EU Transport: the rationale for modal shift policy in the era of zero-emission trucks

A focus on freight transport

Final report

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Executive summary

In the era of zero-emission trucks, a reassessment of the traditional rationale for modal shift policies is warranted. A more nuanced, data-driven, and mode-neutral approach, grounded in robust carbon pricing, strategic policy and targeted investments, is essential to achieve sustainable, efficient, and resilient freight transport across Europe.

This study critically examines the rationale for modal shift policies in the European Union's freight transport sector in light of the accelerating deployment of zero-emission trucks. Historically, EU transport policy has promoted a shift from road to rail and waterways to enhance sustainability. However, despite decades of investment, regulatory support, and modal shift targets, the actual shift in freight volumes has been limited. This has raised questions about the effectiveness and continued relevance of such strategies in their current setup.

Key findings

- **Modal split trends:** road freight continues to dominate, with rail and inland waterways losing modal share over the past three decades. While rail volumes have grown modestly, they have not kept pace with overall freight growth. Inland waterways have declined in both share and volume.
- **Cost structures:** Capital costs are the dominant cost driver in rail, whereas personnel costs are the highest in road transport. Energy costs are the second most important for both modes. The transition of road freight to zero emission vehicles is expected to lower total cost of ownership (TCO), with lower energy costs offsetting increased capital costs.
- **External costs and sustainability**: Zero emission trucks will significantly reduce climate, air pollution and noise externalities and thus close the environmental gap with rail.
- **Infrastructure and policy effectiveness**: EU investments have heavily favoured rail infrastructure, yet operational bottlenecks, lack of terminal density, and poor cross-border coordination significantly hamper the positive impact. Modal shift targets have often been unrealistic and not aligned with freight market dynamics. Incentive schemes have suffered from low uptake and administrative complexity.

- **Technological evolution**: digitalisation, automation, and AI are reshaping freight transport. Zero emission trucks and autonomous driving will further enhance road competitiveness. Rail remains the most energy efficient mode, but must strive for system-level improvements, such as traffic management, digital integration, and service reliability to maintain its competitiveness.

Policy recommendation

Reassessing modal shift rationale: modal shift should not be pursued as an end in itself. Instead, policies should focus on internalising external costs across all modes and enabling market-driven decisions based on efficiency and sustainability.

1 Introduction

Over recent decades, European transport policy has promoted a shift in freight transport from road to rail, maritime and inland waterways, with the aim of improving sustainability (and emissions specifically). These efforts have been supported at EU level by numerous legislative measures that have called modal shift from road to other modes as its main rationale, and implemented at national level in the form of infrastructure investments, taxes, and financial incentives designed to enhance the competitiveness of non-road modes[1]. Despite these policy initiatives, the shift in freight volumes has remained limited, which raises questions about the effectiveness, continued relevance and justification of such strategies.

At the same time, the freight transport sector is changing due to the development and gradual deployment of zero-emission technologies in road transport—particularly electric and hydrogen-powered trucks. These developments are expected to reduce the environmental impact of road freight, and may affect the relative sustainability of the different transport modes. This justifies the need for additional research and potentially revisit the rationale for modal shift transport policies, which have largely been based on the assumption that non road modes of transport are per se more environmentally friendly than road transport.

Against this background, the present study seeks to examine whether a continued policy focus on modal shift remains justified in the context of a decarbonising freight sector. It considers the sustainability, efficiency, and cost-effectiveness of different modes, taking into account both environmental developments and structural features of the freight system.

[1] Beil & Putz (2023), *Modal shift measures to increase the use of eco-friendly transport modes: a literature review*, https://doi.org/10.1016/j.trpro.2023.11.343

2 Recent evolutions in freight transport and modal split

2.1 Volumes and shares

In this section, we focus on the data regarding modal split and its evolution over the past three decades when modal shift efforts were at the centre of the EU's transport policy with the aim of improving sustainability.

Between 1970 and 1990, rail freight transport in the EU declined from 207 to 176 billion tkm, while road freight more than doubled from 377 to 796 billion tkm. Consequently, rail's modal share fell from 27.8 % to 15.4 %, whereas road's share rose from 50.6 % to 69.9 %. In **1970**, inland waterways accounted for **13.6%** of freight transport (in tonne-kilometres). By **1990**, their share had **declined to 9.8%**, despite a slight increase in absolute volume. These numbers and modal shares were presented in the 1992 White Paper on Transport Policy[2] , which did not include figures on maritime transport shares. This sharp imbalance prompted the 1992 White Paper, to strongly promote modal shift as a strategic objective, especially from road to modes like rail, inland waterways, and short-sea shipping. It sought to revitalise rail through market liberalisation, interoperability, and investment in trans-European networks, while also encouraging short-sea shipping and inland waterways as environmentally friendly alternatives to congested roads. This objective was conditional on the maritime sector - at the time still highly polluting - being able to decarbonise.

Despite the rail revitalisation policies in the 1990s, the 2001 White Paper on European transport policy for 2010: time to decide[3] recognised that these ambitions had yielded limited results, with rail freight stagnating and road traffic growing faster than expected. This new White Paper therefore introduced explicit modal shift targets, aiming to shift freight over 300 km from road to rail or water alongside measures to open rail markets further, develop combined transport corridors, and promote maritime links through the Motorways of the Sea initiative.

The 2011 White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system[4] retained the shift objectives, 30 % of long-haul freight from road to rail and waterborne by 2030 and 50 % by 2050 but reframed them within a broader decarbonisation strategy. Over the past three decades, the instruments of modal shift policy have remained largely unchanged, with only limited adaptation to evolving circumstances. Yet, technological progress has transformed the transport sector, and electrification of road transport now calls into question whether the traditional modal shift strategy should be maintained, reconsidered, or at least refined to reflect this new reality.

2.1.1 General evolution and projections

In the first graph, we show the evolution of modal split (relative) between 1995 and 2023. The share of rail transport gradually lost share from 16.3% in 1995 to 11.8% in 2023. Road's share increased

[2] COM(1992)494 final, 2.12. 1992
[3] COM(2001)370 final, 12.09.2001
[4] COM(2011)0144 final, 28.03.2011

from 49.1% to 54.1%. Maritime (intra-EU) remained relatively constant around 30% and inland waterways lost share, dropping from 5.3% to 3.5%.

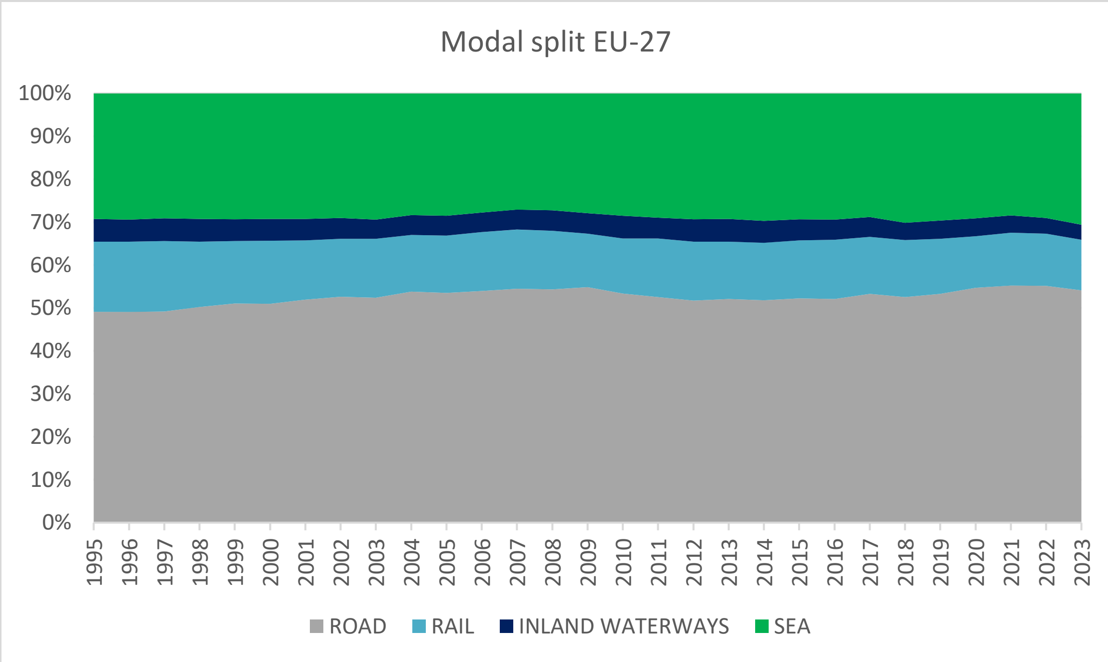

Figure 2-1. Modal split freight transport in the EU-27. Shares of the different modes are based on tkm. Short sea shipping is included in SEA. Source: Statistical pocketbook 2025, EU Transport in figures, European Commission[5].

The total transport volume, measured in tonne-kilometres (tkm), increased by 45.5% between 1995 and 2023. Despite the drop in modal share for rail, rail volume still grew by 5.6% since 1995 (see Figure 2-2), though inland waterway transport did decrease by 4.5%. Growth was stronger for road and sea transport, with increases of 60.3% and 52.0%, respectively in tkm.

[5] Note provided in the source: Sea is only domestic and intra-EU-27 transport, based on Eurostat data. The time series for maritime activity from 1995 to 2004 have been recalibrated by DG MOVE in line with the new EU-27 figures to avoid break in series. Following methodological changes, the times series (2005-2020) for maritime were backwards revised.

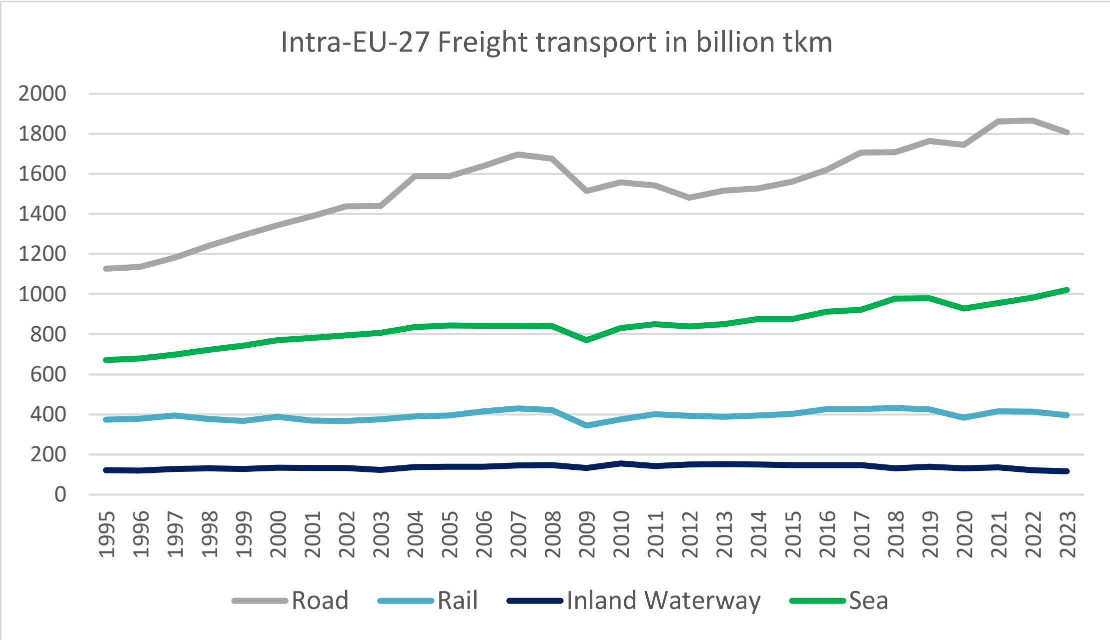

Figure 2-2: absolute evolution of freight tkm (source: EU Statistical Pocketbook 2024)

Looking ahead, the 2020 EU Reference Scenario[6] only provides data and projections for road, rail, and inland waterways from 2005 onwards. In the Reference scenario, modal shares will remain more or less stable in the future for road relative loss of share is 2.2%, while rail grows with 3.5% just above a modal share of 20% by 2050. However, the total freight transport volume is projected to increase by 43.7% for road and by 89.9% for rail between 2020 and 2050. Achieving a 20% modal split by 2050 will require the absolute volume of rail transport to almost double. That principally indicates that the capacity should double as well. This essentially implies that capacity would also need to double by 2050, either through improved operational efficiency or through expansion of the rail network.

[6] EU Reference Scenario 2020 Energy, transport and GHG emissions - Trends to 2050, July 2021

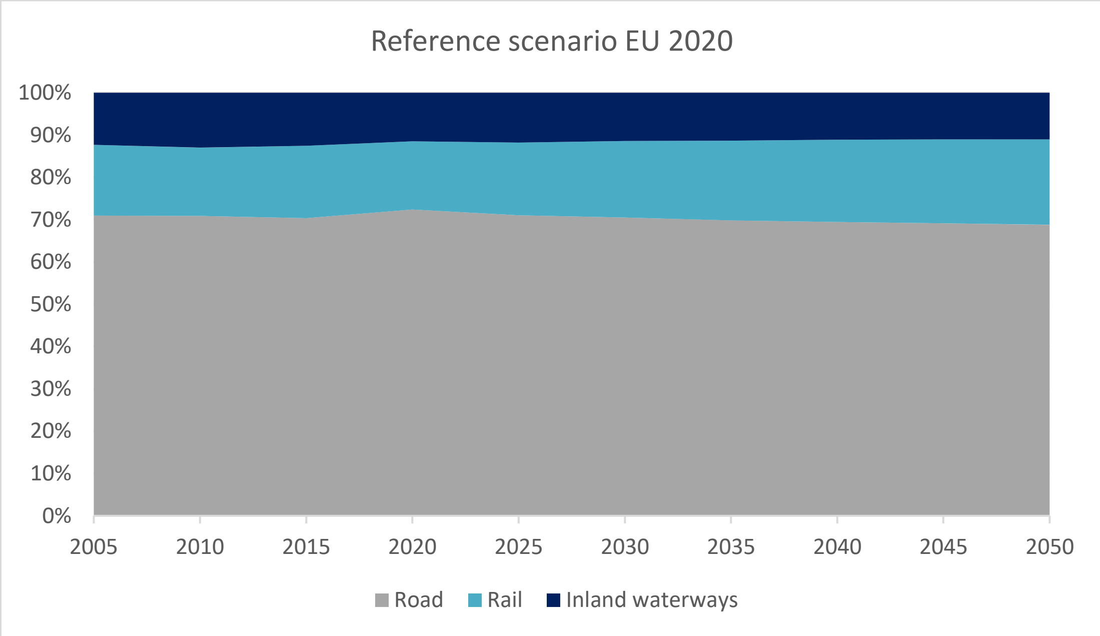

Figure 2-3 Modal split freight transport according to the EU reference scenario up to 2050. Shares of the different modes are based on tkm.

2.1.2 Regional developments

There are important regional differences in inland modal split. In Figure 2-4, the share of road transport in overall inland freight transport is shown. A darker shade represents a high share of road transport, while lighter shades indicate a greater combined share of inland waterways and rail. It is shown that rail and inland waterways have a relatively high combined share mostly in Eastern and central European countries, though the Netherlands and Sweden stand out in Western and Northern Europe. In Southern Europe, Ireland, Norway and Denmark, modal split is more in favour of road freight transport.

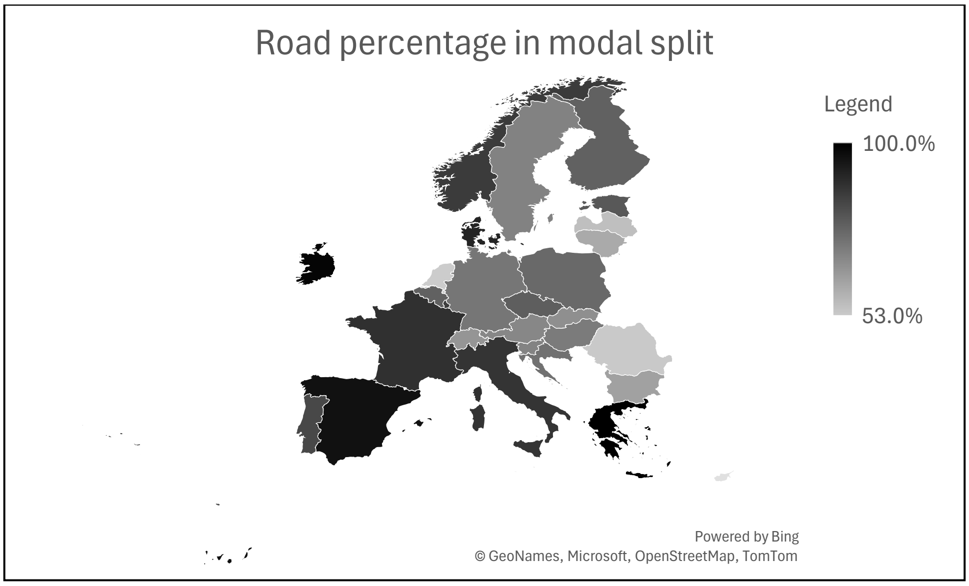

Figure 2-4 Share of road freight transport in total inland freight per country in the EU-27 in 2023 (colour coded).

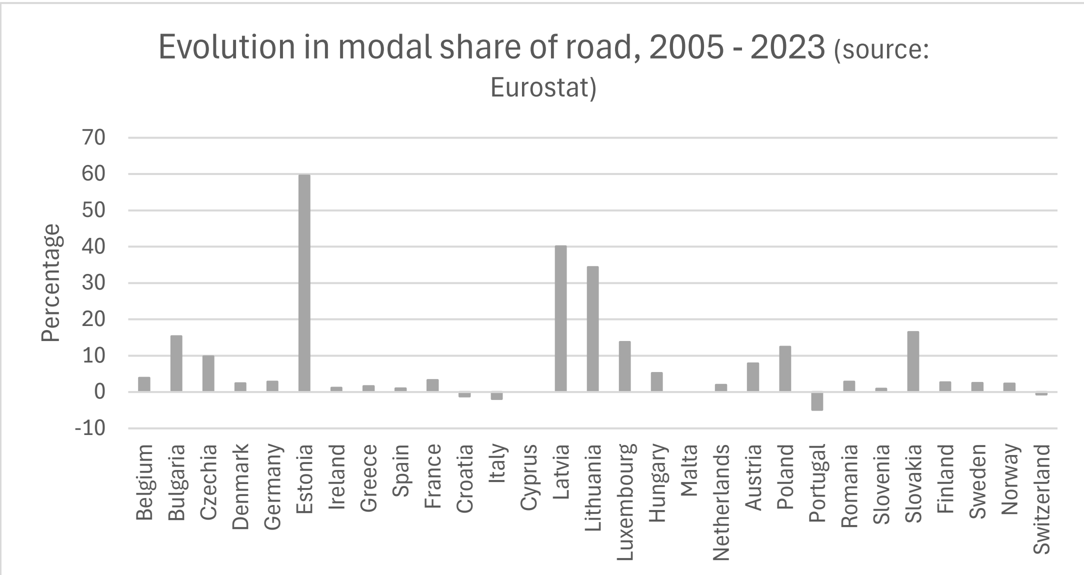

Figure 2-5 Difference in % of modal split share for road per EU countries between 2023 and 2005. 2005 serves as the reference year since data collection by many Member States began after that date.

Figure 2-5 shows the main changes in the modal share of road transport between 2005 and 2023, with the largest increases (30–60%) observed in Estonia, Latvia, and Lithuania. Several factors explain the increase. Much of the rail infrastructure in these countries stems from the Soviet era, with limited westward links, and lost relevance as trade reoriented toward the EU and seaborne routes. Market liberalisation allowed Baltic hauliers to expand across Europe, capturing most new freight flows.

Only three EU countries (Croatia, Italy and Portugal) show small decreases in the road transport share. Overall, the modal shift policy does not appear to have significantly increased the share of rail freight, though it may have helped to prevent a further decline. Over time, maritime transport and particularly road transport have captured the largest gains in modal share.

2.1.3 Evolutions in rail freight submarkets

Rail freight has a few submarkets which show distinct differences in their evolution. According to the 2024 Combined Transport report[7], the volume of conventional rail freight (block trains and single wagon loads) did not change much between 2010 and 2022. However, combined transport (rail and IWW) increased by 42% over that period, and now represents 37% of non-road inland freight, up from 27% in 2010.

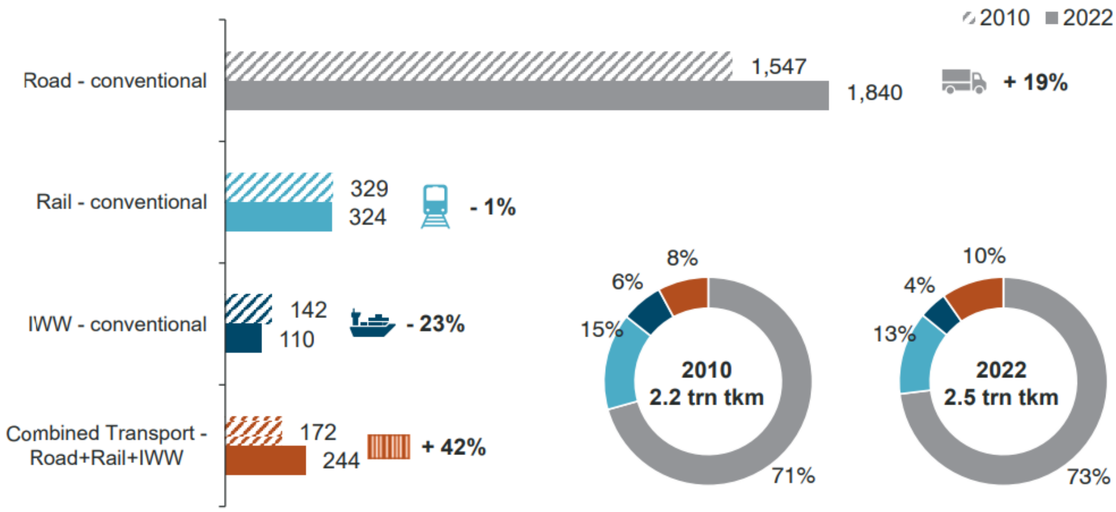

Figure 2-6: Development of modal split of Combined Transport and total European freight transport (billion tkm) (source: Combined Transport Report 2024)

2.1.4 Conclusion

After a decrease in the 1990's, the share of rail has remained mostly stable the past 20 years, keeping up with the growth in total transport volume, while both the share and absolute volume of inland waterways have decreased. This evolution is not in line with the objective of modal shift policy that was to increase the modal share of rail and inland waterways. The modal share and its evolution differ among the regional submarkets, where Eastern Europe freight markets have seen the most drastic changes away from rail and towards road and maritime. The evolution of the modal share is also very different for the different freight markets with a shift away from traditional rail freight markets (bulk and industrial goods) towards more container transport that use road freight and combined road-rail/IWT operations.

2.2 Costs structure differences between transport modes

An **important element in any transport decision taken by shippers is the price/cost of transport**. Freight transport is a very competitive business, with low profit margins, which implies price and cost are narrowly connected. In this section, we will review information on cost components of freight transport for different modes to understand how it may impact the mode choice decisions. Cost components are subject to different trends and a higher or lower share of a component in the total could mean that one mode is more sensitive to certain evolutions than another. Given that detailed information on cost components is scarce, we initially rely on a dataset

[7] UIC, UIRR (2024): Combined Transport Report

that covers the Netherlands only (as a database with detailed cost components for this country was readily available, which is not the case for other countries). Later, we consider evolutions at the EU level on a more aggregate level. Since the e-trucks market is still maturing, the amount of available data is extremely limited. While the exact numbers cannot be retrieved, a short discussion about the influence of this technology on the cost structure of road transport will be presented. Finally, this section aims at presenting and discussing the available data. More detailed insights around policy implications are collected through interviews and discussed in Chapters 4 and 5.

2.2.1 Detailed freight cost components – Netherlands case study

The following figure presents an overview of the cost evolution for container transport on Road, Rail and Inland Waterways (IWW) in the Netherlands between 2015 and 2024. The costs are reported per ton transported and per hour and include taxes and subsidies.

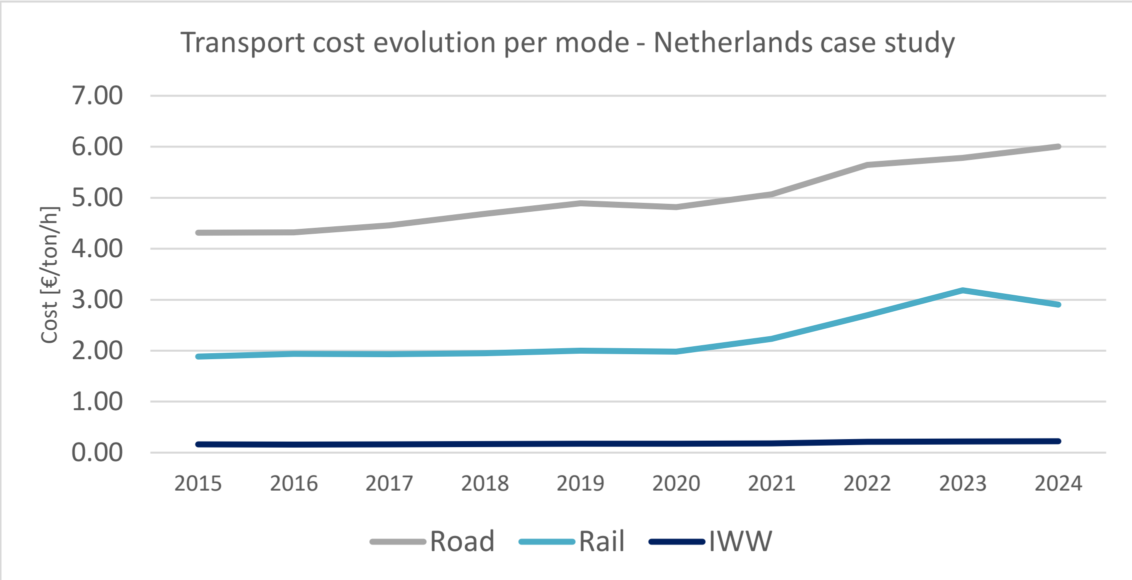

Figure 2-7: Evolution of costs per mode in The Netherlands (source: Panteia with the use of various Dutch databases and sources)

Inland Waterway transport exhibits the lowest costs due to the high payload capacity compared to the other two modes. Since a train also has a higher transport capacity than a truck, the costs per ton are approximately half of those for Road. The absolute difference in costs between these two modes has increased through the last decade: it was around 2.5€/ton/h in 2015, increased between 2017 and 2019 to reach around 2.9€/ton/h, and increased again to 3.1€/ton/h in 2024. Both Road and Rail faced a substantial cost increase in the early 2020's mostly driven by a sharp rise of energy costs due to the situation in Ukraine.

The evolution of cost components for Road and Rail is exposed in more details in the figures below.

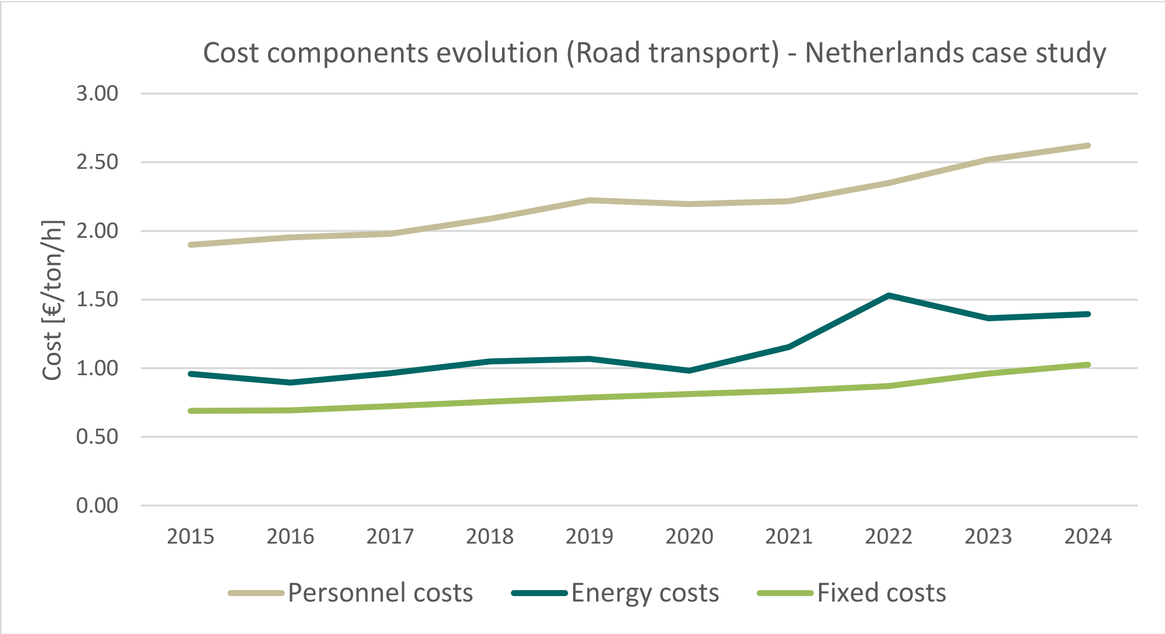

Figure 2-8: Evolution of primary cost components for road (source: Panteia with the use of various Dutch databases and sources)

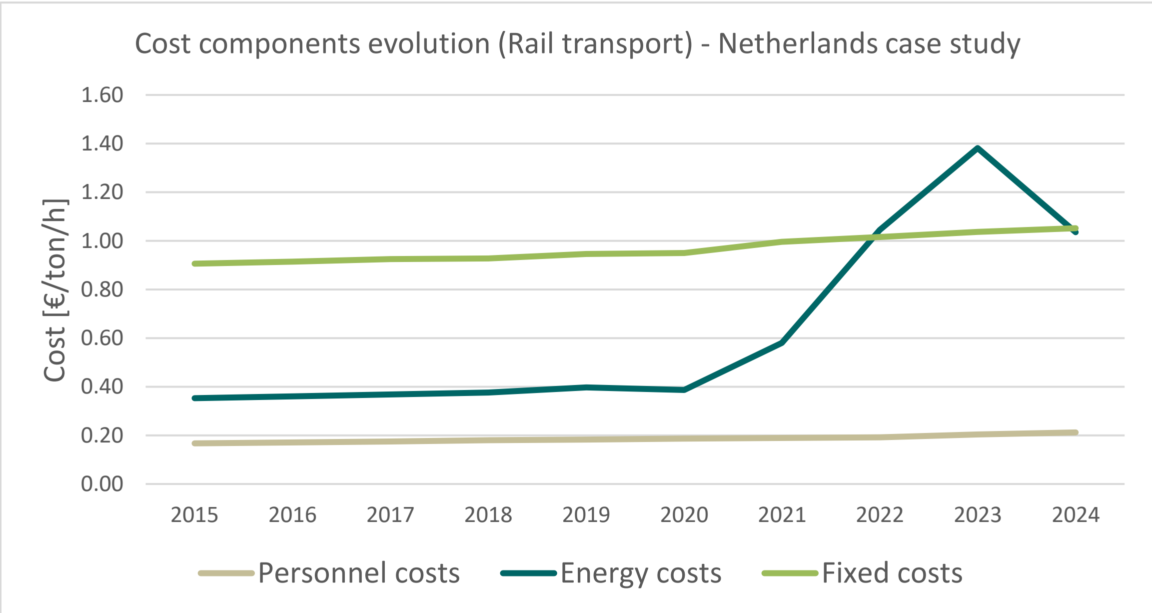

Figure 2-9: Evolution of primary cost components for rail (source: Panteia with the use of various Dutch databases and sources)

These figures illustrate the **extreme impact of the energy prices on both modes**. In particular, the electricity price tripled between 2020 and 2023 and the fuel price rose by 50% between 2020 and 2022. Both prices decreased since but remain much higher than the pre-pandemic level.

For Road transport, the increase in total costs is mostly driven by the cost of personnel. Therefore, changes in the collective labour agreements will explain most of the cost variations. EU policy also has an impact here, e.g. through the Mobility Package and the requirements for the wages of posted drivers. For Rail transport, the costs were traditionally driven by the fixed costs of rolling stock (the locomotives and wagons). Nevertheless, the energy cost has become considerably more important, while the personnel costs remain marginal. These trends are not unique to the Netherlands; similar evolutions are impacting costs in most other EU countries.

The impact of taxes and levies on transport costs, while linked with European policy to a degree, cannot be generalised to other EU countries. In road transport, amendments to the Eurovignette Directive should bring more harmonisation in the impact of taxes, charges and levies on total costs. However, **in rail freight, national policies can be very different even between neighbouring countries, for example with regard to access charges**, subsidies, network organisation, etc. This patchwork of national rules is not conducive to the development of cross-border long-distance rail transport, which in principle should be the market where rail is at its strongest.

2.2.2 *Cost comparison for other countries*

To get a broader picture at European level, the figure below shows a comparison of rail and road costs for 12 European countries in 2024.

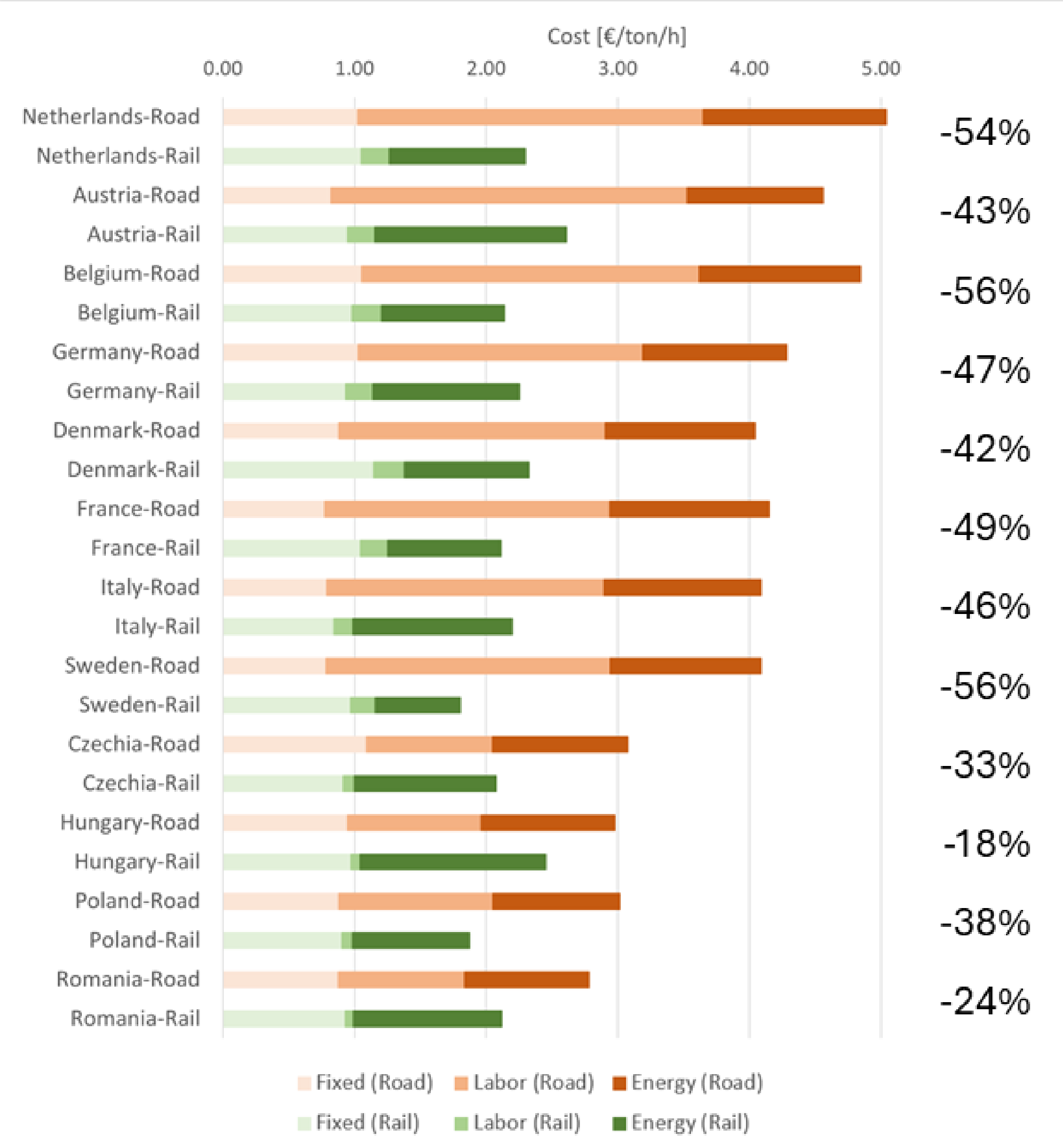

Figure 2-10: Cost components per mode in 2024 (source: Panteia with the use of various European databases and sources), together with relative cost difference for Rail compared to Road

The key take-aways of the comparison between modes are presented in the Table 2-1.

	Road	Rail
Energy costs	- 3 countries above 1.2€/ton/h (Netherlands, Belgium, France) - 2 countries below 1.0€/ton/h (Poland, Romania)	- 2 countries above 1.4€/ton/h (Austria, Hungary) - 5 countries below 1.0€/ton/h (Belgium, Denmark, France, Poland), Sweden even reach 0.65€/ton/h
Labour costs	- Western Europe: 2.0 to 2.7€/ton/h - Eastern Europe: 0.9 to 1.2€/ton/h	- Western Europe: 0.15 to 0.25€/ton/h - Eastern Europe: 0.05 to 0.08€/ton/h
Capital costs	Between 0.75 and 1.10€/ton/h	Between 0.85 and 1.15€/ton/h

Table 2-1 Overall Comparison between modes

While the range of capital costs remain similar for the two modes, more differences and wider ranges are observed for labour and energy costs. For labour costs, there is a clear distinction between Western and Eastern Europe. Indeed, **in Eastern Europe, wages are approximately half of those in Western Europe**. As mentioned above, wages are the largest component of road transport costs, therefore truck transport is more competitive with respect to rail in Eastern Europe. Regarding energy, the costs depend a lot on the fuel taxes and the energy policies of each country. The **electricity costs are particularly volatile**, which has a strong impact on rail transport. For example, the remarkably low electricity costs in Sweden makes it the country with lowest rail transport costs.

Regarding the cost differences between road and rail, three countries have a difference higher than 50% (Netherlands, Belgium, and Sweden). The first two are the ones with the highest Road cost (and some of the highest road congestion), whereas Sweden has the lowest Rail costs. On the other hand, the difference is less than 25% for Hungary and Romania due their lower wages (lowering road costs) coupled to the high electricity costs (increasing rail costs). The difference is in the range of 40% for the remaining of Western Europe and of 30% for the other Eastern European countries.

Finally, the figure below compares the different access charges to Road and Rail networks for the same 12 countries.

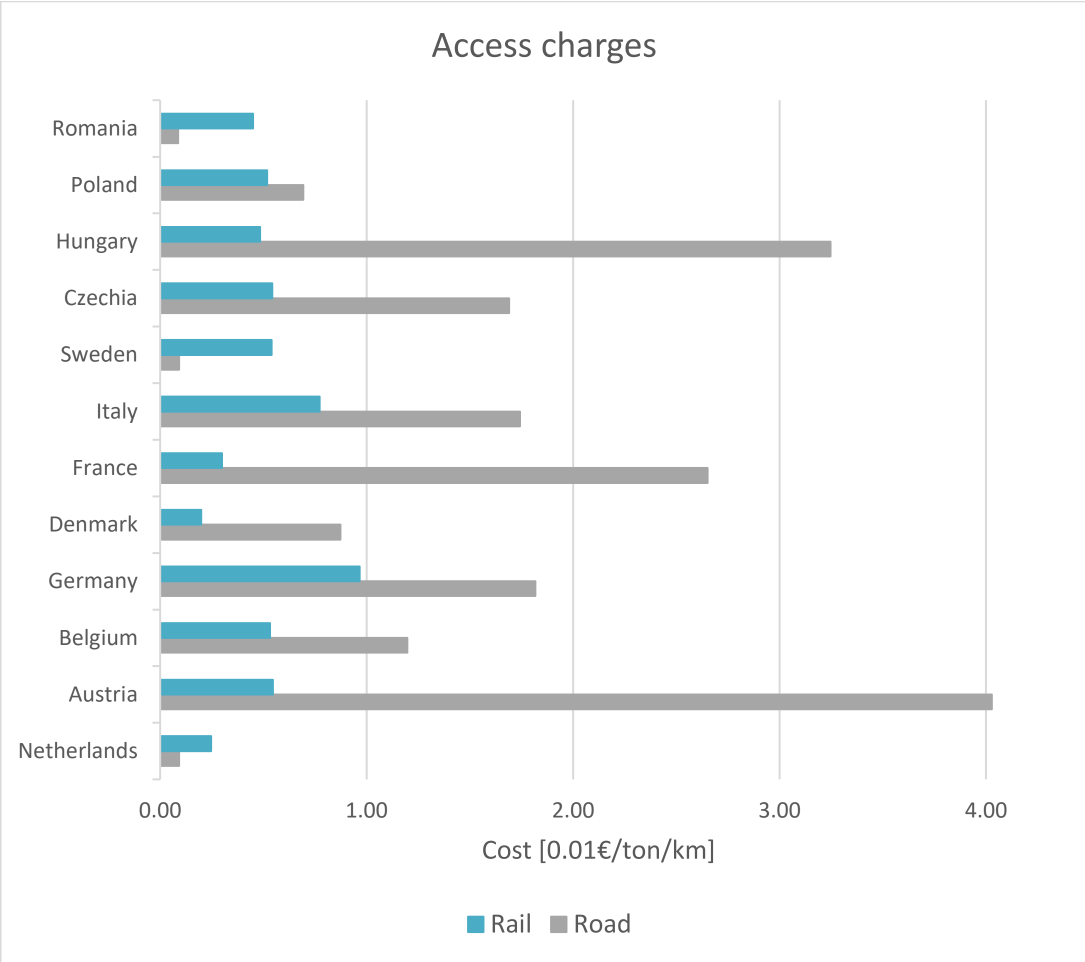

Figure 2-11: Access charges per mode, as of January 2025 (source: Panteia with the use of various European databases and rail network statements)

The Road access charges for heavy-duty vehicles vary widely across the countries. Only three countries have lower charges than rail and they rely on the Eurovignette (Netherlands and Sweden), or Ro-vignette (Romania). The absence of variable road tolls makes Road much cheaper per kilometre than all the other countries, which rely on distance-based tolls. On the other hand, Austria and Hungary have high imposed large charges for trucks as this is of interest for countries with a high share of transit truck traffic.

The **Rail access charges are more uniform across the countries** compared to Road, reflecting the European harmonisation through Directive 2012/34/EU[8], which establishes common rules for track access charging. As a result, Rail access charges are higher than those of Road for the three countries having a vignette system for Road access. For all other countries, Rail access is cheaper (particularly for countries with high tolls).

[8] European Parliament and Council of the EU (2012), *Establishing a single European railway area*, http://data.europa.eu/eli/dir/2012/34/oj

2.2.3 *Impact of electric trucks on cost structures*

The transition from diesel-powered to electric trucks has a direct impact on the cost structure and development, which increases the complexity of cost estimations. The market for diesel trucks is mature, and the cost structure is relatively stable. On the other hand, the e-truck market is very innovative and technological developments rapidly follow each other.

While electric trucks are about to reach similar total cost of ownership for last-mile delivery with diesel trucks[9], this is not yet the case for long-haul transport. In 2024, the purchase prices of e-trucks are in the range of 250 000 - 300 000€[10]. This is significantly higher than those of diesel trucks because their production costs are 2.5 times greater[11]. Moreover, the residual value and depreciation of electric trucks remain uncertain[12]. Therefore, the **fixed costs of electric trucks are currently higher than diesel** ones. Nevertheless, as the technology matures and the production volumes increase, the purchase prices are expected to decline.

Regarding operating costs, wages will remain similar although new technologies such as platooning or autonomous driving have the potential to substantially decrease them in the future. Given that electricity is generally cheaper than diesel[13], the **energy costs are expected to decrease**. Moreover, the rapid improvement of the performance of electric trucks in terms of battery range, charging speed, or capacity means that newer trucks models will have lower operating costs than older ones. These changes in both fixed and operational costs complicate the evaluation of electric trucks cost structure.

While historical cost structures make rail significantly cheaper (especially in terms of energy and labour costs), the ongoing deployment of electric trucks may change this landscape. With lower energy costs and reduced maintenance, the gap between road freight and rail freight will diminish. Autonomous driving can lead to high personnel cost savings, however the adoption rate of this technology is expected to remain slow in Europe with expectations for 2035 of 4% of autonomous heavy-duty trucks on the road[14] and 13% of long-haul new sales being autonomous trucks[15]. Therefore, as long as a human is needed, road transport will be more expensive than rail due to the importance of wages in the total costs even though the gap will remain smaller in Eastern European countries where wages are lower.

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[9] The ICCT (2022), *ELECTRIFYING LAST-MILE DELIVERY: A total cost of ownership comparison of battery-electric and diesel trucks in Europe*, https://theicct.org/wp-content/uploads/2022/06/tco-battery-diesel-delivery-trucks-jun2022.pdf

[10] ING Think (2024), *Europe's market for e-trucks set to accelerate in 2025*, https://think.ing.com/articles/europes-market-for-e-trucks-set-to-accelerate-in-2025/

[11] McKinsey (2024), *The bumpy road to zero-emission trucks*, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-bumpy-road-to-zero-emission-trucks

[12] Panteia (2025), *Kostenontwikkelingen in het wegvervoer*, https://panteia.nl/webshop/kostenontwikkelingen-in-het-wegvervoer-2025-2026/

[13] Association of European Vehicle Logistics (2022), *On Costs For Electric Trucks: The realities of going green for Europe's FVL trucks*, https://www.ecgassociation.eu/wp-content/uploads/2022/04/ECG-Business-Intelligence-22.04-Cost-of-going-electric.pdf

[14] McKinsey (2024), *Will autonomy usher in the future of truck freight transportation?*, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/will-autonomy-usher-in-the-future-of-truck-freight-transportation#/

[15] World Economic Forum (2025), *Autonomous Vehicles: Timeline and Roadmap Ahead*, https://reports.weforum.org/docs/WEF_Autonomous_Vehicles_2025.pdf

2.2.4 Conclusion

The cost structures of road and rail are very different. Capital costs are very high in rail, whereas personnel costs are the highest in road transport. Energy costs are the second most important for both modes, but the spike in energy prices due to COVID and the Ukraine war has had a larger impact on rail. The **volatility of electricity prices makes rail vulnerable to high cost fluctuations**. Nevertheless, the transition to electric trucks will make the road sector more sensitive as well, especially for operators not having in-house charging.

Regarding geographical differences, **road transport is much more competitive with respect to rail in Eastern Europe due to the lower wages**. For energy costs, there is a limited variation for road transport due to fuel taxes disparities. But the volatility is higher for rail transport due to the differences in energy mix and policy of each country.

The impact of taxes, charges and levies on the cost of transport differs widely between countries. Where time-based vignettes are still in place, infrastructure access costs per km are much lower than in countries where distance-based charges are already in place. Rail infrastructure access charges are often used by governments to promote rail through subsidies, and only where they are charged in full, they are an important component of total costs.

3 Sustainability and external costs

3.1 Definition of "sustainability" in transport, link to "external cost" concept

To justify modal shift policy, the greater sustainability of modes like rail and IWT is cited among the main reasons. "Sustainability" is a broad term that covers many aspects, with varying degrees of quantifiability (both in terms of calculating a reference value and doing so in a sufficiently consistent manner). While the classic interpretation, as followed by the European Commission, focuses[16] on environmental aspects like climate and air quality (for example in the Green Deal), the concept is sometimes widened beyond those traditional purely environmental aspects, to include secondary economic and social aspects such as long-term resource availability, ecosystems as well as poverty issues. Some of these issues are only remotely relevant for organising freight transport.

These "externalities" – economic consequences (costs or benefits) of an industrial or commercial activity which affects other parties without this being reflected in market prices – also include aspects beyond the environmental: infrastructure, congestion, safety, noise, subsidies, scarcity are the most prominent ones in the transport sector. Assessing competitive positions of different transport modes in a correct and balanced manner requires a proper evaluation of externalities, as part of a just integration of European economies.

In light of the main research questions of this study, we will pay particular attention to the emission (health, decarbonisation) and infrastructure components.

3.2 Current state of external cost and internalisation research

3.2.1 General

External cost concepts started to be used in the 1990s focusing first on cars in an urban environment. The concept of externality was (and is) used as a guide for the environmental regulation of cars as well as for a better pricing of their use. Integrating the external costs in the pricing of cars and trucks and the use of stricter standards for new vehicles (EURO norms) helps to have the correct balance within each mode of transport between reducing the volume of vehicle use and the "greening" of car and truck use".[17] Adding the external costs to the user costs of the different modes adds then to a more correct use of the different modes.

Two fundamental principles are at the basis of an efficient transport system: proper pricing and proper investment decisions.

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16 https://transport.ec.europa.eu/transport-themes/sustainable-transport_en

17 A historic overview can be found for passenger transport in Mayeres, I., Ochelen, S., & Proost, S. (1996). The marginal external costs of urban transport. Transportation research part d-transport and environment , 1(2), 111-130 for freight transport there is less documentation. The 2011 White paper is among the first to discuss external costs of freight.

Proper pricing means that users pay the full cost of their freight trip. The prices need to include the resource costs of the users (costs of the vehicle, the fuel, the driver), but also the external costs imposed upon society. Via prices that include the costs for the rest of the society, the users opt for the most efficient transport system for society.

Relying on user's choices is a better guarantee for an efficient transport system than to rely on imposed modal shares. Imposing target modal shares is not in line with the proper pricing of transport. The target modal shares approach neglects the knowledge of the users of their own resource costs, which in the freight sector can be very context specific and in constant evolution, as they evolve with the locations and type of goods to be transported.

Proper investment in transport systems (roads, rail lines, ports, airports) requires that all investments are assessed comparing the benefits (reduction of user costs and external costs – example: shorter route) and the costs of the investment (building and maintenance).

The same pricing and investment principles need to be applied to all modes of transport.

Advancing ex ante target modal shares for freight, as the European Commission does, is not in line with these basic economic principles.

3.2.2 Europe: Handbook on External Costs and internalisation of external costs

The EU Handbook on External costs presents for all types of vehicles an estimate of the different external costs. The focus of the first version (2008) version was on marginal external costs of transport as a basis for the definition of internalisation policies (in line with the marginal social cost pricing principle). It covered all main external cost categories, including air pollution, climate change, noise, accidents and congestion. The update of 2014 added infrastructure wear and tear costs for road and rail transport. The addition of infrastructure wear and tear costs is important, as it cleared the path to generalised and rational (cost-based) distance pricing in heavy duty road transport, which helps avoid both the overcharging and the tax exploitation of foreign trucks.[18]

The current version (2019)[19] is an update of the publication that was started in 2008. It presents the different external costs and the extent to which the external costs are internalized in the current taxes, though it does not include subsidies. Some of the data used in this handbook date from almost 10 years ago but an update will not be available before 2026. As these data are the only ones available for the whole of the EU, they need to be considered with caution. For those categories where there are big changes expected, we **will include our provisional estimate.**

We concentrate our discussion on the heaviest category trucks and freight rail (rail does not compete with small freight vehicles). Correct pricing requires that users pay their own

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18 The distance pricing of trucks by member states spread quickly when one country started to implement it allows to protect its revenues from low diesel taxes in neighbouring countries (e.g. Luxemburg). To avoid that distance charging overcharged trucks, the EC required that the revenues of distance pricing of tucks are in line with the infrastructure costs (Mandell S., Proost, S. (2016). Why truck distance taxes are contagious and drive fuel taxes to the bottom. Journal of Urban Economics, 93 (2016), 1-17)

19 European Commission: Directorate-General for Mobility and Transport, CE Delft, Essen, H. v., Fiorello, D., El Beyrouty, K. et al., Handbook on the external costs of transport – Version 2019 – 1.1, Publications Office, 2020, https://data.europa.eu/doi/10.2832/51388

resource costs + the external costs and variable infrastructure costs they impose on society. We discuss briefly the different types of costs and the extent to which they are covered by user charges.

COSTS	HGV-ROAD	FREIGHT TRAIN	Comments
Accidents	x	x	The marginal accident costs represent the extra costs that adding an extra vehicle to the traffic flow brings but that are not paid by the user (via insurance etc.)
Air pollution	x	x	
Climate Change	x	(x)	Only relevant for HGV (diesel) and Freight train (diesel) Electricity is carbon neutral as it is covered by ETS
Noise	x	x	Large differences between day/night operation
Congestion - scarcity	x	missing	When Freight trains hinder other trains, there is a congestion or scarcity cost – this is not included in the EU handbook for rail, but these costs do exist
WTT	x	x	External costs mainly related to energy production (electricity, fuel production)
Variable infrastructure costs	x	x	These are the infrastructure costs associated to the maintenance ("wear and tear") that are caused by the use of the infrastructure
USER CHARGES	**HGV-ROAD**	**FREIGHT TRAIN**	**Comments**
Road	x		Fuel taxes, vehicle taxes, road charges (distance taxes)
Rail		x	Fuel taxes (diesel trains), ETS charges, Electricity taxes, infrastructure access charges

Table 3-1: types of external costs and user charges

The average level of external costs and their internalization is summarized for the different freight modes in the following table and figure. This table is based on Annex D of the EC internalization report with one important addition. An extra column has been added to represent the electric HGV trucks.

in € -ct/tkm	HGV diesel Costs	*HGV - Electric* Costs	Electric freight train Costs	Diesel freight train Costs	IWT Costs
Accidents	1.25	*1.25*	0.07	0.07	0.06
Air Pollution	0.76	*0.38*	0	0.68	1.29
Climate Change	0.53	*0*	0	0.25	0.27
Noise	0.42	*0.21*	0.65	0.45	0
Congestion	0.13	*0.13*	0	0	0
WTT	0.2	*0.2*	0.16	0.14	0.13
SUM	**3.29**	***2.17***	**0.88**	**1.59**	**1.75**
Infrastructure	0.72	*0.72*	0.55	0.56	0.13
Taxes and Charges	1.32	*?*	0.52	1.33	0.25
SUM	**2.04**		**1.07**	**1.89**	**0.38**
Cost Coverage ratio	33%	?	37%	62%	13%

Table 3-2: average variable external and average variable infrastructure costs vs. average variable taxes and charges in EU by mode (source: adapted based on State of play of Internalisation in the European Transport Sector, 2020)

This is an average for the EU28 (before UK left the EU) and can only give a rough picture of the status (2019) for new HGVs and trains.

There are also large differences in external costs in function of place and time:

- external costs of road congestion are particularly high in peak periods;
- external costs of air pollution of trucks are much higher in urban areas;
- external costs of noise are much higher at night, both for road and rail transport.

There is also a large diversity of charging and taxing practices. Many countries use distance charges for trucks that cover the wear and tear maintenance costs of roads. Countries with a high share of transit traffic, tend to charge more for the use of their roads – a practice known as tax exporting (see Mandell & Proost, 2016, op.cit.). For rail freight, infrastructure providers have to charge freight trains the variable maintenance costs. There is still an ongoing academic debate on how to calculate these charges, as part of the infrastructure is also used by passenger transport. Sweden is one of the countries that want to charge the rail infrastructure costs correctly: they foresee a 40% increase in track charges in 2025 to be in line with the EU framework (https://www.uirr.com/news/mediacentre/2811.html.) On the other hand, some countries give discounts on the maintenance charges of rail to promote the modal shift towards rail. These subsidies are not in line with the proper pricing principle we advanced above.

Overall, road transport pays the most in taxes and charges per tkm, as is also noted in the CE Delft report (2019) "Transport taxes and charges in Europe". However, as noted in CE Delft (2019), "State of play of Internalisation in the European Transport Sector", p.186:

"For freight transport, the highest variable cost coverage share is found for diesel trains (62%), which is significantly higher than for electric trains (37%), due to the fuel taxes on the respective fuels. The HGV cost coverage of 33% is achieved through revenues from road tolls and fuel taxes."

As such, despite the high absolute internalisation, road lags behind rail in (relative) cost coverage (at least for the time frame covered by the study), but all are well below 100% - which means that user prices for both modes of transport do not fully cover the external costs.

3.2.3 Main evolutions

There are 3 important changes expected in the next 20 years:

1. the decarbonization of trucks (legal requirement) and diesel trains (expected/assumed)
2. the charging of congestion on road and rail networks.
3. the growing importance of the external costs of noise

3.2.3.1 The decarbonisation of trucks and diesel trains

Climate damage is an important component of the external costs of trucks and of diesel trains. The external climate damage is valued at 100 €/ ton of CO_2 in the external cost assessments of the handbook version 2020. This is more or less in line with the price of ETS permits on the EU market (https://sandbag.be/carbon-price-viewer/).

For large new trucks, the EU requires manufacturers to decrease the CO_2 emissions per km by 15 % in 2025 (compared to 2019/2020), by 45 % in 2030, by 65 % in 2035 and by 90 % in 2040 (EU Regulations 2019/1242 and 2024/1610). The main technology that accomplishes this is the electric truck: in practice either the battery electric truck or the electric truck with powerlines on the roads (ERS). These two electric truck technologies are expected to become cost-efficient in the coming years [20]. The ERS technology is more efficient for dense countries but requires investment coordination across EU countries. In the future (5-10 years) one can expect the massive introduction of electric trucks (new trucks are intensively used in the first 7 years), at which point climate considerations are no longer an important differentiation between road and rail freight. For this reason, an extra column "HGV electric" has been added to Table 3-2. It has no climate costs because the carbon emissions of the electricity needed is capped by the ETS as in the case of electric freight trains. We also reduced the air pollution costs of HGV electric with 50% because the emissions of electric HGV are limited to friction of the tires and the breaks.

The EU will also integrate diesel for trucks into ETS2 [21]. Diesel will together with gasoil and natural gas be phased in slowly over the next 5 to 10 years. This means that from 2027 onwards, diesel from trucks will be capped and will have to decrease. This means that also the climate externalities of diesel trucks will become zero, even if they physically still emit CO_2[22].

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[20] Borjesson M., Proost S., Costs and Benefits of E-Roads versus Battery Trucks: uncertainty and coordination, Resource and Energy Economics, 2025

21 https://climate.ec.europa.eu/eu-action/carbon-markets/ets2-buildings-road-transport-and-additional-sectors_en

22 The existing truck fuel excises are proportional to the carbon content of the fuel and are de facto "carbon taxes" (150 €/ ton of CO2 – with important variation between countries) that are already larger than the ETS prices. Integrating the road freight sector into the ETS is therefore not necessary and could

This change in truck technology has important consequences for any freight investment strategy as the benefits of any investment are situated in the very long term (with benefits after 2035 for investment decisions made in 2025).

Diesel trains can also be decarbonized by electrifying the rail line. Currently close to 60% of the rail lines are electrified but there are large regional differences. (https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20240313-1): in some countries it is 75% or more, in other countries it is less than 20%. This means that decarbonizing rail freight (for which there is no legally binding objective) will require large investments in some countries and that one needs a correct CBA, line per line.

3.2.3.2 The external congestion costs

The external congestion costs are an important external cost for truck and rail transport. In the case of trucks, congestion is mostly relevant in urban areas at peak times. When congestion is priced via tolls (or tradable permits), this leads to a redistribution of traffic over the day and a more efficient use of the network. Improvement in electronic charging technology will make the implementation of congestion charges easier. However, it should be noted that for congestion pricing to work, all road vehicles should be subject to it – not just HGVs.

In the case of rail, congestion exists on the network where passenger and freight trains want to use the same tracks at the same times. The railway infrastructure manager must allocate the scarce capacity to one of the trains. As in the case of road pricing, an efficient way to do this, is to use a bidding process so that the bidder with the highest willingness to pay for that track can use it. However, current practice is strongly driven by political choices, with passenger trains mostly getting priority over freight trains; this is even more notable in the long-distance market, where high speed passenger trains operate.

Charging for congestion in road and rail will ensure that capacity is used more efficiently and ease the pressure to extend infrastructure capacity.

3.2.3.3 Noise costs

With evolutions in research, the importance of noise costs has increased significantly in recent years, to the extent that they are now often considered as more important than local air pollution costs. Noise is not only responsible for discomfort, but also for a negative health impact.

The increasing costs of noise will affect trucks as well as freight trains. It is expected that electric trucks can reduce the external noise costs significantly. A reduction of 10 dB is expected and means that noise costs are halved compared to a new diesel truck.[23] This is the assumption we used for the electric HGV noise costs.

This is much less the case for rail freight where the noise is generated by the friction of train and infrastructure.

lead to an excessive carbon charge on truck fuel. The member countries can decrease their fuel excises to compensate the introduction of ETS charges.

[23] This seems to be the case for MAN, VOLVO and MERCEDSES trucks. https://www.truckpages.co.uk/information/alternative-fuels/how-loud-is-an-electric-truck/

3.2.3.4 Summing up the evolutions in external costs of truck and rail freight

The main evolution in the coming years is the introduction of electric trucks. These will have no CO_2 emissions and reduce the noise costs by 50% compared to diesel trucks. This evolution will bring the external costs of trucks much closer to the external costs of rail freight.

4 Modal shift policy

For decades, the EU has made modal shift one of its priorities as part of its policies to fight climate change and improve sustainability. In this section, we review some of the most important elements of those policies and consider their effectiveness. As sources for this review, a literature study was conducted, and the list of reviewed documents is provided in appendix 6.1. The main findings of the literature review have been complemented with insights gathered from the interviews with important voices in the realm of EU freight transport and modal shift policy:

- Alan McKinnon (Kühne Logistics University, formerly Heriot Watt University)
- Jose Viegas (TIS, formerly OECD-ITF)
- Juan Montero (European University Institute, Florence School of Regulation)
- Godfried Smit & Matteo Nenciolini (European Shippers Council)
- Claus Doll (Fraunhofer ISI)
- Fernando Liesa (ALICE, Alliance for Logistics Innovation through Collaboration in Europe)
- Inge Vierth (Swedish National Road and Transport Research Institute)

The results of the literature review and the interview are integrated in the sections below.

4.1 Infrastructure investments in road and rail

Historical data on European funding in the TEN-T corridor infrastructure were gathered and analysed. The following figure presents an overview of the European investment in Rail and Road infrastructure.

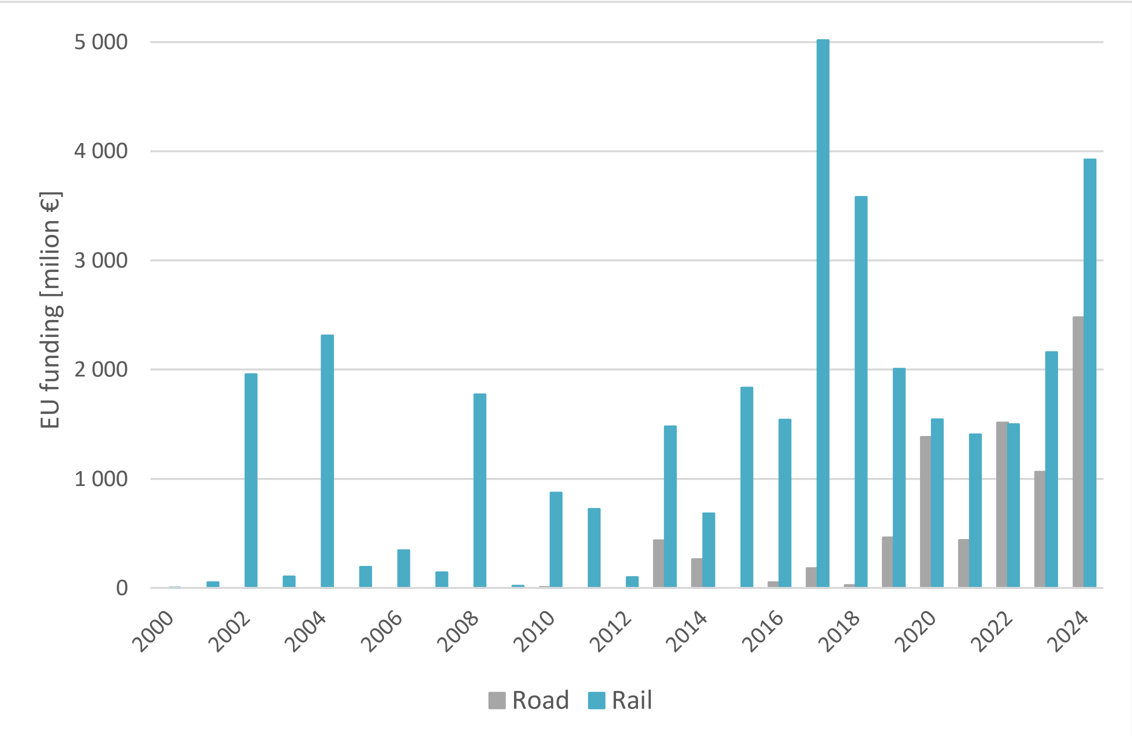

Figure 4-1: Yearly European funding amounts in TEN-T Rail and Road infrastructure projects (source: Panteia)

In the past years, lots of investment has been done in transport infrastructure to support the growth of the European single market. **From 2000 to 2024, most of the EU-level investment went into rail infrastructure**: cumulatively, rail accounts for 80% of the total funding. Road funding emerged later, with a significant acceleration in the 2020s, to reach its absolute highest mark in 2024. Considering only the 2020s, road accounts for 40% of the total funding. This is mainly for expanding road networks in Eastern European countries and developing Safe and Secure Truck Parking Areas throughout Europe.

The 2021 Support Study for the Evaluation of the TEN-T[24] identifies the **uneven development of infrastructure across the EU**. Moreover, many co-funded projects have experienced delays and cost overruns, and the administrative burden related to funding instruments and reporting can undermine the efficiency of the TEN-T. Despite this, the TEN-T still aligns with the overall EU priorities, such as the European Green Deal, the Sustainable and Smart Mobility Strategy, and the Digital Single Market. However, the study observes that alignment with climate adaptation, urban mobility, and logistics digitalisation policies remains insufficient.

A 2022 report from the International Transport Forum[25] highlights that while subsidies and financial incentives can temporarily shift behaviour, long-term change depends on correcting structural imbalances, such as the lack of last-mile intermodal connections or inconsistencies in infrastructure standards. But **infrastructure improvements alone are not sufficient to influence mode choice**, they must be complemented by governance mechanisms that ensure coordination across transport chains. On this topic, the 2018 TRAN Committee report[26] argues that the TEN-T policy, the Connecting Europe Facility (CEF), and the Marco Polo Programme have not always succeeded in translating investments into effective operational solutions. Another issue is that **a lot of investments were done for high-speed passenger rail, with no perceivable effects (or targets) for freight**. As a result, intermodal terminals remain underdeveloped and less accessible in many parts of Europe. And since the terminal network is not sufficiently dense, it adds distance for intermodal transport which requires first- and last-mile solutions. Recent studies[27,28] confirm that rail infrastructure investments have often lacked strategic alignment with real-world freight flows, leading to network inefficiencies and congestion, particularly on busy corridors. For instance, investments have not adequately targeted reactivating closed cross-border lines or expanding terminal capacity in critical areas.

[24] EC (2021), Support study for the evaluation of Regulation (EU) N° 1315/2013 on Union guidelines for the development of the trans-European transport network, https://op.europa.eu/en/publication-detail/-/publication/1f938a68-4c20-11ec-91ac-01aa75ed71a1/language-en

[25] ITF (2022), Mode Choice in Freight Transport, https://www.itf-oecd.org/sites/default/files/docs/mode-choice-freight-transport.pdf

[26] EU (2018), Modal shift in European transport, https://op.europa.eu/en/publication-detail/-/publication/dbe95c09-1317-11e9-81b4-01aa75ed71a1/language-en

[27] Nassar, Ghisolfi, Annema, van Binsbergen, & Tavasszy (2023), A system dynamics model for analysing modal shift policies towards decarbonization in freight transportation, https://doi.org/10.1016/j.rtbm.2023.100966

[28] European Union Agency for Railways (2024), Modal shift analysis for the 2024 ERA Compelling Vision: Final report, https://www.era.europa.eu/system/files/2024-05/ERA_modal_shift_report_20240502.pdf

Regarding road, the interviewed experts indicate that **a robust and well disseminated charging infrastructure is critical**. In this context, e-highways could also facilitate the electrification, but should not be the only way to decarbonize road transport. From an economic standpoint, the **dominance of road transport remains in place through its cost-effectiveness and flexibility**. Road freight continues to gain market share in many contexts, as it better supports just-in-time logistics and maintains a price advantage due to lower infrastructure access charges and fewer administrative burdens[29,30]. Moreover, according to the interviewed experts, road transport operators can sometimes charge services below their costs.

Finally, most interviewed experts advocate that the analysis of infrastructure development on the road and on the rail should consider the technological evolutions of the modes, in particular regarding automation. Infrastructure assessments should not be performed based on current technologies, as they are changing fast.

4.2 Modal shift objectives and why they have not been realised

In spite of heavy policy support, rail and IWT have not increased their market share in accordance with the targets set by the EC. The special report from the European Court of Auditors[31] highlights that the Commission's approach has not succeeded in making intermodal options competitive with road freight.

First, the increase in modal share of rail is judged unrealistic, as it is not based on robust analysis (the target was set top-down rather than bottom-up). Second, many investments focused on general (long-distance) rail infrastructure **without improving the operational interfaces needed for seamless intermodal transfers**. Typically, some junctions could be improved and crossings in the rail network could be upgraded, but these kinds of projects are less appealing politically. The lack of a comprehensive overview of existing terminals and the absence of detailed planning for future ones has also led to inefficiencies. For example, logistics operators often lack access to critical information about terminal capacities or real-time network conditions, making it difficult to plan optimal intermodal routes. Moreover, the TRAN Committee report[32] also identifies several obstacles, including insufficient multimodal infrastructure, limited interoperability between national rail systems, high access charges, lack of service reliability, and regulatory inconsistencies. In particular, the authors call for a greater alignment between national and EU-level transport strategies. Therefore, funding should be more strategically directed toward critical infrastructure such as intermodal terminals and last-mile connections, and better aligned with measurable objectives for modal shift.

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[29] Sallnas, Rogerson, & Santen (2022), *Trusting the power: Facilitating a modal shift in relationships between shippers and logistics service providers*, https://doi.org/10.1016/j.rtbm.2022.100864

[30] Langenus, Dooms, Haezendonck, Notteboom, & Verbeke (2022), *Modal shift ambitions of large North European ports: A contract-theory perspective on the role of port managing bodies*, https://doi.org/10.1016/j.martra.2021.100049

[31] European Court of Auditors (2023), *EU still far from getting freight off the road*, https://www.eca.europa.eu/Lists/ECADocuments/SR-2023-08/SR-2023-08_EN.pdf

[32] EU (2018), *Modal shift in European transport*, https://op.europa.eu/en/publication-detail/-/publication/dbe95c09-1317-11e9-81b4-01aa75ed71a1/language-en

Moreover, recent literature[33] stresses that infrastructure must be accompanied by operational and technological measures, such as dynamic scheduling, digital train control, and real-time capacity management, to yield meaningful modal shift. **Infrastructure-only approaches have proven insufficient when not integrated with such system-level improvements**. This also applies to infrastructure maintenance, which is as crucial as expanding capacity. With the current technologies, lots of information can be collected and used to optimise maintenance planning and execution. It can also provide more information to the end users of the network and improve the reliability of supply chains.

In parallel, modal shift incentive programs, such as those under Marco Polo, often suffered from unclear policy targets, excessive bureaucracy, and limited uptake by private actors: poor communication and lack of transparency further reduced the effectiveness of these schemes[34,35].

On the other hand, road charging policy has a limited effect in transferring freight demand to non-road modes; indeed **road freight demand evolution has shown a very inelastic behaviour over time**: therefore, it makes tolling better at collecting funds than at achieving a modal shift[36]. This inelastic behaviour is mostly explained by the flexibility that can be provided by road services, even more so in a just-in-time context.

Interviewed experts indicate that the **scarce capacity of rail is a major issue causing a loss of economic value due to the extensive travel and waiting times**, which in addition also come with uncertainty/unpredictability. It represents an additional capital cost for the shippers, as well as opportunity cost in the case of late delivery of the goods. This leads to shippers avoiding the use of rail because it is perceived as unreliable. A big part of this poor reliability lies in the infrastructure bottlenecks, but also in the lack of intermodal transfer facilities and in the low priority of freight transport against passenger transport in the capacity allocation process. Moreover, **the rail system is insufficiently flexible and overly complex**: it may take up to half a year to get a slot, making proactive planning impossible. The sector is currently a patchwork of different rules per country (even within countries), that are often outdated. Therefore, these reasons are significant drivers of the low modal share of railways for freight. Recent work stresses that without operational improvements, such as re-prioritising freight paths and addressing peak-hour bottlenecks, modal shift targets will remain unreachable[37].

[33] European Union Agency for Railways (2024), *Modal shift analysis for the 2024 ERA Compelling Vision: Final report*, https://www.era.europa.eu/system/files/2024-05/ERA_modal_shift_report_20240502.pdf

[34] Takman, & Gonzalez-Aregall (2021), *A review of public policy instruments to promote freight modal shift in Europe: Evidence from evaluations*, https://www.diva-portal.org/smash/get/diva2%3A1577493/FULLTEXT01.pdf

[35] Simonelli, Sterle, Masone, Tocchi, Tinessa, Mancuso, Papola, & Marzano (2024), *New freight transport incentive to achieve modal shift targets: Methodology and application to Italy*, https://doi.org/10.1016/j.trip.2024.101166

[36] Gomez & Vassallo (2018), *Has heavy vehicle tolling in Europe been effective in reducing road freight transport and promoting modal shift?*, https://doi.org/10.1007/s11116-018-9922-3

[37] Nassar, Ghisolfi, Annema, van Binsbergen, & Tavasszy (2023), *A system dynamics model for analysing modal shift policies towards decarbonization in freight transportation*, https://doi.org/10.1016/j.rtbm.2023.100966

The presence of bottlenecks also points to the lack of scarcity pricing in rail. Scarcity pricing makes sure the most valuable (fast) freight is given priority at peak times. Extension of capacity can only be justified in the presence of scarcity pricing.

4.3 Success of modal shift policy

The previous sections highlight the relatively low performance of the European policies to promote modal shift. This is consistent with broader trends reported across the EU, where **rail's modal share has remained stable or even declined despite ongoing investment**. Recent statistics show that road transport continues to gain ground due to its reliability (even with growing congestion), availability, and competitive cost structure[38]. But, in the absence of a good counterfactual, it is possible that the policies have prevented a modal backshift from rail to road[39].

Traffic management and coordination will be crucial for rail to be successful. Maximising the potential of new technologies for train tracking (5G, satellite, IoT…) can make capacity allocation more dynamic. The time gaps requested for the different trains (for safety reasons) to come on similar paths are so high that they inevitably strongly reduce capacity. These technologies will also give more information to the shippers about ETAs, which will help improve the reliability and resilience of supply chains. In fact, a solution for intermodal transport may be to move slightly away from just-in-time solutions by building flexibility in the supply chain, such that longer lead times are doable if they are accompanied by better reliability.

Moreover**, capacity allocation decisions should be made by independent infrastructure managers with an international perspective** – national guidelines will too often favour local (passenger) trains, prioritising local voters over (transit) freight that present few benefits to the local economy. Related research indicates that the lack of cross-border network coordination (e.g.: train numbering that changes when crossing a border) significantly undermines capacity efficiency. Efforts to digitalise rail operations and integrate international governance frameworks have shown promise but remain fragmented[40].

As suggested by some interviewed experts, a way to move forward could be to finance less infrastructure and act more at the service level of rail, going for improvements for specific flows. Infrastructure is part of the solution, but how it is used is also very important. At present, network management is very poor at the European level compared to, e.g., aviation or electricity networks. Therefore, infrastructure managers should be incentivized to improve the management function.

As pointed out by some experts, an existing paradox is that a very successful modal shift may not be desirable. Indeed, if a significant portion of road cargo shifts to rail, the rail network will not be able to absorb such a shift. Therefore, the shift has to happen in micro-doses, focusing on corridors/connections that have the best chance of generating actual modal shift. This aligns with proposals from recent studies to adopt regionally tailored policies and incentive schemes that reflect

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[38] European Union Agency for Railways (2024), *Modal shift analysis for the 2024 ERA Compelling Vision: Final report*, https://www.era.europa.eu/system/files/2024-05/ERA_modal_shift_report_20240502.pdf

[39] Takman & Gonzalez-Aregall (2023), *Public policy instruments to promote freight modal shift in Europe: evidence from evaluations*, https://doi.org/10.1080/01441647.2023.2279219

[40] European Union Agency for Railways (2024), *Modal shift analysis for the 2024 ERA Compelling Vision: Final report*, https://www.era.europa.eu/system/files/2024-05/ERA_modal_shift_report_20240502.pdf

corridor-specific freight dynamics. **Rather than pan-European strategies, more targeted approaches offer greater potential to generate meaningful modal shift**[41]. This could be achieved by clustering volumes and target intermodal solutions around those volumes, or by connecting companies that are big traffic generators directly to the rail network.

Finally, a conceptual consideration: do we need to pursue a (top down) modal shift target? Should proper pricing, including the different external costs, not be the main guide for the shippers of freight? This view is increasingly echoed in the academic literature. A growing number of authors argue that the **internalisation of external costs (e.g. emissions, congestion, accidents) through accurate pricing mechanisms can offer a more efficient and market-driven pathway to decarbonisation** and balanced modal use than rigid top-down modal targets[42].

5 Lessons for modal shift rationale

5.1 Competition between road and rail

Besides the cost aspects highlighted above, **other mode choice factors** are highlighted by various studies and play a role in making one mode more competitive towards the other. The report from the International Transport Forum[43] highlights how non-cost-related aspects, such as **logistical reliability, ease of handling, and IT integration**, increasingly influence mode selection in competitive supply chains. The report also underscores the potential of digitalization and automation as emerging game-changers in freight transport. These technologies can improve service predictability, reduce transaction costs, and modify the competition dynamics between transport modes. This idea was confirmed in the interviews. An important **competitive disadvantage for rail is the heterogeneity in the level of digitalisation** with many digitalisation gaps. Compared with the road market's mature and continuously improving digital platforms, intermodal services have fewer integrated tools for pricing, tracking, and booking across borders and operators. Better transparency and data exchange are seen as necessary to reduce perceived risk and improve service reliability for shippers.

However, forthcoming technological change in the future in road transport is expected to affect competitive dynamics. **Electric trucks will significantly reduce operating costs and environmental externalities, and driver-assistance** (and, later, motorway-only automation) could enable 24/7 operations with less manpower, further improving road's cost and service position. Some caution that this trajectory could erode rail's environmental advantage and widen road's operational lead unless rail simultaneously upgrades traffic management (e.g., moving-block concepts), expands capacity on freight-relevant corridors, and digitises processes to close the reliability gap. Others add that Europe's power system may face medium-term bottlenecks as

[41] Simonelli, Sterle, Masone, Tocchi, Tinessa, Mancuso, Papola, & Marzano (2024), *New freight transport incentive to achieve modal shift targets: Methodology and application to Italy*, https://doi.org/10.1016/j.trip.2024.101166

[42] Sallnas, Rogerson, & Santen (2022), *Trusting the power: Facilitating a modal shift in relationships between shippers and logistics service providers*, https://doi.org/10.1016/j.rtbm.2022.100864

[43] ITF (2022), *Mode Choice in Freight Transport*, https://www.itf-oecd.org/sites/default/files/docs/mode-choice-freight-transport.pdf

multiple sectors electrify, which could make rail's inherent energy efficiency relatively more valuable in constrained periods on e-charge loading infrastructure.

These interacting trends make digitalisation, capacity management reform, and corridor-level investment decisive for rail's future competitiveness. **Rail will have a structural advantage over e-trucks because they are more energy-efficient and require less manpower than road**. Energy efficiency is the result of steel-on-steel traction reducing rolling resistance and energy consumption for a given tonnage. Yet road's door-to-door flexibility and just-in-time responsiveness weigh heavily in shippers' modal choice decisions, and lead to a dominant position in many markets. **There is a trade-off between efficiency versus flexibility**: rail can be very efficient on "thick" long-haul corridors, whereas road remains superior for direct, time-sensitive delivery and dispersed origins or destinations. However, regarding elasticity and flexibility, **road adapts much faster to fluctuating demand**. Trucking companies can expand or shrink capacity in weeks, while intermodal services take months or years to organize. This lag makes rail less attractive when demand is volatile.

Another aspect in this competition is reliability and predictability. Rail freight routinely loses priority to passenger services during planning and operations, which makes freight timetables less reliable and undermines shipper confidence. This is linked to **structural capacity scarcity** on key European lines and the political preference for passenger trains. The reliability issue is compounded by **slow cross-border path coordination**. By ad-hoc disruptions, works, or detours delivery time increases, and supply chains are destabilised. This contrast with the U.S., where extensive freight-dedicated lines avoid direct competition with high-speed passenger services. These operational disadvantages in Europe tilt shipper choice towards road when reliability is paramount. Rail's competitive potential is highest where freight can move on corridors with fewer passenger conflicts and where terminal capacity and last-mile access are adequate. Access is key and depends for rail on intermodal terminals. Where terminal networks are sparse or poorly located, intermodal routings become circuitous, handling increases, and the end-to-end value proposition weakens relative to direct trucking. In some segments, rail competes more directly with inland waterways than with road. Regarding reliability, climate impacts (low water levels) make inland waterways less reliable, which increases the need for strong rail capacity.

Shipper behaviour and contracting practices also shape competition. Representatives of shippers explain that **many purchasing departments still buy primarily on price, which tends to favour road in the absence of very reliable rail products**. At the same time, front-runner shippers do value "green" transport as a brand attribute and are willing to support longer-term contracts that underwrite the capital required for low-emission or intermodal solutions. Modest increases in planned lead times can be acceptable if reliability is high and information is transparent.

Finally, **the "contestable share" of freight is emphasized as much smaller than the total market**. Only a limited fraction of tonnes is genuinely contestable between road and rail when accounting for distance, commodity characteristics, and service requirements, which means that policy and investment should be carefully targeted. Rail and road are not truly in direct competition, since capacity in both modes is already too limited. In rail, the scarcity of slots allows operators to charge relatively higher prices, sustained by strong demand. By contrast, road haulage is characterised by intense competition among trucking companies, which keeps prices under pressure and margins low. **With respect to capacity, both modes are vital**.

5.2 External cost coverage

There is broad agreement that **neither rail or road fully cover all external and infrastructure costs under today's charging and taxation systems, though the mix of covered and uncovered components differs by mode and is evolving with technology**. For road, fuel excises and distance-based tolls internalise part of infrastructure wear and carbon emissions, but large externalities remain only partially priced, particularly congestion crashes, and noise - though the latest amendment of the Eurovignette Directive[44] opens the possibility of congestion charging and noise internalisation. As **trucks decarbonise** and as fleet standards tighten, the **climate component of road's external costs will shrink significantly**, shifting the emphasis to those other externalities. The noise generated by e-trucks is considerably lower than that of ICE vehicles. They also point out that existing fuel taxes already function as an implicit carbon charge and that duplication through overlapping carbon instruments must be avoided to prevent excessive burdening.

For **rail, infrastructure access charges typically cover variable maintenance costs but often exclude scarcity costs** arising from capacity conflicts with passenger services, even though those conflicts impose real socio-economic costs through delays and unreliability. One interviewee argued that many so-called "external costs" (like rail subsidies or capacity scarcity) are better described as social costs rather than true externalities, since they result from policy choices and planned state investments. In many countries, governments have reduced or waived freight access charges to promote modal shift, and some have compensated infrastructure managers through state aid. This practice can enhance rail's competitiveness but means **rail, too, does not consistently face the full price of the capacity it consumes**. Experts differ on the desirability of such subsidies: some view them as justified by wider policy goals, while others warn that they can distort incentives for infrastructure managers and do not substitute for structural capacity solutions.

Several interviewees recommend **broadening cost assessments to reflect full life-cycle effects**. They urge comparing road and rail not only on fuel and tailpipe emissions, but also on the environmental impacts of manufacturing vehicles and rolling stock, constructing and maintaining infrastructure, and generating electricity or hydrogen. Zero-emission trucks carry heavy batteries, reducing payload. This may increase the number of trucks needed for the same tonnage, which could worsen congestion and infrastructure wear unless regulations adapt weight/size limits. Electrification will cut CO_2 externalities, but congestion and infrastructure costs may rise if fleet size increases due to payload penalties. Stakeholders add that the growing importance of noise as a health externality should be reflected in pricing and standards for both modes. In the near term, they caution that the current patchwork of rules across Member States results in uneven internalisation and can bias competition. Some experts stressed caution against double-counting CO_2 costs (e.g. overlap between fuel taxes, ETS, and road charges). Clarity is needed to avoid overburdening road transport.

Against that background, **the statement that "road transport does not cover its full infrastructure and external costs" remains broadly valid in the interviews, but so does the observation that other modes, including rail, also do not consistently cover all relevant externalities or scarcity costs under current regimes**. Interviewees therefore see a strong case for

[44] Directive (EU) 2022/362 of the European Parliament and of the Council of 24 February 2022

improving the design and scope of user-pays instruments across modes, with attention to congestion and capacity scarcity on both networks.

5.3 Conclusions on modal shift policy

From a supply chain perspective, modal shift is just one of the many measures for energy saving and decarbonisation within the transport and logistics sector and represents a small part of the full reduction potential[45],[46] - **modal shift is not an objective by itself**. The environmental effects of modal shift depend on a trade-off between emission gains versus increased distances compared to direct road transport[47]. Moreover, modal shift objectives are set assuming a relative environmental performance between transport modes, which is not static as road freight is decarbonizing at an increasing rate (also facilitated by the faster turnover of the fleet as compared to other modes)[48]. Many experts agree that **modal shift policy rationale regarding the green deal objectives should be reassessed** considering a new era of electrification, digitalisation, automation, and artificial intelligence that can play transformative roles, enabling smarter, more adaptive transport systems. This is also suggested in the ITF Transport Outlook[49].

Regarding the modal shift policy outcome, and despite decades of targets, subsidies, and infrastructure programmes, **rail's overall share has not increased meaningfully**, and in some markets, road has continued to gain share. Experts attribute this to several structural issues: persistent **capacity scarcity** on mixed-use lines; systematic **passenger priority** in both planning and real-time dispatch; **slow cross-border coordination**; **under-investment or mis-alignment of investments with freight needs**; and **insufficient density and performance of intermodal terminals**. These factors have limited rail's reliability and, by extension, its attractiveness to shippers who prize predictability. A focus on targeted rail corridors throughout Europe with clear freight value, on digital and operational measures that increase usable capacity (for example, moving-block signalling, better cross-border coordination, and more dynamic capacity management), and on a denser, better-sited terminal network can make rail more attractive[50].

Interviewees criticized that EU and national investments often focus on large infrastructure projects or high-speed passenger lines, while freight-relevant bottlenecks (cross-border gaps, junctions, terminals) remain underfunded. Several experts stressed **that policy has been**

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[45] Tavasszy, van Meijeren (2011), *Modal Shift Target for Freight Transport Above 300km: An Assessment*, https://acea.auto/uploads/publications/SAG_17.pdf

[46] Pinchasik, Hovi, Mjøsund, Grønland, Fridell, & Jerksjö (2020), Crossing Borders and Expanding Modal Shift Measures: Effects on Mode Choice and Emissions from Freight Transport in the Nordics, https://doi.org/10.3390/su12030894

[47] Ibidem

[48] Björk, Vierth, & Cullinane (2023), Freight modal shift: A means or an objective in achieving lower emission targets? The case of Sweden, https://doi.org/10.1016/j.tranpol.2023.08.013

[49] ITF (2023), *ITF Transport Outlook 2023*, https://www.oecd.org/en/publications/itf-transport-outlook-2023_b6cc9ad5-en/full-report.html

[50] Langenus, M., Dooms, M., Haezendonck, E., Notteboom, T., & Verbeke, A. (2022). Modal shift ambitions of large North European ports: A contract-theory perspective on the role of port managing bodies. *Maritime Transport Research, 3*, 100049

infrastructure-driven instead of demand-driven. More pragmatic, shipper-focused programs (e.g. clustering flows, supporting private terminals, targeted intermodal pilots) could yield more impact. Beyond new infrastructure, better use of existing networks is possible via AI-assisted traffic management, automation, and reducing long nightly maintenance slots. This could release capacity for freight without massive new builds. Success varies across countries. Switzerland and Austria prioritize rail due to environmental protection in sensitive Alpine regions; Germany historically privileged its car industry, which weakened freight rail policy. Political will and societal narratives shape modal shift success.

From an environmental-efficiency perspective, interviewees note that **as trucks decarbonise, rail's carbon advantage narrows**. Externalities, such as congestion, safety, and noise become relatively more important in deciding where modal shift delivers the greatest social benefit, and there as well, electrification and automation in road transport are closing the gap. Some experts stress that internalising congestion on roads and pricing scarcity on rail would help allocate limited capacity to its highest-value uses, improving the cost-effectiveness of any shift. Others caution that Europe's electricity supply may be a binding constraint during the transition to electrified transport and industry, which, if it materialises, would heighten the system value of energy-efficient modes like rail on appropriate corridors. While rail and road are both essential to meet Europe's freight transport needs, they do not necessarily compete as long-haul, high-volume, and predictable flows may be more suitable for rail, whereas road retains advantages in flexibility, responsiveness, and short-distance or time-sensitive deliveries. Recognising this is key to designing effective modal shift policies that reflect the strengths and limitations of each mode. Time dynamics matter for policy efficiency, and modal shift is typically slow to materialise; policy measures can lose effectiveness over time as actors adapt, and packages combining early, stricter measures with reallocation of infrastructure investments accelerate the shift. **Modal shift alone will be insufficient to achieve CO_2 reduction goals; complementary technological decarbonisation of road and operational improvements in non-road modes are very much needed**[51].

The more promising path is to couple **improved, mode-neutral pricing of externalities** with **sharply targeted rail and intermodal investments and operational reforms** on specific corridors where rail's service proposition can be made reliable. In parallel, **policy support for the electrification and gradual automation of road freight** will change the comparative calculus and deliver durable emission reductions per euro spent instead of spending tax money on blanket modal share targets.

51 Nassar, R. F., Ghisolfi, V., Annema, J. A., van Binsbergen, A., & Tavasszy, L. A. (2023). A system dynamics model for analysing modal shift policies towards decarbonization in freight transportation. Research in Transportation Business & Management, 48, 100966. https://doi.org/10.1016/j.rtbm.2023.100966

6 Appendixes

6.1 Appendix 1: Sources Reviewed in the Literature Study

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