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Combined transport in Europe: Scenario-based projections of emission saving potentials

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Hamburg Institute of International Economics

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Contact:
Dr. Malte Jahn
Hamburg Institute of International Economics (HWWI)
Oberhafenstraße 1 | 20097 Hamburg | Germany
Phone: +49 (0)40 340576-351 | Fax: +49 (0)40 340576-150
jahn@hwwi.org

Dr. Jan Wedemeier
Hamburg Institute of International Economics (HWWI)
Fahrenheitstr. 1 | 28359 Bremen | Germany
Phone: +49 (0)421 2208-243 | Fax: +49 (0)40 340576-150
wedemeier@hwwi.org

HWWI Research Paper
Hamburg Institute of International Economics (HWWI)
Oberhafenstr. 1 | 20097 Hamburg, Germany
Telephone: +49 (0)40 340576-0 | Fax: +49 (0)40 340576-150
info@hwwi.org | www.hwwi.org
ISSN 1861-504X

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Combined Transport in Europe: Scenario-based Projections of Emission Saving Potentials

Malte Jahn, Paul Schumacher, Jan Wedemeier,
André Wolf

Study of the Hamburg Institute of International Economics (HWWI) within the framework of COMBINE and the EU Baltic Sea Region Programme (2014-2020)

COMBINE -Strengthening Combined Transport in the Baltic Sea Region
is co-founded by The Baltic Sea Region Programme 2014-2020
Priority Transport, 3.1. Interoperability, EUSBSR flagship
https://projects.interreg-baltic.eu/projects/combine-190.html

COMBINE

Interreg Baltic Sea Region

EUROPEAN UNION

EUROPEAN REGIONAL DEVELOPMENT FUND

EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP

Combined Transport in Europe:
Scenario-based Projections of Emission Saving Potentials

Malte Jahn, Paul Schumacher, Jan Wedemeier, André Wolf

Abstract The paper at hand discusses the different typologies of combined transportation in Europe. It shows that an improvement of handling infrastructure for combined transport can positively reduce environmental costs of trading between regions. However, the expected emission reduction effects are relatively small in comparison to the total emissions of the transport sector. This means that, in order to achieve a substantial reduction of emissions, combined transport initiatives need to be complemented by a reduction of the specific emissions of the relevant transport modes. The paper closes with an outlook towards the development of the combined transportation sector.

Key words combined transport, European Union, hinterland transportation, sustainability, regional economics, Baltic Sea Region

JEL R4, R40, R48, Q56

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1 | Introduction

The need to lower economic and environmental costs in the transportation sector challenges people to re-think the way goods are transported. A new approach to reduce these transportation-related costs is the combined freight transport which will be the focus of this paper. Whereas optimizing economic costs has always been a common approach, environmental concerns regarding the use of certain transport mode have become more relevant over the last decades.

After the financial crisis of 2008, a serious decrease in transportation volume of cargo was observed around the world and especially in Europe (Reis et al, 2012). This decrease and the associated loss in revenue confronted and still confronts different actors in logistics and transportation until today. Shippers, railroad companies and other logistic service providers were urged to lower their costs and expenditures to stay competitive on the market. At the same time, the transport sector in the EU faces increased pressure to reduce its carbon footprint. In its strategy for low-emission mobility, the EU commission demands by mid-century a reduction in Greenhouse Gas (GHG) emissions from transport by at least 60 % compared to 1990 (European Commission, 2016). A potential option to reduce both economic and environmental costs which is often overlooked is the application of combined freight transportation. In the European White Paper on transport 2011, the publishers state that freight transport in Europe is currently dominated by truck transportation, although there is a growing demand for a change to an integration of different modes of transport, such as rail or waterborne transport (European Commission, 2011).

We want to analyse the above-mentioned transition and consider their work as an explanation of the theoretical framework of combined transport. The considered modes are transportation via road, rail and inland waterway. The paper consists of four main chapters. At first, we will reflect on common definitions of combined transport applied in the European Union. In a second chapter, we will elaborate how the combination of individual modes of transportation can solve current logistical, financial, and environmental challenges under a cost projection for the European Union of 27 including negative externalities. In the third part, we will model the emissions of unimodal modes of freight transportation and will provide quantitative data about the potential savings through combined transport in the EU27 until 2030. Chapter 4 concludes with a conclusion and outlook.

The paper has been developed in the framework of the Baltic Sea Region project COMBINE (see Box 1).

Box 1

COMBINE Project description

COMBINE project, funded by the INTERREG Baltic Sea Region Programme (BSR), aims at enhancing the share of combined transport (CT) in the Baltic Sea Region to make transport more efficient and environmentally friendly.

COMBINE project follows a comprehensive approach to strengthen all parts of the transport chain: main leg, terminal handling and last mile. New technologies regarding these different parts of the transport chain as well as modern and efficient transport organization are opportunities for the Baltic Sea Region. To inhibit pure road transport, it is vital to use the benefits of each transport mode and to optimize each part of the transport chain where appropriate.

COMBINE is led by Port of Hamburg Marketing and implemented together with 14 partners from Belgium, Denmark, Germany, Finland, Lithuania, Latvia, Poland and Sweden. These partners have joined their forces to work towards a higher share of combined transport and to increase the knowledge about combined transport in the Baltic Sea Region. The project has also 14 selected associated partners from Belarus, Germany, Denmark, Finland, Latvia, Poland and Sweden supporting the project partners in their respective fields. All national ministries of transport are involved in COMBINE as partners or as associated organizations. Further, regional and local public authorities, infrastructure and public service providers, business support organizations, interest groups, enterprises and research institutes are participating. This wide range of different experiences, responsibilities and networks ensures valuable outputs that contribute to the aimed change in the Baltic Sea Region.

COMBINE will contribute to closer cooperation in the policy level, stronger support for combined transport and a stronger role of combined transport in the BSR transport system. The project's budget amounts to 3,49 M€ of which 2,72 M€ is co-financed by the BSR Programme (ERDF). The COMBINE project started in January 2019 and will run until June 2021.

2 | Definitions of freight transport modes

In this chapter, we provide an overview of possible developments of the transport chain away from unimodal transport by road and use definitions introduced by the Economic Commission for Europe of the United Nations (Economic Commission for Europe, 2001) which are also applied by the European Commission (Council Directive, 1992). Table 1 presents different freight transport modes according to three characteristics, where the considered modes of transport are i) rail, ii) road and iii) inland waterways/sea. The first characteristic is the number of modes in the transport chain. The second characteristic refers to the possibility for a mode change during the transportation. The EU legal framework does not further define the terms 'intermodal loading unit' (ILU)- or 'intermodal transport unit' (ITU) but rather identifies the types of units, such as semi-trailer, trailer, swap body, container, road vehicle. The Commission proposed a Directive on intermodal loading units in 2003 which was revoked in the end. On the following pages, we refer to a transportation of goods in a container, barrel or any other vessel. The third characteristic concerns the dominant mode of transportation in the chain.

Table 1: Characteristics of different freight transport modes.

	Number of modes of transports	Change of transportation unit	Most used transportation mode of the transport chain
Unimodal freight transport (UT)	One (predominately Road)	Possible by definition, but unusual	Varies by destination
Multimodal freight transport (MT)	More than one (predominantly Road and Rail)	Possible	Varies by destination
Intermodal freight transportation (IT)	More than one (predominantly Road and Rail)	No	Varies by destination
Combined freight transport (CT)	More than one (predominantly Road and Rail)	Possible	Non-Road

Source: UNECE (2009); HWWI.

A unimodal freight transport (UT) is the transport of goods by just one mode, most commonly road. An example would be the transportation of a good that is picked up at a factory by a truck, brought via highway to a supermarket, where it is directly sold to the final consumer. A multimodal freight transport (MT) is the transport of goods by more than one mode of transport in regular practice (Lowe, 2006; UNECE, 2009). As an example, one can think of a good that is picked up in a factory by a truck, brought to a port and loaded onto a water vessel as the second mode of transport in the chain. At the destination port, it is unloaded and sold at the harbour. During the transportation, the good may change its transport unit, e.g. from a package on a truck to a box on a water vessel.

Intermodal freight transportation (IT) describes the transportation of goods in one and the same intermodal transport unit by successive modes of transport without handling the good itself while changing modes. (UNECE p. 157, 2009). The intermodal transport unit can be a container, swap body or another vessel (Crainic & Kim, 2007). As an example, one can think of a good that is picked up in a factory by a truck, brought to a port and reloaded to a water vessel. The good is brought by the vessel to its destination. At the destination port, it is unloaded and sold at the harbour. This time, the good does not change its transport unit.

The combined freight transport is a multimodal freight transport of goods where the major part of the journey is completed by rail, inland waterway or sea and any initial and/or final leg carried out by road is as short as possible (UNECE p. 157, 2009). The EU Directive 92/106/CEE limits the distance on road of the initial and final leg (measured in airline distance) to 100 km for road-rail transport and to 150 km for road-inland waterway or sea. Also, both legs shall not exceed 20 % of the airline distance between the loading point for the initial leg and the unloading point for the final leg, when it amounts to a distance of more than 100 or respectively 150 km per leg (Council Directive, 1992). Additionally, the Directive 719/2015 limits the length of a transport unit to 45 feet. As an example, a good is picked up in a factory by a truck, brought to a port and reloaded to a water vessel. The good is brought to the destination on water. At the destination port, the good is unloaded and brought by a truck to a different place to sell it.

Furthermore, the International Union of Railways (Report on Combined Transport in Europe (UIC) differentiates in their observation of Combined Freight Transport between unaccompanied combined transport (UCT) and accompanied combined transport (ACT). At the former, the movement of goods happens in one and the same loading unit or road vehicle, while using successively two or more modes of transport without handling the goods themselves in changing modes. An example would be a transport of a loaded container from a factory first by truck, then by ship and finally again by truck to the supermarket. The latter is the transport of a road vehicle or an intermodal transport unit that is accompanied by the driver and uses another mode of transport (for example a ferry or a train). Accompanied combined transport is popular for transportation in the Alps or at the Euro Tunnel where in 2017 1.6 Million trucks reached the other end by train which marks an increase by 10.3 % compared to the volume of 2013. Nevertheless, the total continental accompanied combined transport volume decreased over two years by 10 % to approximately 0.67 Million Twenty-foot Equivalent Unit (TEU) in 2017 (UIC, 2019).

For measuring combined transportation, Eurostat differentiates between the transport modes rail, sea, road, inland waterways, air, and pipelines. The unit of measure is usually in (metric) tonne-kilometres (transportation of one ton of good over a distance of one kilometre) or absolute volume (tonnes), values (Euro) or number of containers transported in shares of transport modes (Eurostat, 2019).

These definitions do not consider efficiency and therefore leave a gap between theoretical success and practical implementation. Both Steadie Seifi et al. (2014) and Verweij (2011) include efficiency in their definition of combined transport and prefer the term *synchro modal transportation* or *co-modal transportation* where the carriers or customers select, at any time, the best transportation mode based on the operational circumstances and/or customer needs. The efficient and successful use in practice of one mode or of several modes combined, depends on how well economic, logistical, and environmental challenges are solved. In the following, these challenges are discussed.

3 | Stylized facts on logistical, financial, and environmental concerns and utilities in the transport mode choice

In the process of finding the most cost-effective transport mode for a certain good, carriers or customers are confronted with at least three different kinds of challenges or concerns: logistical, financial, and environmental. In this chapter, we analyse which unimodal transport mode has which strengths regarding the different concerns. The observed unimodal modes of freight transport are road, rail, and inland waterway transportation. Sea (maritime), pipeline and air freight transportation are not the of focus of this paper.

Logistical concerns

According to Reis (2013), transportation on road has three main logistical advantages. First, its flexibility allows the carrier to reach almost every node in Europe directly. Second, compatibility of the roads system in Europe allows an actor to use the same type of freight truck on almost every road on the European continent. Third, on medium and short distances up to 300 km (Carboni et al., 2018), goods cannot be transported faster by any other mode of transport. However, the most important limitations are the capacity constraints of the highways. For example, most of the highways in and around the city of Hamburg, Germany have already reached a level of capacity between 71 up to 90 % (Holtermann et al., 2015), which causes congestions during most parts of the day.

These advantages of road transport constitute disadvantages of rail and of inland waterway transport. A door-to-door transport is often not possible because the required infrastructure is not developed. The required infrastructure investment costs are very high and exceed the benefits in many cases.

In contrast to the road system for freight trucks, even in the European Union, railways do not always have universal specifications (track gauge, etc.) and regulations (traffic control systems, etc.). Freight trains of one country (rail gauge in Spain 1668 mm) do not always fit with the track gauge of other countries (continental standard: 1435 mm; Russia: 1520 mm) in Europe (Puffert, 2002).

Barge vessels on inland waterways are of lower velocity than freight trucks are on the network of roads (e.g. highways, main roads). One reason why transportation on inland waterways might still be efficient on longer distances is that truck drivers have limited working hours according to EU rules (Carboni et al., 2018). According to the Directive 2003/59/EC, a freight truck handler is allowed to drive 9 hours a day which can be extended to 10 hours twice a week. In a single week, drivers can be on the road for 56 hours and for 90 hours in any two consecutive weeks (European Union, 2003). Another difference between truck and rail freight traffic is the presence of mixed traffic and a wide speed range (with an average of 45 km/h to 230 km/h) (Teuber et al. 2015). Moreover, the transportation on freight trains and inland waterway barges is relatively slow in comparison to trucks on short- and medium-term distances, a significant time-loss already occurs during shunting and loading procedures.

While a freight truck counts for one standardized Intermodal Transport Unit at forty-food equivalent (ITUs 40′), a train contains around 20 ITUs 40′, and a barge, depending on the water infrastructure, can carry up to 250 ITUs 40′ (Economic Commission for Europe 2010; Carboni et al., 2018). This implies the loading time of a single freight truck is shorter than that of a single freight train or inland waterway vessel but at the same time, the amount of ITUs a truck can transport is by far lower than that of the other two equivalents (economies of scale).

On inland waterways, logistic companies are in demand of an increasing number of carried ITUs per inland waterway barge which leads to a demand for bigger vessels. This confronts the port managers with the task to create deeper riverbeds for the bigger vessel and create more storage facilities for the logistic companies to allow them to bypass the time until the last ITU is ready to be shipped (Reis, 2013). More restrictions are the lack of year-round navigable passageways (e.g. rivers Elbe and Oder), and bridge passage heights (Teuber et al., 2015)

Financial concerns

The financial crisis of 2008 led to a decrease of global and European trade which reduced the profits in the transportation and logistics sector. Many actors have responded by reducing their costs and investments until today, even though the volume of trade in Europe and on the globe has increased again in recent years. While analysing the costs in the sector, we distinguish between internal costs which are covered in this subchapter and external costs (externalities) which will be covered in the next subchapter as environmental challenges.

Internal costs are costs that a business bases its price on. Black et al. (2003), Janic (2008), Kim et al. (2011) and Carboni et al. (2018), in their quantitative analysis of internal costs for freight transportation, refer to price estimations for a kilometre covered by a certain mode of transportation. They rely on the project REal COst Reduction concerned with door-to-door intermodal transport which was supported by the European Commission. In their calculation, they estimate the price for the transportation by truck to be 0.58–1.37 Euros per kilometre for a 40-foot container (ITU 40′), with an assumed vehicle utilization rate of 0.85. In the same study, we suggest that the costs are in the range between 0.46 and 1.35 Euros per kilometre for transportation on rail plus costs at the rail terminals of about 27 Euros for an ITU (40′) in the case of a rail-rail-transfer, and of about 36 to 60 Euros for an ITU (Black et al., 2003; Janic, 2008; Kim et al., 2011; Carboni et al., 2018; European Commission, 2002).

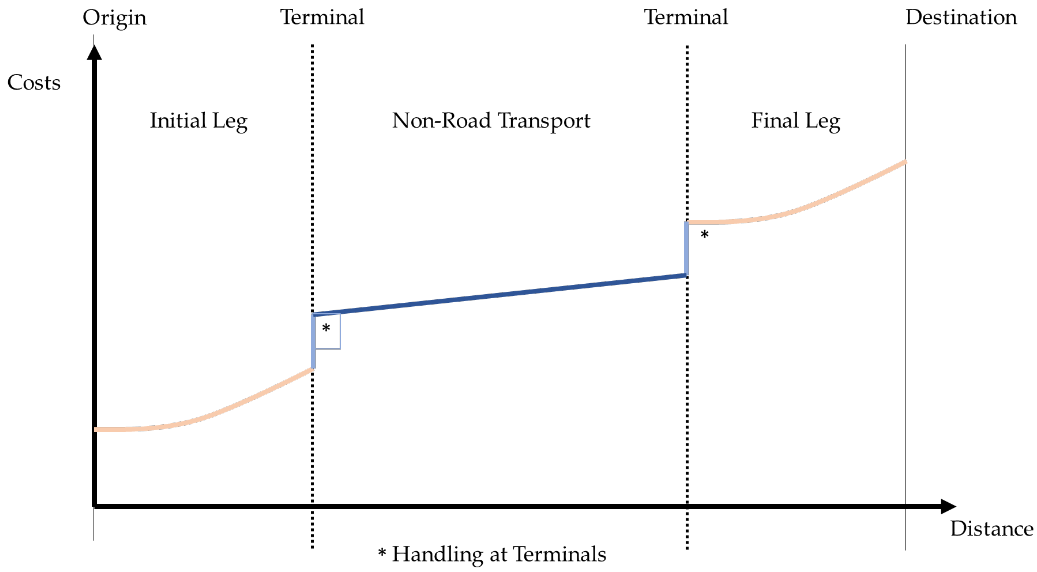
These numbers emphasize the lower unit costs of transportation by rail compared to unit costs of transportation on road. Additionally, organizational and management costs are lower for the transportation on road than those for transportation on rail or on water due the additional handling of goods at the terminals for rail and water transportation (Reis et al., 2013). Other internal costs which will not be covered in this paper's analysis are the cost of ownership of vehicles, use of infrastructure, depreciation costs, staff costs, consumption costs, maintenance costs, insurance costs, taxes or tolls.

Carboni et al. (2018) analyse the internal and external cost advantages of combined transport by road and rail compared with unimodal road transport. They compared both types of costs over different total track lengths and different lengths of the initial and final haulage. The scholars claim that the combined transport is less costly in external costs. Regarding internal costs, it depends on the two variables total track lengths and lengths of the initial and final haulage. To illustrate, if a track was in total 1,000 kilometres long, the transport on road only and the combined transport would have the same costs if the terminals were 60 kilometres away from the origin or destination respectively. If the initial and final haulages were less than 60 kilometres, a combined transport would be cheaper in terms of internal costs.

A constant cost factor in the calculations of Carboni et al. (2018) are the costs that accrue in transition terminals, also known as "transhipment costs". The faster these terminals operate and the lower the operational costs are, the higher the competitiveness of the combined transfer (Behrends and Floden, Hanssen, Ishfaq and Sox (2012). Furthermore, Frémont and Franc (2010) argue that the additional costs for planning the intermodal transfer is worth the investment if the cost for transportation can be reduced by ten to 20 %.

Dalla and Pellicelli (2011) differentiate the combined freight transport according to three different stages and allocate different costs for these stages, as illustrated by Carboni & Dalla Chiara (2018) (Figure 1): the initial and final leg covered by truck, the handling processes at terminals and the non-road transport in between. The pre- and post-haulage cost are higher than the costs for non-road haulage over long distances and are estimated to about 1.23–3.78 Euros per kilometre for a 40-foot container (ITU 40′).

Figure 1: Qualitative cost scheme showing the structure for combined transport



Source: Carboni & Dalla Chiara (2018), HWWI.

Environmental concerns

Besides financial costs which we are referring to as internal costs, challenges also emerge from the impact of transportation activities on the environment. We interpret environmental concerns as external costs, as these costs are in absence of regulatory attempts usually not included in the price calculation of businesses. An externality arises when a person engages in an activity that influences the well-being of a third party who neither pays nor receives any compensation for the (positive or negative) effect. The social costs include the external plus the private costs of production. The social costs are always higher than the private costs. These social costs must be internalized in the production process (internalization of external costs) in order to achieve an efficient outcome.

In theory, there are many solutions for solving the externality problem, e.g. the Coase theorem (by private agreement, respectively direct negotiation between parties), regulation (e.g. CFC and halon ban in the aviation industry), Pigouvian taxes. A further example is to establish strict and precise property rights on public or environment goods (e.g. certificates on emission rights and corresponding trading schemes), but this is not always possible or viable. As an overview, the negative externalities of freight transport are summarized in Table 2. They take the form of air emissions, water and noise pollution, congestion, accidents, and land use.

Table 2: Classification of negative externalities of freight transport

Air Pollution	Greenhous Gases	Water Pollution	Noise Pollution	Congestion	Accidents	Land Use
Sulphur Oxides	Carbon Dioxide Equivalent	Petroleum Hydrocarbons	0 – 60 dBA quiet/ comfortable	Wasting Time	Cost of Emergency Services	Destruction of Habitats
Nitrogen Oxides	Carbon Dioxide	Heavy Metals from Motor Vehicles	61 – 85 dBA moderate	Delays	Delay of Traffic	Visual Intrusion on the Landscape
Carbon Monoxide	Methane	Cargo	85 – 110 dBA very loud	Health Risk		Disruptive Effect
Volatile Organic	Nitrous Oxide	Shipwrecks	110+ dBA uncomfortable/ dangerous	Wear and Tear on Vehicles		
Compounds	Ozone			Inaccurate Travelling Times		
Particulates	Chlorofluorocarbon					
Other Gases	Other Gases					

Source: Carboni & Dalla Chiara (2018), HWWI

Frémont, A., & Franc, P. (2010) showed that the transportation sector is the only major sector of the economy in the EU that is responsible for a growing percentage of CO_2 in total emissions of the EU. Nevertheless, the per unit emissions have decreased significantly over the last decades, for reasons of cleaner engine technologies or economies of scale.

Table 3 summarizes this chapter and displays the performance of road and non-road modes of freight transportation with focus on logistical, financial, and environmental concerns.

Table 3: Logistical, financial and environmental concerns for different transport modes

	Logistical concerns	Financial concerns	Environmental concerns
Road	Flexibility	Low organizational costs	
	Compatibility of European roads system		
	Fastest mode for transportation of		
	below 300 km		
	Limited work hours for drivers	High unit cost per km	High CO_2 emission per km
	1 ITU per service		
Rail and inland waterways	Less limited working hours	Low unit costs per km	Low CO_2 emission per km
	More than 1 ITU per service		
	No door-to-door operation	High organizational costs	
	Different rail gauges and shipping piers		
	Time loss while shunting and loading		

Source: HWWI.

4 | Facts on freight transportation in the EU and realistic future scenarios

Some stylized facts on freight transport

After analysing the theoretical advantages and disadvantages of unimodal transport, we now analyse whether and how the combination of the advantages of unimodal transportation can be a new best fit model for the transportation of freight. 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), about 30 % of road freight over 300 km shall be shifted to other modes of transport by 2030, such as rail or waterborne transport. This value is expected to rise to more than 50 % by 2050. Mathisen and Hanssen (2014) found out that intermodal freight transport grew from the year 2000 onwards due to a stronger political focus, whereas Islam et al. (2016) extended the explanation by the influence of the European White papers to competitive prices of combined freight transport, heavier and longer trains, wider loading gauges, higher speeds, and better utilization of wagon spaces.

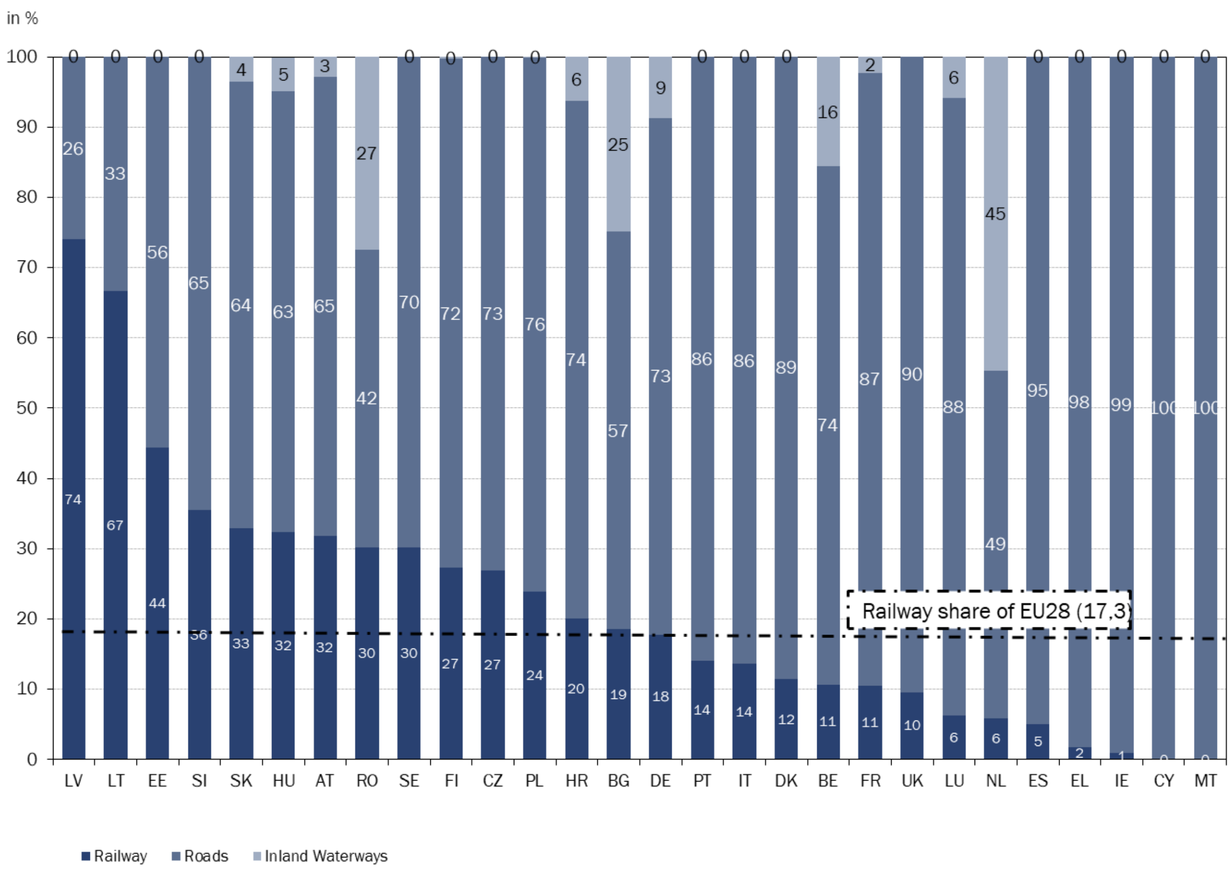
The EU-wide freight transport is mostly dominated by road transportation (77%), followed by railway (17%), and waterways (6%). Just a few countries have road shares below 50%. These are Latvia (74% rail), Lithuania (67% rail), Romania (30% rail, 27% inland waterways), and the Netherlands (6% rail, 45% inland waterways) (Figure 2).

A key target of the EU's transport policy is to achieve a 60% reduction in greenhouse gas (GHG) emissions from the transport sector by 2050 (compared to 1990 levels). One of the strategies to reach this goal is to shift 30% of the long-distance road freight (over 300 kilometres) to transport modes with lower CO_2-emissions, in particular to rail.

The Eurostat indicator 'modal shift potential' provides information on the share of road freight containers transported over distances larger than 300 kilometres. This is interpreted as modal shift potential because these containers could theoretically be shifted to rail or inland waterways, thus contributing to the reduction of CO_2-emissions from the transport sector. 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 %). The difference between the two indicators means that the average container is transported over relatively short distances. The less frequent long-distance transports over 300km or more, however, contribute more to the transport performance (measured in tkm) (Figure 3).

The modal shift potential as provided by Eurostat does not recognize the ability to actually shift the long-distance road freight to rail. In particular, no information on the railway network enters the indicator. In order to obtain more realistic scenarios for the future development, the "realized" modal shift is analysed instead. The realized modal shift is computed from the observed increase of rail in the modal split of freight transport in each country. Figure 4 shows the median[1] increase of the rail freight share in the time period 2006-2017. Most countries did not manage to increase the share of rail freight in most years.

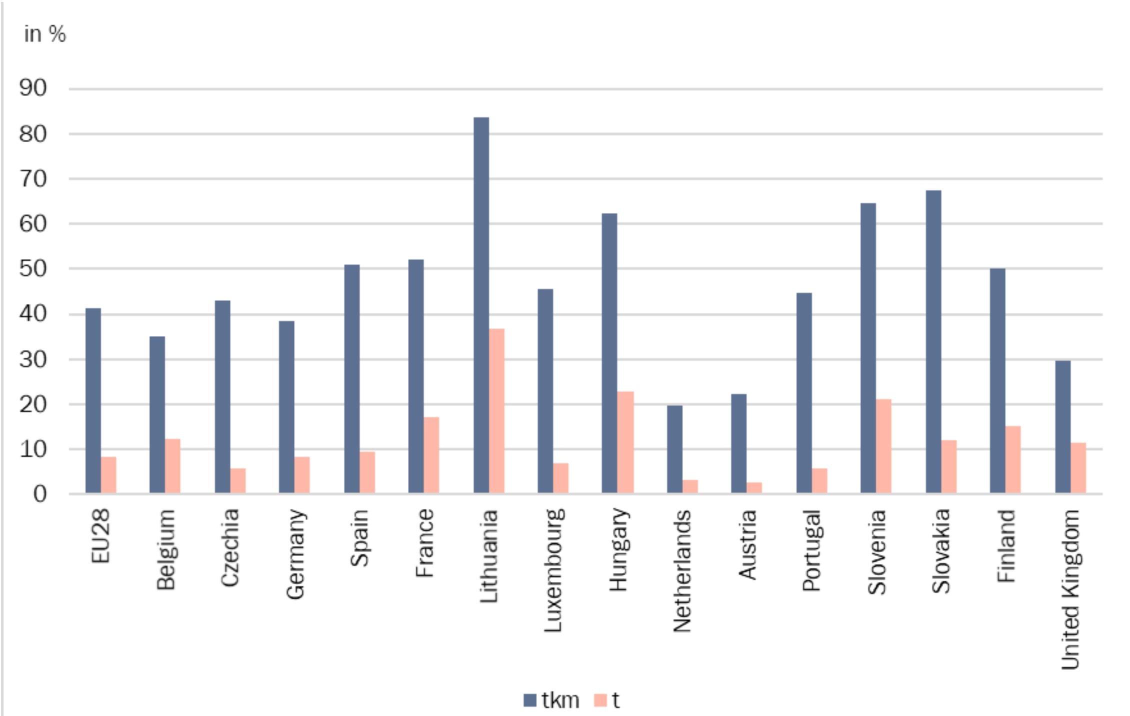
Figure 2: Modal split of freight transport, in % of total transport performance (tkm), 2017



Source: Eurostat (2020), HWWI

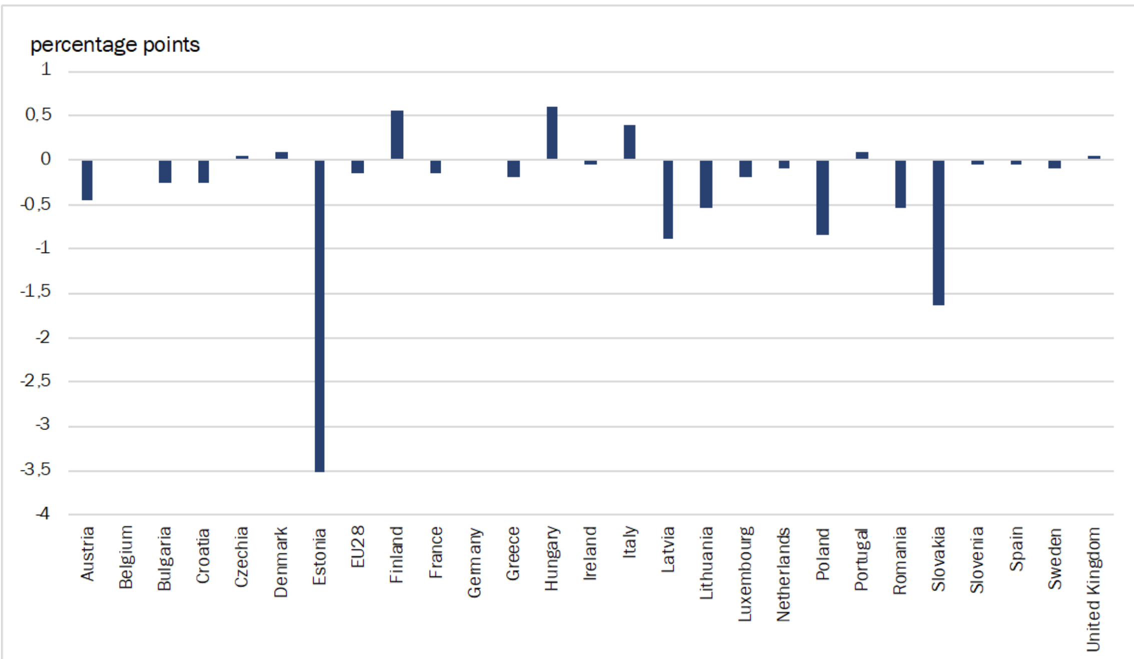
[1] Due to high volatility in the annual growth rates of the rail freight share, the median is used instead of the mean.

Figure 3: Modal shift potential of long-distance road freight in containers (t, tkm), 2017



Source: Eurostat (2020), HWWI

Figure 4: Observed development of the rail share in the modal split (2006-2017)



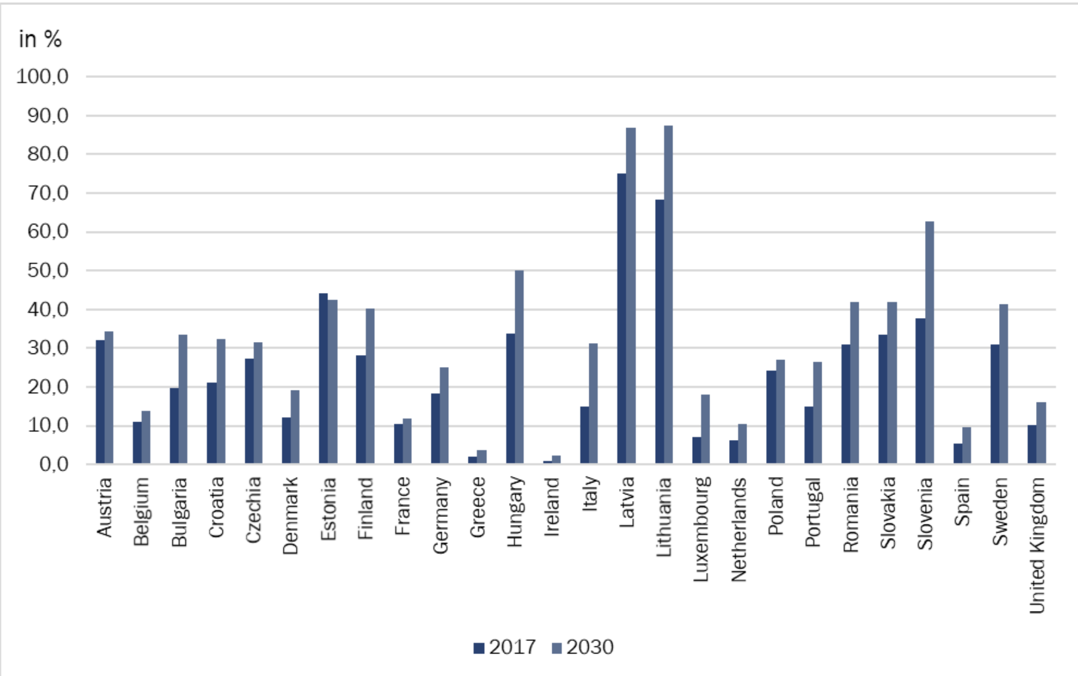
Source: Eurostat (2020), HWWI

For the construction of realistic scenarios for future development of the modal shift, it can be expected that countries will be more ambitious in the future than they were in the past. Therefore, the ambitious scenario assumes an annual increase in the rail freight share corresponding to the 75%-quantile of the observed annual change in the respective countries in the time period 2006-2017. Additionally, the very-ambitious scenario assumes a stronger increase in the rail freight share equal to the 90%-quantile. For both scenarios, it is assumed that the share of inland waterway stays constant at the 2017 level (cf. Figure 2) and that the increase of rail in the modal split corresponds to the (relative) reduction of road freight.

Figure 5 shows the rail share in the base year 2017 and the potential rail shares in 2030 under the ambitious scenario. The very ambitious scenario is illustrated in Figure 6.

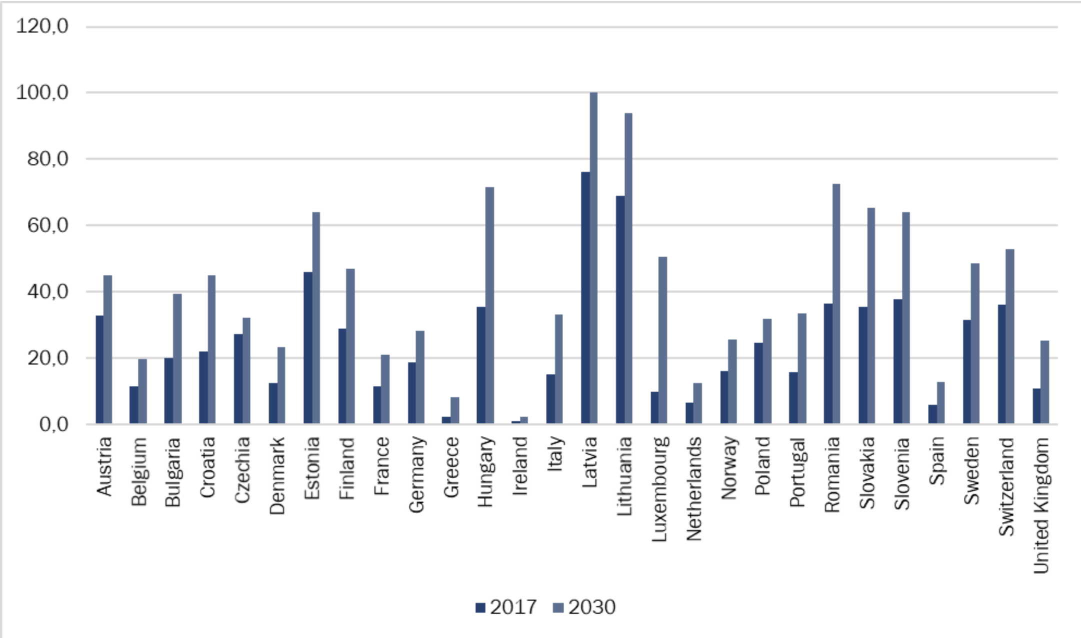
As an average over all considered countries, the rail share would increase from 23.3% in 2017 to 32.6% under the ambitious scenario and to 41.7% under the very ambitious scenario. In the following, the goal is to assess what these scenarios imply for the reduction of GHG emissions from freight transport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

Figure 5: Increase of rail share in freight transport (ambitious modal shift scenario)



Source: Eurostat (2020), HWWI

Figure 6: Increase of rail share in freight transport (very ambitious modal shift scenario)



Source: Eurostat (2020), HWWI

Emissions from freight transportation in the EU

The basic information needed to analyse GHG emissions from freight transport are the specific emissions of the three considered transport modes: road, rail and inland waterway. For this study, we employ recent numbers calculated for Germany (Table 4).

Table 4: Specific emissions of freight transport modes

	CO_2-emissions (g/tkm)
road	103
rail	19
inland waterway	32

Source: German Environmental Agency (2018); HWWI.

Based on the difference in the specific emissions between road and rail (Table 4), the CO_2emission saving potential is calculated from the officially published modal shift potential. The resulting volume of emissions can be multiplied by a conservative estimate of the social cost of carbon (25 Euro/t) in order to estimate the monetary benefits of such a shift. The 151.3 million Euro constitute a lower bound for the benefits of realizing the modal shift potential in the EU-28 countries (Table 5).

Table 5: Modal shift potential, emission saving potential and social cost saving potential, 2017

	million tkm	CO2e (tonnes)	Emission cost saving potential (million Euro)
EU-28	45,041	3,783,444	151.3
Belgium	1,360	114,240	4.6
Czechia	1,316	110,544	4.4
Germany	15,989	1,343,076	53.7
Spain	4,594	385,896	15.4
France	3,108	261,072	10.4
Lithuania	1,057	88,788	3.6
Luxembourg	282	23,688	0.9
Hungary	481	40,404	1.6
Netherlands	1,636	137,424	5.5
Austria	182	15,288	0.6
Portugal	3,504	294,336	11.8
Slovenia	518	43,512	1.7
Slovakia	848	71,232	2.8
Finland	834	70,056	2.8
United Kingdom	2,443	205,212	8.2

Source: Eurostat (2020); German Environmental Agency (2018), HWWI.

In relation to the total annual emissions from the transport sector in the EU of over 1 billion tons, the emissions saving potential of around 3.8 million tons would only mean a very small reduction. In other words, even if the modal shift potential is fully exploited, the total emissions from the transport sector would be reduced by less than 1%. Furthermore, as argued previously, the modal shift potential does not provide enough information for determining realistic future pathways for the modal shift. Therefore, in the following, we consider the emission saving potential resulting from 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 associated mode-specific emissions (Table 6, column 1). The index is scaled in a way that the modal split of the EU28 in 2017 yields 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 share or inland waterway share. The "ambitious" and "very ambitious" modal shift scenarios can also be expressed in terms of the emission index. Regarding the EU28, the ambitious scenario corresponds to a decrease of GHG emissions from the transport sector of 3.2% (ambitious) or 6.5% (very ambitious) by 2030. Note that these numbers ignore possible developments in the total transported volumes and refer only to the reduction related to a modal shift from road to rail.

Table 6: Index of GHG emissions from transport sector (scenarios)

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

Source: Eurostat (2020); German Environmental Agency (2018), HWWI.

5 | Conclusion and outlook

In this paper, we have examined definitions of unimodal, multimodal, intermodal and combined transport and corresponding policies at the EU level regarding the implementation of combined freight transport. We have considered the current state of the modal split in freight transport in EU28 countries, which is still dominated by road transport.

Our scenario-based projections show that a modal shift in freight transportation in the EU28 is not able to decrease total GHG emissions of the transport sector significantly. Even under very optimistic modal shift scenarios and constant total freight volumes, the emission reduction would only be 6.5% in 2030 (compared to 2017). We conclude that additional measures must be taken. As a reduction of trade volumes seems unlikely, the remaining option would be to reduce the specific emissions of the transport modes. In turn, this requires the implementation of additional policies targeted at internalizing the social costs of emissions for companies in the transport sector. The debate on the appropriate instruments for this is still ongoing.

In addition, policy measures need to be complemented technological efforts to improve the relative cost effectiveness of multimodal transport.

A smooth transition between two modes of transportation is crucial for the efficient use of a multimodal transportation. For an easy Inter Terminal Transportation (ITT) between barge and rail or truck, Heilig (2017) suggest installing a network of non-public roads at ports, which allows using terminal equipment such as multi-trailer systems (MTS) and automated guided vehicles (AGV) more efficiently. A sophisticated data infrastructure is required for an ITT operating system to provide information about the container's location, destination, duration of stay at the terminal, and about the available modes and connections (Tierney et al., 2014).

Other suggestions are to increase efficiency through IT-based solutions to find empty containers, exploit storage possibilities or to increase economies of scale for goods that go on railway less frequently (Reis et al., 2013). Furthermore, most project developers are concerned about raising the efficiency of ports and their hinterland settlement. The current development leads to a bigger scope for transportation geography for hinterland transportation whereas advanced technological developments could also cause a reorganization of market value chains.

The trend of a globalization of value chains appears to come to an end, further provoked by the recent Covid-19 epidemic. Moreover, the emerging markets tend to move from export-intensive industries towards (domestic) service markets. Digitalization will further push the transportation industry and will reshape the values chains with its intermodal organization forms (Jahn et al. 2018).

In general, one has to stress that multimodal transport may have additional social benefits other than emission saving. It may reduce other forms of external costs from road freight such as land use, congestion, or noise.

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Hamburg Institute of International Economics (HWWI)

Oberhafenstr. 1 | 20097 Hamburg | Germany
Telephone: +49 (0)40 340576-0 | Fax: +49 (0)40 340576-150
info@hwwi.org | www.hwwi.org