road transport also significantly contributed to the increase, by around 2%, reflecting an expansion of the vehicle fleet by over 20 million vehicles, mainly in China, India and Southeast Asia, reflecting rising incomes and population growth [1].

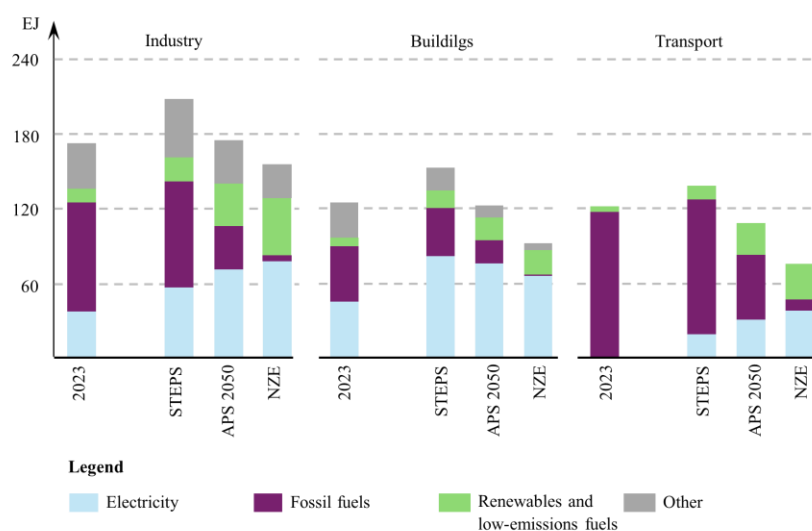


Fig. 2. Total final consumption (in exajoules) by energy source in selected sectors by scenario, 2023 and 2050 [1]

In the EU, road transport is the largest energy consumer, responsible for 73.6% of total energy consumption in transport. Final energy consumption in road transport increased steadily from 1990 to 2007, peaking at 11,322 PJ (an increase of 34.1% compared to 1990). After a slight decrease in energy consumption during the financial crisis in the period 2008-2014, the upward trend in energy consumption in road transport resumed until 2019, when energy consumption in road transport was similar to that recorded in 2008. After the lifting of restrictions imposed during the COVID-19 pandemic, energy consumption in road transport increased again, and the reported consumption in the EU in 2022 was 97.4% of the 2019 level [5].

The use of energy sources in road transport has changed considerably since 1990 (when the primary source of energy in road transport was motor gasoline at 54.7%, followed by gas/diesel oil at 43.8%) to 2022 (65.4% of final consumption in road transport was provided by diesel oil, 25.2% by motor gasoline, 6.4% by renewable energy sources and biofuels, 2.0% by liquefied petroleum gases, 0.7% by natural gas and 0.3% by electricity). However, fossil fuels remain the primary source of energy in road transport in the EU, representing 90.6% [5].

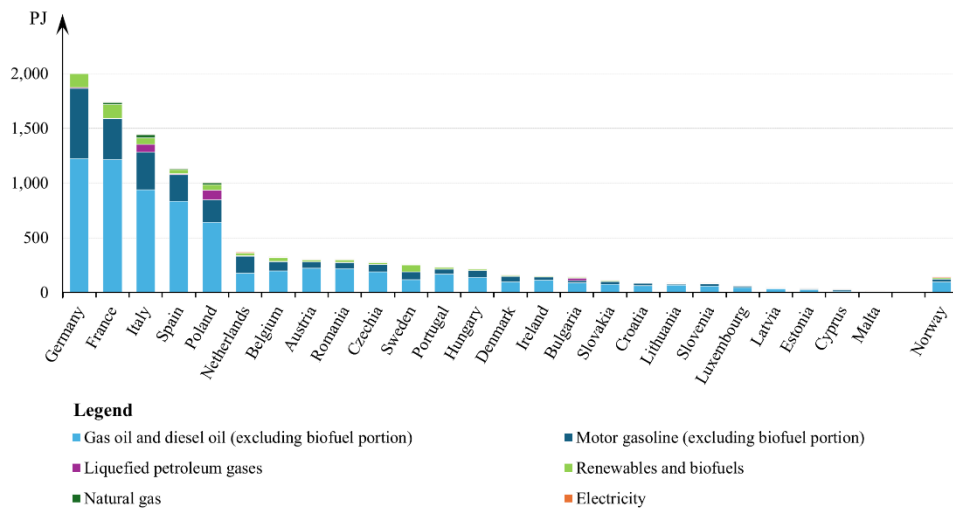
Electric vehicles are considered a main mechanism for reducing emissions in the road transport sector. Ambitious plans from governments and the electric vehicle and battery industries have supported their prospects in recent years. However, the transition to mass market adoption is unlikely to be linear and further efforts are needed to strike the right balance between incentives for broader consumer adoption, ensuring adequate charging infrastructure and strengthening the electricity grid [1]. More than 7 million electric cars were sold in the first half of 2024, an increase of almost 25% compared to the same period of the previous year. The share of electric vehicles in the total global car fleet is likely to approach around 5% by the end of

2024. China contributes almost 80% of the growth. Excluding China, the overall percentage growth in sales in the global market is over 10%. In the EU, electric car sales have remained flat, with a decline in Germany offset by growth in other countries [1]. Under these circumstances, electricity consumption in road transport in the EU has increased from 0.05% in 2018 to 0.34% in 2022 (an increase of more than six times). However, the use of electricity in road transport remains almost marginal [5]. Even in the case where the use of electric vehicles is stimulated by financial compensation or by imposing severe restrictions on pollution standards, fossil fuel consumption remains significant in road transport [6].

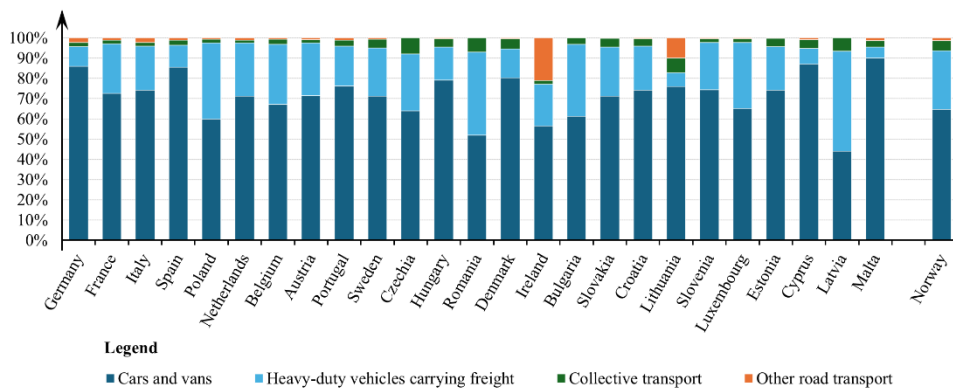
Figure 3 shows the energy consumption in road transport by vehicle category. In 2022, the largest category in almost all EU countries was represented by cars and vans (with a maximum mass of 3.5 tonnes). For the final energy consumption of heavy-duty vehicles (or lorries over 3.5 tonnes) for freight, Romania stands out with a share of 41% (compared to 52% for cars and vans), preceded by Latvia, the only country with this percentage, 49.5%, higher than that of cars and vans, at 44% [5]. These data highlight the primary position that road transport occupies in market segments where rail transport should take over significant freight flows. Therefore, in the next section, the competitive relationships that may arise between road transport and rail transport will be analysed.

In the analysis of energy consumption in road transport (Figure 3), Romania also stands out for the share in collective public transport (at 7.0%), preceded by the Czech Republic and Lithuania, with the highest shares (8.0%, respectively 7.1%) [5]. Obviously, in order to have an interpretation of how these energy consumptions have been judiciously used, additional assessments of the productive and commercial efficiencies achieved in public transport systems are necessary [7]. Therefore, the following section presents the multitude of factors and intercorrelations that influence the distribution of travel and transport demand by transport modes and, implicitly, the energy efficiency for modal services and, overall, for the whole transport system.

In the analyses of global energy consumption, it is contradictory that rail transport is not presented, despite being considered a high-capacity transport that should contribute to higher performance than road transport in satisfying the movement demand (passenger and freight) in economic systems. Rail transport is reported only in the three scenarios – STEPS, APS and NZE, in case of strategies established by certain states (France, Germany, UK, USA, China, India, Indonesia, Turkey) [1]. Generally, the considered strategies aim to increase the share of electricity consumption in rail transport and investment in rail infrastructure to improve the accessibility and attractiveness of rail transport (STEPS, APS, NZE), reduce the share of road transport in favour of rail transport and reduce the share of continental air transport in favour of rail transport through investments in high-speed rail networks (APS, NZE).



a) Final energy consumption in road transport by energy product per country, EU, 2022



b) Final energy consumption in road transport by category (%), EU, 2022

Fig. 3. Final energy consumption in road transport in the EU, 2022 [5]

In 2022, in the EU, rail transport accounted for only 1.4% of total energy consumed in transport, significantly below road transport (73.6%), air transport (11.4%) and water transport (13%). Furthermore, it is the transport mode with a decreased final energy consumption in 2022 compared to 1990 by 31.5%. Total electricity consumption (the primary source of energy in rail transport) remained quasi-constant, with a slight increase of 3.1% in 2022 compared to 1990. The increasing share of electricity use was achieved by reducing the use of diesel-based traction. In 2022, the share of electricity was 78.9%, compared to 52.4% in 1990.

In Romania, the total energy consumption in rail transport was 35.88% provided by electricity, with shares of 37.4% in rail freight transport, 33.6% in conventional rail passenger transport, and 28.9% on the metro network [5].

Certainly, all these values related to energy consumption must be correlated with the performance achieved for each mode of transport and with their share in the overall transport system (Figure 4).

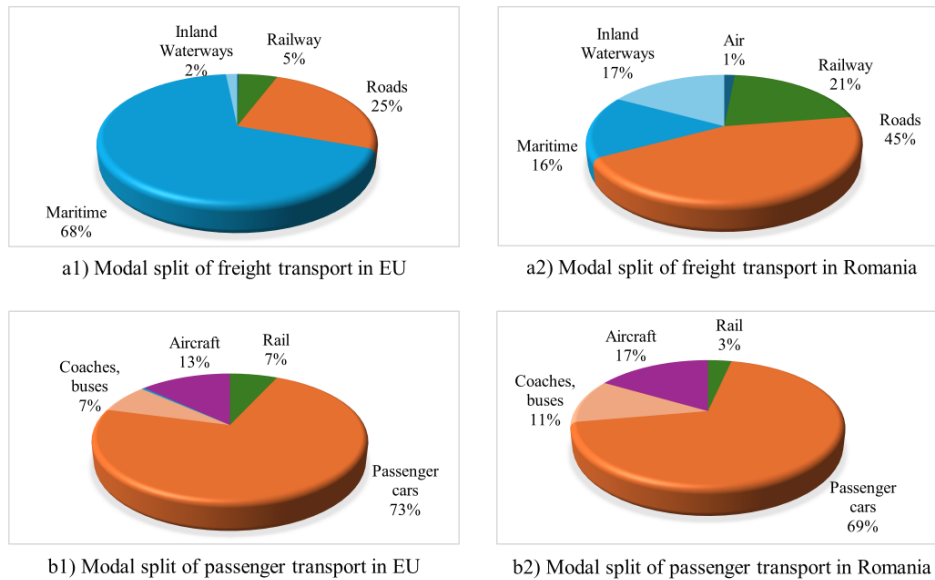


Fig. 4. Comparison of the modal split of transport in Romania relative to the EU (27 countries), in 2022 (processed based on [5])

Considering the percentages of energy consumption associated with the performance of different modes of transport, as previously mentioned, the issues that must be analysed refer to the energy efficiency obtained through the technologies specific to each mode of transport [8,9].

### 2.3. The need for energy efficiency assessments of different modes of transport

The synthetic data previously presented provide an overview of the evolution of energy consumption in the transport sector and of the activity in the modal transport systems. However, they do not reveal any metrics of the energy efficiency of the different modes of transport. For comparisons of the energy efficiency of the different modes of transport and, subsequently, the assessment of the energy efficiency of intermodal transport solutions, complex analyses are required to determine the performance achieved and the operating conditions at the modal level, at different geographical scales (urban, peri-urban, regional, national), as well as assessments of energy consumption, as far as possible from the upstream phase of energy production [2,4,9].

At the national level, no comprehensive studies provide a relevant evaluation of energy efficiency for different modes of transport. There are no recent studies at the international level either. Some tools allow the assessment of CO<sub>2</sub> emissions and

energy consumption for particular conditions of certain goods [10] or people [11] transports, in which the physical characteristics of the routes, the transport loads and the loading coefficients of the vehicles can be taken into account. These tools are helpful in comparing modal variants for particular transport loads for a given origin-destination pair. However, they do not allow an overall analysis of energy efficiency at the level of modal transport subsystems and the analysis of policy scenarios to improve energy consumption at the level of the whole transport system that meets the mobility demand of the served area.

An example of a study that allows the identification of the effects of operating conditions for different modes of transport on energy efficiency and associated emissions was the one carried out in France for data from 2005 [12]. The assessment of energy efficiency and specific emissions of different modes of transport took into account the entire process of energy production and transport (including the upstream stage). Based on energy consumption and traffic databases provided by transport companies and operators, energy efficiency and emissions specific to the stage of transport and travel were calculated and multiplied by the results of the upstream stage to obtain the overall energy efficiency and emissions in gep/passenger-km or gep/tonne-km and passenger-km/kep or tonne-km/kep. Parameters such as speed, specific energy consumption, vehicle occupancy rate, fuel type, electricity source, etc., were examined for each mode of transport to identify factors with significant effects on energy efficiency [12]. That study provides an example of a methodology applied to understand the factors influencing the energy efficiency and CO<sub>2</sub> emissions of different modes of transport. The results were obtained for specific conditions of operation of transport and travel in France, in 2005 (electricity sources, modal share of flows, vehicle occupancy rate, etc.). Therefore, the results cannot be transferred to comparisons of other transport systems for different operating conditions [12]. However, it can be stated that energy efficiency in the transport system can be increased both by improving the energy efficiency of each of the modes of transport, and by a rational split of transport demand on modes of transport capable of realising substitutable services [2,4,9].

The transport system and, in particular, energy consumption in the transport sector, are influenced by numerous parameters. Demographic and economic developments, changes in land use and urban planning, services offered by different modes of transport, social changes, public policies, as well as the availability and cost of energy and other resources require diachronic analyses to understand the influence on energy efficiency, dependence on fossil fuels and other non-renewable resources, but also on other externalities of transport (pollution, congestion, risk of traffic accidents, etc.). This complex issue requires a systemic vision of the problem, considering the most critical parameters of observed or future developments, as well as the interactions among all the components (Figure 5). Changing one element of the system can simultaneously affect several other components. The numerous interactions, as well as the uncertainties surrounding many parameters, must also lead to particular cautiousness in the interpretation of the results and possible future developments.

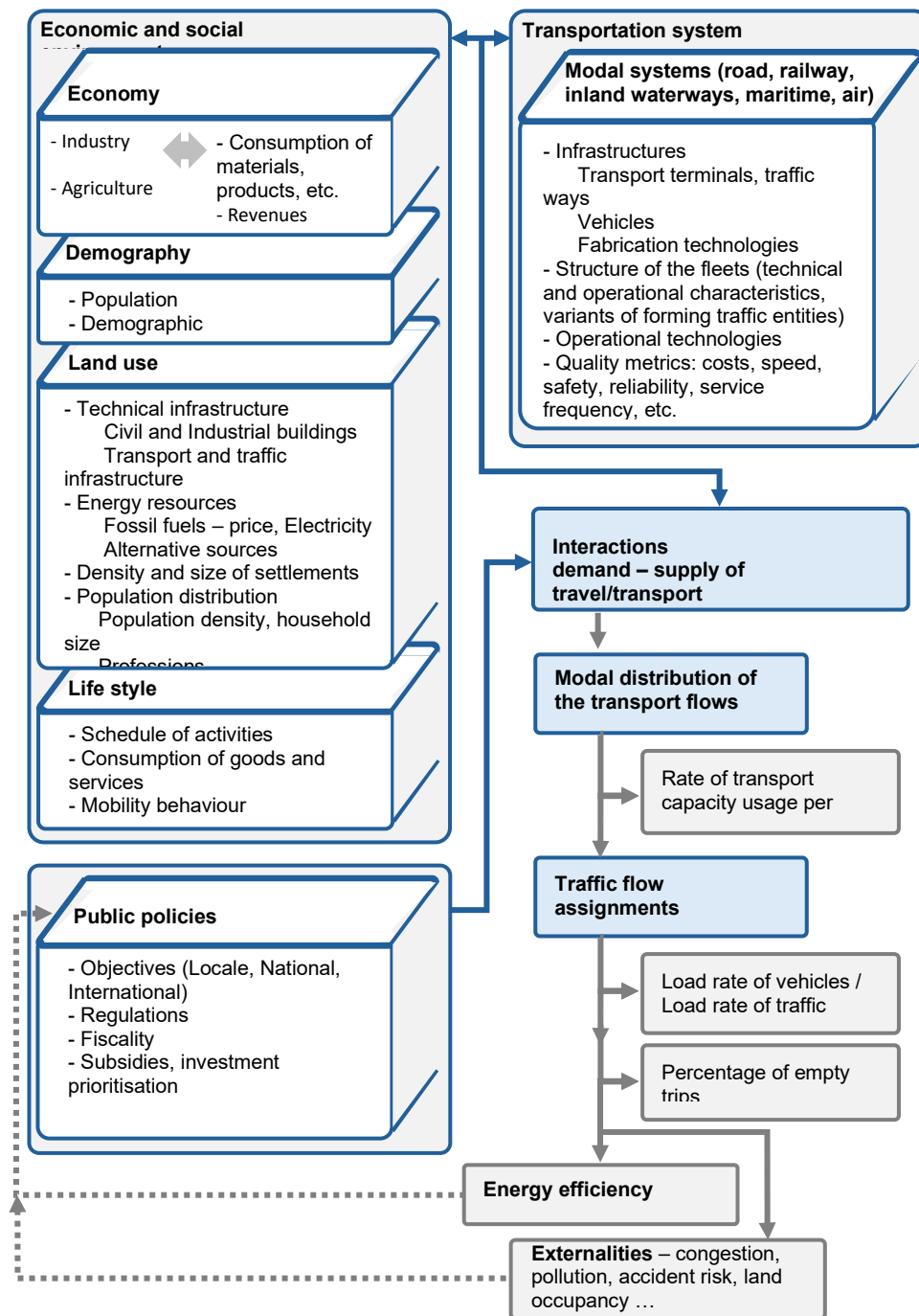


Fig. 5. Interrelationships among components that influence final energy consumption and energy efficiency in the transport system.

The analysis must consider attributes particular to modes of transport, such as cost, comfort, safety, convenience, and travel time that intervene in the multi-criteria decision of the user [9]. In addition, the external effects on the environment and quality of life produced by one mode of transport or another are not always in the same ratio as the energy efficiency. Therefore, the external costs complementary to the arguments regarding energy efficiency must be evaluated and used in the substantiation of decisions.

### **3. Competition between road and rail transport**

#### **3.1. Competition relationships**

Each mode of transport is characterised by physical and commercial parameters that define its opportunities in the market of travel and transport offers [9,13]. The shares of goods and passengers allocated to each mode of transport are determined mainly by the physical and commercial characteristics of the transport demand addressed to the level of the whole transport system and by the way in which the mobility offer has been adapted to these characteristics. Many analyses considered that the users and transport operators have a dominant role in the modal choice. However, the modal choice depends on a complex set of interactions between:

- Beneficiaries of travel or transport.
- Providers of integrated travel/transport services for passengers and goods.
- Transport operators - public or private entities responsible for the service network.
- Infrastructure managers - public, private or hybrid entities with a central role in streamlining the management of the physical infrastructure network - roads and motorways, railway infrastructure, modal and intermodal terminals, etc.
- Public authorities - including government entities, state-owned companies, and transnational entities responsible for the fiscal system. This system governs access and use of infrastructures, vehicles, and other facilities operating, as well as grants subsidies for specific categories of services or users and incentives for particular technologies.

As the above analysis shows, road transport occupies a majority share compared to other modes of transport. In addition to the attributes that make it attractive to users, road transport has also intensified due to the inadequate regulation of the interactions between various categories of stakeholders involved in the modal choice: inappropriate policies in urban planning and land use (insufficiently correlated to the existing or possible development of rail transport offers), financial procedures that have favoured the growth of the road vehicle fleet, the use of road infrastructure, the reduction of prices applied for road services, the lack of a system for assuming the externalities in transport prices, etc. [2-4]. Externalities include the costs related to accidents, air pollution, noise, congestion, damage to habitats, and other adverse effects generated by transport. For each mode of transport, externalities vary depending on several factors such as the energy sources used for transport, traffic intensity, the load rate of the system elements, and the physical attributes of the

crossed area. Generally, rail and inland water transport tend to generate lower external costs than road transport. In 2016, in the EU, for freight transport, the average external costs for heavy-duty trucks were estimated at 4.2 Euro/tonne-km, compared to 1.3 Euro/tonne-km for rail and 1.9 Euro/tonne-km for inland waterway transport [14].

Consequently, the issue of reducing the share of road transport must be addressed, at least for mass flows, which can be directed towards rail transport, recognised as a mode in which specific energy consumption and externalities are lower, and financial benefits due to economies of scale can be obtained. However, given that access to services and the attributes are different on the road transport market compared to those of rail transport, the debate of how to analyse competition between the two modes of transport arises. Because, in economic theory, competition between two producers could be stated if the goods or services are substitutable. Two goods are considered substitutable if, when the demand for one varies, the demand for the other tends to vary in the opposite direction (negative elasticity). They are independent if the demand variations are not correlated (inelasticity) and are complementary if, when the demand for one varies, the demand for the other tends to vary in the same direction (positive elasticity). Thus, in a transport system, supposing the overall demand for travel and transport and the services offered by different modes of transport, then the modes of transport are considered competing. The various modes of transport share the market, and the increase in demand for one of them determines the decrease in demand for the others [9,15].

However, in many circumstances, even if we consider trips for the same origin-destination routes, precisely because of the specific attributes of the different modes of transport, they cannot be regarded as substitutable. Assuming that the relations between road and rail transport are relations of competition and substitutability, a distorted approximation of a much more complex reality intervenes [9]. Transport modes offer different services, which in operation are not comparable in terms of quality attributes (commercial speeds, transport capacities, technologies necessary for the formation of traffic entities, etc.) and external effects (energy consumption, polluting emissions, accidents) [2,4,16]. These attributes define a technical domain of competence for each mode of transport, which can be delimited within an economic area of intervention. The boundaries are established by the scale of intervention costs, compared to other transport modes. In relation to these areas, the following categories can be delimited [9]:

- The exclusivity domain for each mode of transport is established by its appropriateness in terms of physical and commercial parameters, for example, road transport in urban distribution logistics or for trips in areas with low population density.
- Competitive domain, in which the economic areas of intervention of two or more modes of transport overlap; for example, rail transport and inland water transport for mass goods over long distances, or road transport and rail transport for large volumes of goods over long distances (as indicated in the previous section).

In the long term, infrastructures and vehicles evolve substantially and differently across transport modes, leading to changes in the technical domain of competence.

Energy costs have a different impact on transport modes. In addition, the social and economic environment changes, leading to variations in the structure of transport demands and requirements of the users (e.g., reduction in the share of heavy industry, increase in the share of services, changes in the location of industries, diversification of production, increased interest in reducing the costs of ambulatory and non-ambulatory stocks, emergence of new categories of users, modification and diversification of the social activities and schedules, etc.). Thus, these factors and complex intercorrelations modify the competitive relationships between transport modes [2,4,9,16].

### **3.2. Interventions to adjust relationships of competition**

In the medium to long term, public policies play a critical role in shaping the economic areas of intervention for various modes of transport. Given the results regarding modal split, energy consumption, and pollutant emissions in transport, the public authorities must influence the modal distribution of traffic or its evolution. Depending on the pursued objectives, public interventions can be classified as follows [9]:

- Conjunctural regulations, which are not directed to the transport sector itself, but to its consequences on the economic environment. E.g., the price of freight transport is an essential element of the cost of numerous industrial and commercial activities.
- Modal split regulations aim to adjust or maintain the boundaries of economic intervention areas for different modes of transport. This category also includes interventions for the development of inter- and multimodal transport systems, which, for particular demands, ensure complementary relationships between transport modes. Because two modes offer different levels of service, they can complement each other and cumulate the advantages provided by each of them.
- Regulations specific to a mode of transport that seek to influence the conditions under which demand is distributed between service providers. E.g., among rail transport operators at the regional and national level.

Studies on the methods of state interventions in the transport domain highlight the need to ensure coherence between them, both at the level of modal policies and at the level of global policy. Additionally, it is observed that assessing the effects of specific policies and identifying appropriate measures in certain circumstances is difficult. The accessibility, speed, flexibility and reliability of road transport offers are generally higher than those of rail transport, so that price changes do not fundamentally change user decisions regarding the modal choice. In many circumstances, in road transport, demand is inelastic and prevents interventions from producing a real change.

Therefore, the transport system, consisting of modal subsystems that intervene with competing and complementary offers for the mobility demand generated by the system of social activities characteristic of the served area, must be coordinated at a global level in terms of investments, infrastructure usage pricing, regulations of the establishment of transport prices and working conditions.

## 4. Complementarity between road and rail transport

### 4.1. Goal of promoting complementarity relationships

The choice of the preferred mode of transport is often part of a broad decision-making process, which depends on the interactions between a multitude of factors. Depending on the circumstances, the modes of transport can be competing or complementary in the transport market. Transport chains are often made up of several modes, leading to multimodal, intermodal and combined transport solutions, which involve vertical or horizontal integration of flows to achieve increases in the efficiency of the provided services [2,13,16,17].

As previously stated, the public interventions aiming to regulate the modal split between road and rail transport also include those that favour the complementarity of the two modes by developing multimodal or intermodal transport solutions (Figure 6). In this case, the complementarity relationships differ from those determined by the need to ensure the continuity of the flow between intervention areas specific to different geographical characteristics that occur, for example, between maritime transport and continental transport (river, rail or road) or between air transport and regional transport (rail or road). In the case of complementarity relationships between rail and road transport, the purpose is to integrate the services of the two modes of transport in order to cumulate the advantages offered by them, to increase the flexibility of the transport offer and, overall, to improve the performance of the transport system. The decrease in the share of road transport caused by the tendency to atomise passenger and freight flows can be achieved by consolidating flows along corridors that lead to benefits generated by the rational use of rail transport [13,17,18].

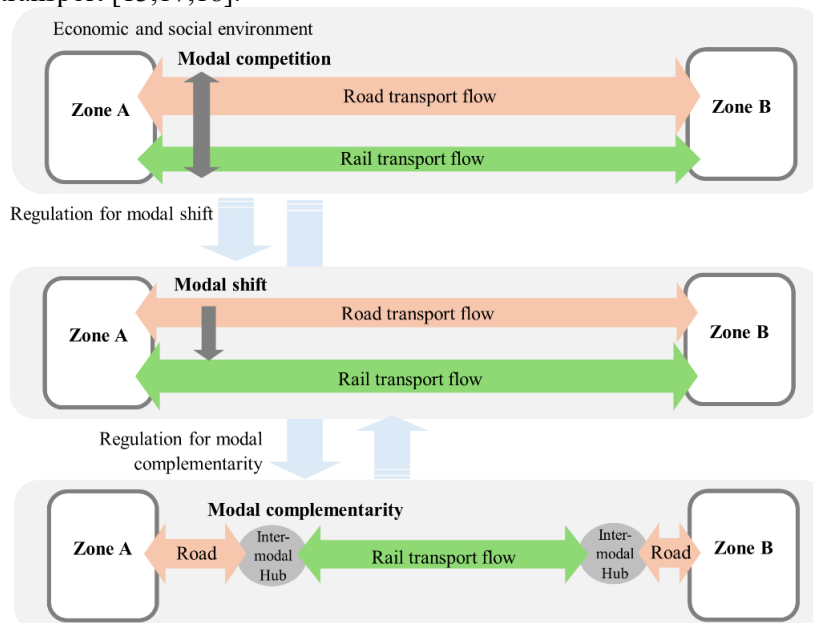


Fig. 6. Types of interventions for adjusting the modal split

In order to satisfy the passenger mobility demand in line with the requirements of sustainable development, intermodal rail-road transport is promoted, generally, to increase the accessibility of services and, in particular, to improve the productive and commercial efficiency of high-capacity services [16,18]. In freight transport, depending on the way of consolidation/deconsolidation of loads, contractual integration of services and provision of door-to-door transport, complementarity relationships can be ensured through multimodal, intermodal or combined transport. In both passenger and freight transport, distance is a primary decisive factor in the possibility of integrating the two modes of transport. The necessary transfers between services belonging to different modes of transport determine additional durations and energy consumption, which, overall, throughout the entire logistics chain, can be compensated by the economy of scale obtained through flow consolidations only if the flow and distances over which the transport is carried out exceed a critical value [2,17,18].

#### **4.2. Interventions to foster complementary relationships**

Although the advantages of multimodal and intermodal transport are demonstrated in numerous cases, the share of these types of services is low [2,13,17,19]. Frequently, the legislative and financial support of the public authorities has been insufficient or ineffectively targeted [19]. Rail transport subsidy programs have often been inconsistent, lacking periodic reviews that would lead to adaptations in relation to the dynamics of the political, economic and social environment. In addition, funding programs for railway traffic infrastructure and terminals facilitating intermodal transfers have been reduced and implemented over short periods, leading to a lack of confidence in these categories of services. Thus, a physical network of infrastructures has not been consolidated to enable the planning of a network of services with satisfactory performances, which would lead to the modification of the modal split in favour of rail transport. The exceptions are Slovenia and Austria, which, through regulations and investment policies, have managed to increase the share of rail transport [2].

In order to foster complementary relationships between road and rail transport, which ultimately lead to changes in modal shares, all components of the logistic chain require coordination and cooperation. Coherent interventions are needed to strengthen specific corridors and finally networks, ensuring multimodal and intermodal options with complementarities and interoperability between different modes [2,19,20]. The interventions must be correlated with management strategies at various spatial levels, including those that are not oriented towards the transport sector itself, but that influence the generation of passenger and freight flows, the areas of intervention of different modes of transport and the areas of influence of intermodal terminals.

In addition, the choice of intermodal transport by users requires information systems that allow for the adequate evaluation of multimodal options and transfers. Thus, in the development of intermodal transport systems, an important role is also played by information systems, supported by standards and legislation that ensure information

integration and, at the same time, correctness and ethics in the exchange of data and information [19,21,22].

## 5. Conclusions

Data on non-renewable energy consumption in transport and external effects, primarily CO<sub>2</sub> emissions responsible for global climate change, fully argue for major responsibilities that are addressed to both policymakers and authorities, as well as research in the field. To identify appropriate policies for reducing energy consumption and evaluate their effects, research is needed on assessing energy efficiency for different modes of transport and service categories. The study of energy efficiency must be based on the real operating conditions of the vehicles, on comprehensive statistical records related to the quasi-similarity of the operating circumstances: geographical scale (urban, regional, interregional transport), transport settings (speed, accessibility, travel time; length of travel, etc.).

Contemporary mobility demand is influenced by integrated transport systems that require flexibility in the use of each mode of transport. Therefore, modal competition occurs on different scales and takes several magnitudes. The modes of transport can compete or complement each other in terms of cost, speed, accessibility, frequency, safety, comfort, etc. In the analysis of the modal distribution of transport loads, despite the difficulty of carrying out statistical analyses that allow comparisons, a general constant trend towards an increase in the share of road transport is evident. In the land transport sector (road and rail), joint policies are needed to reduce energy consumption, primarily that obtained from non-renewable sources. On the one hand, these policies must aim to regulate the conditions in which competition between the services of the two transport modes follows. On the other hand, complementary relationships leading to road-rail intermodal services must be facilitated so that long-distance transport tasks can be concentrated on corridors and taken over by rail transport.

Overall, these policies require the correlation and coordination of a broad set of measures:

- Promoting vehicles and transport technologies with increased energy efficiency and reduced external effects.
- Coherent fiscal regulations related to the amount and structure of energy consumption in modal transport subsystems (ownership taxes for specific categories of vehicles, taxes on fuels, for the use of infrastructure, etc.) correlated with pricing tools for the internalisation of external costs.
- Actions to promote modes of transport and technologies in line with sustainable development requirements, in particular for multimodal and intermodal services and integrated logistics.

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