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## Emission Saving Potentials of Freight Transportation in Europe: Shifting Road to Rail Transport?

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### Abstract

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This paper aims at investigating the savings potential of increasing the share of rail transport in the European freight transport sector regarding greenhouse gas emissions. This paper sets itself apart by using the realized modal shift instead of the potential as the starting point for calculating the associated potential reductions in GHG emissions. The expected emission reductions associated with shifting long-distance freight transport from road to rail until 2030, as considered in this paper, are estimated using the modal shift of EU-member states with the base year 2017 and national growth rates of rail share from 2005 to 2017. The expected emission reductions are relatively small compared to the total emissions of the growing freight transport sector although (very) ambitious scenarios were assumed. To achieve a substantial reduction in greenhouse gas emissions, transport initiatives must be complemented by a reduction in the specific emissions of the respective modes of transportation. The paper closes with a short outlook for the development of the transportation sector.

### Keywords:

Freight transport, Modal shift, Greenhouse gas emissions, Emission reduction

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## 1 Introduction

You can't make a silk purse out of sow's ear – Or you can't make all solutions out of rail transport.

The freight transport sector accounts for almost a quarter of Europe's greenhouse gas emissions (GHG). Within this sector, road transport is the largest emitter, making up approximately 70% of the sector's total GHG emissions (European Commission, 2016, 2014). This paper's objective is to quantify and simulate the savings potential in terms of GHG emissions of shifting shares of road freight transport to rail (and combined) transport.

The literature on the subject of transport-related externalities and emission reduction in general is broad in content and continuously expanding. For example, Demir et al. (2015) deal with the quantitative assessment of negative externalities from freight transportation and investigates different pricing studies to internalize these (social) costs. Others simply

discuss the individual performance, advantages, and disadvantages of different transportation modes or their competition in the freight sector (Reis et al., 2013; Resor et al., 2004). In contrast to previous literature, however, this paper uses the EU-related shift potential of freight traffic from road to rail transport as the starting point for calculating the associated potential reductions in GHG emissions from the freight transport sector.

The European White Paper on transport states – this statement from 2011 is still valid – that freight transport by truck will dominate over short and medium distances (below 300 km) (European Commission, 2011). This prediction of the European White Paper is reinforced by looking at more recent data on the modal split in the EU, showing that the share of road transportation in the total inland freight transport is slowly – but constantly – growing since 2012 and reached a new high at 76.3% in 2019 (based on tonne-

kilometres performed) (Eurostat, 2021). Additionally, another report states that the volume growth in the European land freight transport market expected by 2030 will most likely have a high affinity to road transport (Rail Freight Forward, 2018). One strategy to reduce GHG emissions is to shift long-distance road freight (over 300 kilometres) to transport modes with lower CO<sub>2</sub>-emissions.

The article consists of four main sections. After the introduction, Section 2 briefly discusses the various modes of transport in terms of logistical, financial, and environmental challenges; and makes a political classification in the EU-context. In the third section, the paper presents different scenarios for the future development of the emissions of freight transportation and provides quantitative data on the emission savings potential of truck transportation in the EU27 until 2030. The last section concludes the article.

## **2 EU-Policy strategy and facts on freight transport mode choice**

### **2.1 EU-Policy strategy on transportation**

In its strategy for low-emission mobility, the European Commission demands a reduction in GHG emissions from transport by at least 60 % by mid-century compared to 1990 (European Commission, 2016, 2014). Accordingly, the European Green Deal, among others, seeks to realize cleaner private (and public) transport and accelerate the decarbonisation of energy-intensive sectors (European Commission, 2020; Wyns and Khandekar, 2019). Aiginger and Schratzenstaller (2016) propose seven game changing policy drivers for the decarbonization of the EU, with the fifth being support for new, efficient technologies to decouple energy and material inputs from output and output growth. As stated by the authors of the European White Paper and confirmed by recent data, freight transport in Europe is dominated by truck transportation until today, although there is a growing demand for greater integration of different modes of transport, such as rail or waterborne transport (European Commission, 2011; Eurostat, 2021; Eurostat, 2018).

In the future, both low economic and environmental costs will be crucial for actors in the freight transportation sector to remain competitive and succeed on the market in the long term, drawing growing attention and importance to the concept of intermodal freight transportation and the reduction of road freight transport. Mathisen and Hanssen (2014) found that the academic interest in the form of published articles dealing with intermodal freight transport grew from 2000 onwards presumably to a large extent due to a stronger political focus on intermodal transport as a promising concept to reduce external costs of freight truck transport. In this context, Islam et al.

(2016) added the influence of the European White papers on competitive prices of combined freight transport, heavier and longer trains, wider loading gauges, higher speeds, and better utilization of wagon spaces as further explanations for the recent strengthening of intermodal transport.

The political ambitions also have an increasing macroeconomic dimension. While minimizing firm-level (i.e., internal) costs has always been a common corporate practice and target, the issue of reducing negative (environmental) externalities from using certain freight transport modes has gained attention only in the last decades.

### **2.2 The logistical, financial and environmental dimensions of freight transport modes**

The determination of the most cost-effective transport mode for a certain good depends on three concerns: logistical, financial, and environmental. In this section, we shortly analyse the strengths and weaknesses of the individual modes of transport regarding each of these concerns. The observed modes of freight transport are road, rail, and inland waterway transportation. The unit of measure is usually in (metric) tonne-kilometres (transportation of one ton of good over one kilometre) or absolute volume (tonnes), values (Euro) or number of containers transported in shares of transport modes (Eurostat, 2019). In 2017, road transportation was still the dominant freight transport mode (77%) within the EU, followed by railway (17%), and waterways (6%). Just a few countries have road shares below 50%. These are Latvia (74% rail), Lithuania (67% rail), Romania (30% rail, 27% inland waterways), and the Netherlands (6% rail, 45% inland waterways) (Eurostat, 2020).

From a logistical perspective, transportation on road has three main advantages (Reis et al., 2013). Firstly, carriers can reach almost every node in Europe directly. Secondly, the high compatibility of European road systems allows an actor to use the same type of freight truck on almost every road on the European continent. And third, on medium and short distances of up to 300 km (Carboni and Dalla Chiara, 2018), goods cannot be transported faster by any other mode of transport. However, road freight transport also faces significant limitations, with the most important one being the capacity limits of motorways.

Contrary to the road system used by trucks, railroads do not always have universal specifications (track gauge, etc.) and regulations (traffic control systems, etc.), even within the European Union. For example, cross-border rail freight transport is often hampered by varying rail gauges (e. g. Spain; Puffert, 2002). Other differences between truck and rail

freight traffic include the presence of mixed traffic especially for rail freight transport (i.e., a high reliance on night trips due to the exploitation of the (same) rail network by passenger trains during the day in many countries) and a wide speed range of freight trains (with averages of 45 km/h up to 230 km/h) across European countries (Teuber et al., 2015; UIC, 2020; UN/ECE, 2001).

Compared to inland vessels, trucks using the road networks (e.g., highways, main roads) have higher velocities. Further restrictions on inland shipping include the lack of year-round navigable waterways, such as the Elbe and Oder rivers, and passage restrictions due to bridge heights (Teuber et al., 2015).

In their quantitative analyses regarding the internal costs of freight transportation, Black et al. (2003), Kim et al. (2011), and Carboni and Dalla Chiara (2018) estimate the price of freight transportation by truck at 0.58–1.37 euros per kilometre, referring to the transport of a 40-foot container (ITU 40') and assuming a vehicle utilization rate of 0.85. With regard to rail freight transport, the estimated transport costs per kilometre are between 0.46 and 1.35 euros. However, additional costs are incurred due to the transshipment process in the terminals, amounting to 27 euros and 36–60 euros per rail-rail and rail-road transfer of an ITU (40'), respectively (Black et al., 2003; Kim et al., 2011; Carboni and Dalla Chiara, 2018; European Commission, 2002). In addition, due to the mandatory handling of goods at terminals for rail and water transportation, organizational and management costs are lower for road transportation than for both rail and inland waterway transport (Reis et al., 2013).

Besides private (financial) costs, which are referred to as internal costs, main challenges arise from the impact of transportation activities on the environment. Environmental effects can be regarded as externalities as they are usually not considered by profit-focused firms in their price setting unless they have already been internalized, for example, through regulatory measures. In the case of freight transport, the negative externalities show up in the form of air, water and noise pollution, congestion, accidents, and land use. In what follows, we focus on CO<sub>2</sub> emissions as a particular severe type of long-term externality.

### 3 Freight transportation in the EU and future scenarios

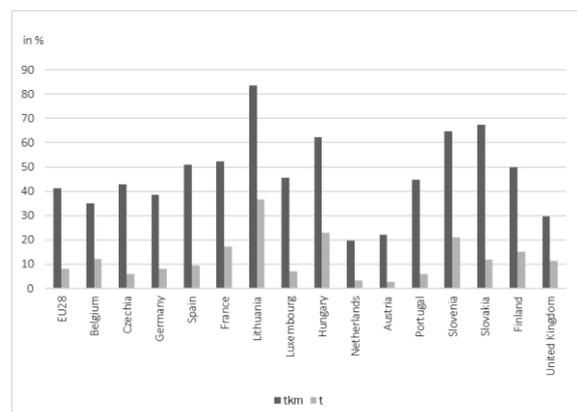
Although the European White Paper (2011) on transport states that freight transport by truck will still dominate over short and medium distances (roughly, below 300 km), which can be confirmed by recent data on the modal split (Eurostat, 2021), it also states that 30 % and more than 50 % of road freight over 300 km shall be shifted to other modes of transport, such

as rail or waterborne transport, by 2030 and 2050, respectively. This goal is still relevant for the conversion of freight traffic. Against this background, the authors analyse whether and how combining the individual advantages of different transport modes (i.e., intermodal, or combined transport) can develop into a new best fit model for the transportation of freight.

#### 3.1 The 'modal shift potential'

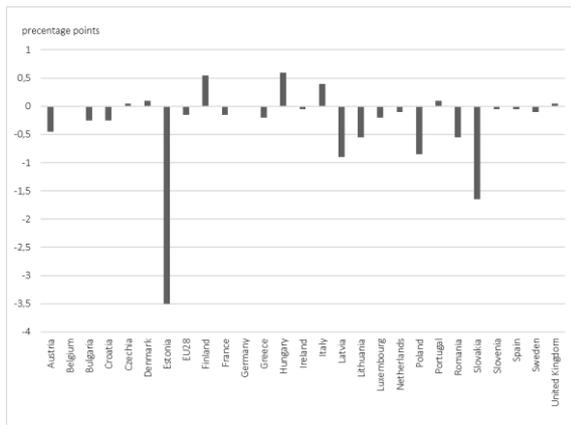
The 'modal shift potential', as an indicator of Eurostat (tran\_im\_mosp), provides information on the share of freight containers transported by road over long distances (300 kilometres or more) in the total number of containers transported in road freight transport. These containers could theoretically be shifted to rail or inland waterways, thus contributing to the reduction of CO<sub>2</sub> emissions from the transport sector. Note that these numbers do not take into account general changes in the total transport volumes and solely refer to the emission reduction potential associated with a modal shift from road to rail. *Ceteris paribus*, this means that all other (technological) factors – such as drive technology, units – remain constant.

In the EU28, the share of such long-distance container transport by road was 41.2% in 2017 when measured in terms of the transport performance (tonne-kilometres). When measured in terms of volumes (tonnes), the share is much lower (8.2%). Since, by definition, the performance is the product of volume and distance, the large discrepancy between the two indicators can only mean that the average container is transported over relatively short distances. The less frequent long-distance transports over 300 km or more, however, contribute more to the transport performance (measured in tkm) (Figure 1).



**Figure 1:** Modal shift potential of long-distance road freight in containers (t, tkm), 2017, Source: Eurostat (2020), HWWI

The modal shift potential as provided by Eurostat does not consider whether the long-distance road freight can actually be shifted to rail. No information on the railway network is reflected in the indicator. Therefore, to obtain more realistic scenarios for the future development, the “realized” modal shift is analysed instead. It is computed from the observed increase of rail in the modal split of freight transport in each country. Figure 2 shows the median increase in the share of rail freight transport between 2005 and 2017. Most countries did not manage to increase the share of rail freight during the observed period.



**Figure 2:** Observed share of rail in modal split (2006-2017), Source: Eurostat (2020), HWWI

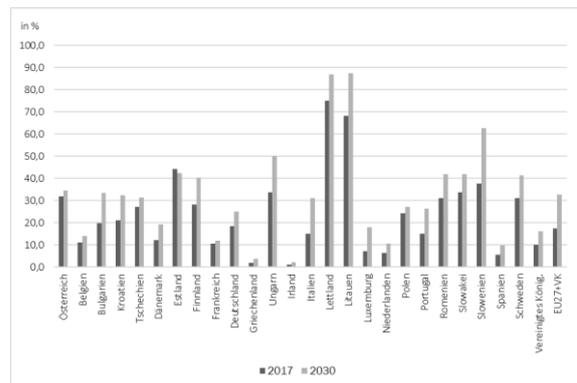
### 3.2 Carbon dioxide scenarios

Given the recently growing public awareness and concern about adverse environmental developments, it can be expected that countries will be increasingly pressured and more ambitious to reduce the share of road freight transportation in the future than they have been in the past. However, realistic scenarios should still be based on the observed development in the past. The median shown in Figure 2 corresponds to the 50%-quantile which means that, in roughly half of the considered years, the respective country achieved at least the displayed increase in the rail share. It seems natural to consider higher quantiles (which are larger) to construct optimistic scenarios for the future growth rates of the rail share.

Therefore, with regard to the ambitious modal shift scenario described in this paper, a constant annual increase in the rail freight share corresponding to the 75%-quantile of the observed median annual change in the EU-28 countries looked at in Figure 2 between 2005 and 2017 is considered. The very ambitious modal shift scenario is calculated under the assumption of an even higher annual increase equal to the 90%-quantile. This means that countries are assumed to achieve an increase in the rail share every

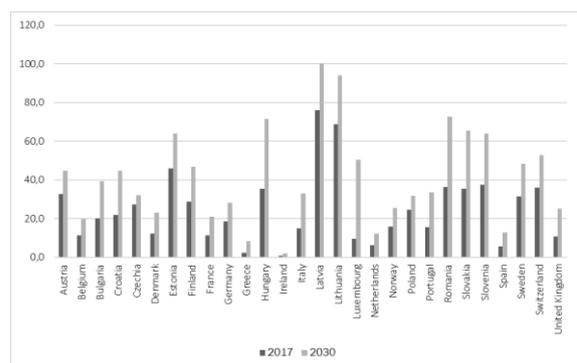
year which they have only achieved very rarely in the past.

For both scenarios, it is assumed that the modal share of inland waterway transport remains constant at the 2017 level and that the increase in the modal share of rail corresponds to the (relative) reduction in the share of road freight transport. The rail share in the base year 2017 together with the calculated potential rail shares in 2030 according to the ambitious and very ambitious scenarios are presented in Figure 3 and 4, respectively.



**Figure 3:** Increase of rail share in freight transport (ambitious modal shift scenario), Source: Eurostat (2020), HWWI

With respect to all countries considered, the rail share would increase on average from 23.3% in 2017 to 32.6% under the ambitious scenario and to 41.7% under the very ambitious scenario. In the following, the objective is to assess what these modal shift scenarios imply for the reduction of GHG emissions from freight transport in the EU.



**Figure 4:** Increase of rail share in freight transport (ambitious modal shift scenario), Source: Eurostat (2020), HWWI

To evaluate the GHG emissions from freight transportation in the EU, we employ recent emission values of the individual modes of transportation calculated for Germany: road 103 CO<sub>2</sub> emissions/tkm, rail 19 CO<sub>2</sub> emissions/tkm, and inland waterways 32 CO<sub>2</sub>

emissions/tkm (German Environmental Agency, 2018). First, the CO<sub>2</sub> emission saving potential is calculated based on the officially published modal shift potential (see Table 1) and the difference in the individual emission values between road and rail. The resulting volume of emission savings can then be multiplied by a conservative estimate of the social cost of carbon (SCC) (40 euros/t) to quantify the macroeconomic benefits of the estimated emission reduction associated with such a modal shift. The 151.3 million euros indicated in Table 1 constitute a lower bound for the benefits of reducing CO<sub>2</sub> emissions according to the modal shift potential in all EU28 countries.

	million tkm	CO <sub>2</sub> e (tonnes)	Emission cost saving potential (million euros)
<b>EU-28</b>	45,041	3,783,444	151.3
<b>Belgium</b>	1,360	114,240	4.6
<b>Czechia</b>	1,316	110,544	4.4
<b>Germany</b>	15,989	1,343,076	53.7
<b>Spain</b>	4,594	385,896	15.4
<b>France</b>	3,108	261,072	10.4
<b>Lithuania</b>	1,057	88,788	3.6
<b>Luxembourg</b>	282	23,688	0.9
<b>Hungary</b>	481	40,404	1.6
<b>Netherlands</b>	1,636	137,424	5.5
<b>Austria</b>	182	15,288	0.6
<b>Portugal</b>	3,504	294,336	11.8
<b>Slovenia</b>	518	43,512	1.7
<b>Slovakia</b>	848	71,232	2.8
<b>Finland</b>	834	70,056	2.8
<b>United Kingdom</b>	2,443	205,212	8.2

**Tab. 1:** Modal shift potential, emission saving potential and social cost saving potential, 2017, Source: Eurostat (2020); German Environmental Agency (2018).

If the modal shift potential (according to the Eurostat indicator) is fully exploited, the total emissions from the transport sector would be reduced by less than 1%, taking into consideration that the total annual emissions from the transport sector in the EU amount to more than 1 billion tons and the emissions saving potential is around 3.8 million tons.

Furthermore, as argued previously, the modal shift potential does not consider enough information to determine realistic future development trajectories for the modal shift. Therefore, in the following, we consider the emission savings potential referring to the empirically constructed “ambitious” and “very ambitious” modal shift scenarios. We calculate transport-emissions indices for each EU28 country based on the modal split in 2017 and the mode-specific emission values (Table 2, column 1). This results in an emission value per tkm which is a weighted average of the three mode-specific values. The weights correspond to the respective share in the modal split. For easy comparisons between countries and over time, the index is scaled in a way that the modal split

of the EU28 in 2017 corresponds to an emission index of 100. Countries with a lower index value have a less emission-intensive modal split than on average, i.e., an above average rail or inland waterway share. The “ambitious” and “very ambitious” modal shift scenarios can also be expressed using the emission index. Regarding the EU28, the ambitious and very ambitious modal shift scenarios correspond to a decrease of GHG emissions from the transport sector of 3.2% and 6.5% by 2030, respectively.

	2017	ambitious 2030	very ambitious 2030
<b>EU28</b>	100.0	96.8	93.5
<b>Austria</b>	88.2	85.6	75.3
<b>Belgium</b>	98.5	95.3	89.4
<b>Bulgaria</b>	82.9	68.0	62.1
<b>Croatia</b>	97.0	84.6	72.3
<b>Czechia</b>	95.5	91.0	90.3
<b>Denmark</b>	110.9	103.1	99.2
<b>Estonia</b>	78.0	80.0	58.6
<b>Finland</b>	94.8	81.9	75.4
<b>France</b>	109.9	108.6	99.5
<b>Germany</b>	97.1	90.0	86.8
<b>Greece</b>	120.5	118.6	114.0
<b>Hungary</b>	85.9	68.4	47.0
<b>Ireland</b>	121.4	120.1	120.1
<b>Italy</b>	108.8	91.3	89.3
<b>Latvia</b>	48.5	35.5	22.6
<b>Lithuania</b>	55.8	35.0	28.6
<b>Luxembourg</b>	111.2	99.5	67.1
<b>Netherlands</b>	78.7	74.2	72.3
<b>Poland</b>	98.4	95.2	90.6
<b>Portugal</b>	108.3	95.9	88.8
<b>Romania</b>	69.1	57.4	26.8
<b>Slovakia</b>	86.5	77.4	54.0
<b>Slovenia</b>	86.9	59.7	58.4
<b>Spain</b>	117.2	112.7	109.5
<b>Sweden</b>	92.2	81.2	74.0
<b>United Kingdom</b>	112.8	106.3	97.2

**Tab. 2:** Indices of GHG emissions from transport sector (scenarios), Source: Eurostat (2020); German Environmental Agency (2018).

#### 4 Conclusion

A modal shift in freight transportation in the EU28 is not able to decrease total GHG emissions of the transport sector significantly. Even under the very ambitious modal shift scenario and assumed constant total freight volumes, the emissions of the freight transport sector would only be reduced by 6.5% in 2030 compared to 2017. Even though the emission reduction effects with respect to the considered modal shift scenarios are rather limited, it should be borne in mind that rail freight transport also has a positive impact on other transport-related externalities such as land use, congestion, and noise pollution. The investigation of other beneficial effects of rail transport and potential reductions in social costs associated with other transport externalities could be subject of future research.

Due to the low emission saving potentials linked to the considered modal shift scenarios, we conclude

that additional measures must be taken to significantly improve the transport sectors' carbon footprint. Since a decrease in transport volume seems unlikely in the future, the remaining option for action would be to reduce the emission values of the individual modes of transport. This, however, requires the implementation of additional policies aimed at internalizing the social costs of transport sector emissions. In its recent "Fit for 55" regulatory package, the European Commission proposes an array of such measures, including market-based instruments (integration of the shipping sector in EU emissions trading, own trading scheme for emissions from road traffic), harmonization of minimum energy tax rates and promotion of the roll-out of a filling station infrastructure for low-carbon fuels (Alternative Fuel Infrastructure Regulation). Investigating the climate efficiency of these measures from the perspective of freight transport will constitute an important avenue for future research.

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