Potential of modal shift to rail transport

Study on the projected effects on GHG emissions and transport volumes

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Summary

The decarbonisation of transport systems stands as one of the European Union's key environmental objectives. While a modal shift from road and air to rail transport could certainly contribute to this aim, the size of this contribution is the subject of debate. Against this background the CER and UIC (Community of European Railway and Infrastructure Companies and the International Union of Railways) asked CE Delft and TRT to investigate the greenhouse gas (GHG) reduction potential of a modal shift to rail.
This study covers both freight and passenger transport and focuses on medium- to long-distance transport. It includes an assessment of existing studies on overall modal shift potential, an assessment and extrapolation of illustrative case studies and an analysis of existing and future infrastructure capacity.

The assessment of existing studies affirms that **rail freight transport** has a significant potential. Studies show that the maximum potential share of rail freight transport in the relevant market is in the range of 31-36%, compared with 18% today[1]. This would imply that rail becomes the dominant transport mode for long-distance transport. While other studies have reported more limited effects, these have generally only considered isolated (policy) measures. To assess the extent to which the maximum potential can be indeed instrumented by government policy and supply-side measures would require investigation beyond the scope of the present study, however.

There is particular scope for rail to increase its market share in certain segments of the freight market where its position is still limited, such as international containerised transport over long distances and non-port-related transport (e.g. chemicals and fresh produce such as flowers and meat).
The feasibility of such growth has already been demonstrated. In Switzerland, for example, broad political support for rail transport through the fragile Alps has led to an increase in the share of rail. Furthermore, the modal shift targets recently defined for hinterland container traffic at several major EU ports may have a significant influence on the modal share of rail in the key market of port hinterland transport. The examples show that political decisions on the member state level can contribute to an increase in the share of rail, but also intensified EU policies are needed to improve interoperability between countries by achieving harmonisation of technical systems and procedures.

Also in passenger transport, rail may have a significant potential for growth. However, the potential growth of **rail passenger transport** is less well documented in the literature. One study estimates that in 2030 rail passenger traffic could have more than doubled compared with the baseline scenario for that year. This significant growth is calculated under the assumption that rail transport further improves its competitiveness with private car transport in terms of speed and costs on links where private car transport is currently more competitive. This requires improved rail supply factors and instrumented political support. For this scenario, too, further research is needed to define the required policies and increased services supply by the rail sector for achieving the potential.

1 This market excludes inland barges and trucks below 16 tonnes GVW.

In the passenger transport market the greatest potential for growth lies in high-speed rail, as an alternative to air transport, and in the segment of local and regional business trips.

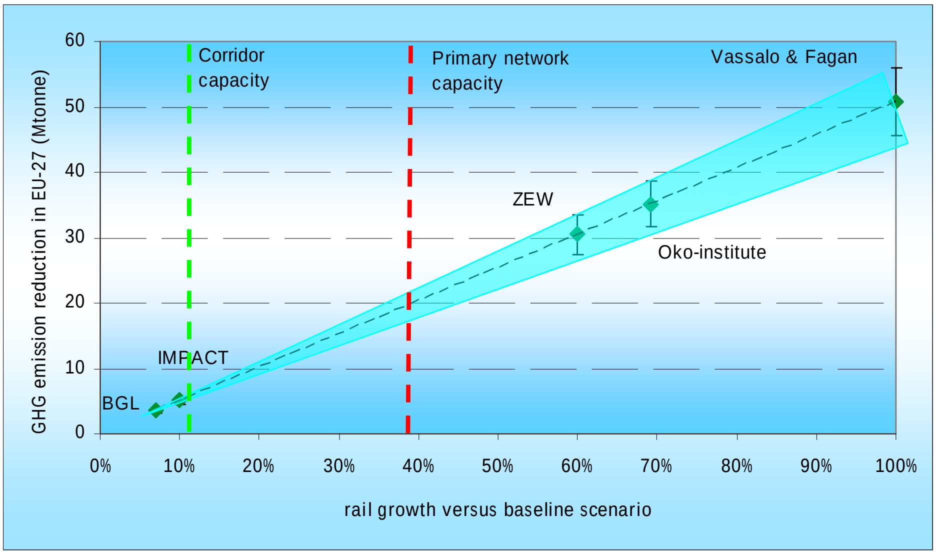
An assessment of the available infrastructure capacity shows that around 30-40% growth in train-kilometres in 2020 can be accommodated by existing infrastructure compared with the baseline for the same year. The potential growth of freight and passenger transport depends on the allocation of the available train-km. Under a 50/50% allocation, by 2020 rail freight traffic could grow by 39% on the primary network and 83% on the network as a whole. Passenger transport could grow by 14 and 23%, respectively. If growth will be concentrated on the corridors only, the growth potential is more limited.

The average **GHG reduction potential** of a modal shift in freight transport is higher than in the case of passenger transport, since the difference in emissions per unit volume is higher for freight.

Based on the potential growth of rail freight traffic, GHG reduction potential has been estimated. Studies that assume single measures like a significant improvement of the quality of supply (ZEW) and EU-wide internalisation of external costs (IMPACT) show GHG reductions of respectively 27-33 Mtonne (ZEW) and 7-8 Mtonne (IMPACT). A doubling of rail freight transport, with no consideration given to the nature of policies and measures (Vassalo and Fagan) could result in a reduction of GHG emissions by 45-55 Mtonne.
This corresponds with 19% of the emissions from the defined market where rail and road transport compete.

Figure 1 summarises the CO_2 reduction potentials for freight, taking into account detouring, transport to and from railway terminals and uncertainties in vehicle utilisation. The green and red dashed lines represent the additional capacity compared with the 2020 baseline scenario under the TEN-T investment scenario. They show that around 5 to 20 Mtonne of CO_2 eq. (2 to 7% of freight transport emissions) could be reduced by fully utilising the main corridors and the primary network, respectively, in 2020.

Figure 1 **CO_2 reduction from an increase in rail freight and decrease in road freight transport (2020) in the EU-27 (ignoring any possible rebound effects; 50% allocation of unused capacity to freight)**



For passenger transport, the GHG reduction potential is less clear-cut. The maximum modal shift calculated in the Öko-Institute study corresponds with a reduction of 70 Mtonne CO_2 eq. in the EU-27 (9% of passenger transport emissions), in 2020.

It should be noted that measures that increase the speed or reduce the costs of transport generally have a **demand-increasing effect**. Case studies on the impacts of new high-speed rail lines confirm that new travellers are attracted, partly offsetting the GHG reduction achieved by the modal shift.

EU Commissioner Kallas has sketched a **vision for 2050** in which rail is the dominant mode for long-distance transport and also has a strong position in regional passenger transport. This vision corresponds to a 38% modal share in freight transport and a 27% share in passenger transport. This would result in a GHG reduction of 238 Mtonne CO_2 eq., or 21%. To put the vision into practice, instrumented political action including a concerted and firm investment in rail infrastructure (1,300-2,000 billion Euro) and further improved rail supply factors would be required. Political measures such as full internalisation of external and infrastructure costs could contribute significantly, achieving a potential shift of between 2 and 8% of road transport volume (equivalent to 10 to 32% growth of rail volume), although a comprehensive set of additional measures is needed for achieving a doubling of rail transport demand.

1 Introduction

1.1 Introduction

Decarbonising the transport sector is one of the European Union's key environmental policy objectives. Mr. Barroso stressed in 2009 that the EU needs to lead the world on climate change:

"The next Commission will decarbonise the electricity supply and the transport sector – all transport, including maritime transport and aviation, as well as the development of clean and electric cars".[2]

Transportation is a significant and growing consumer of energy, accounting for more than 30% of the EU-25's final energy consumption. Under the EU's climate and energy package, greenhouse has (GHG) emissions are to be further reduced by 20%, and cuts in transport emissions will be one element of this drive. Lately there have been discussions on tightening this target to 30%. For the period to 2050, in the run-up to the Conference of the Parties of the UN Framework Convention on Climate Change in December 2009 the leaders of the EU's Member States called for emission reductions of 80-95%:

"The European Council calls upon all Parties … to agree to global emission reductions of at least 50%, and aggregate developed country emission reductions of at least 80-95%... It supports an EU objective, in the context of necessary reductions according to the IPCC by developed countries as a group, to reduce emissions by 80-95% by 2050 compared to 1990 levels".[3]

Recently, EU Commissioner Kallas has stated that railways will need to play a key role in reducing greenhouse gas emissions in the period up to 2050:

"Railways should play an essential role in reducing the dependency of Europe on fossil fuels and the reduction of our emission of greenhouse gases".[4]

Against this background the Community of European Railway and Infrastructure Companies (CER) and the International Union of Railways (UIC), have taken action and asked CE Delft and TRT Trasporti e Territorio Srl to investigate to what extent a modal shift from road to rail transport could contribute to the defined climate objectives, and to inform its position in the upcoming debate on the EU's Transport White Paper and additional proposals on climate action.

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2 http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/1272.

3 *Presidency Conclusions*, Brussels European Council, 29/30 October 2009; see http://register.consilium.europa.eu/pdf/en/09/st15/st15265.en09.pdf.

4 InnoTrans, 21 September 2010, in Berlin; see http://ec.europa.eu/commission_2010-2014/kallas/headlines/speeches/2010/09/doc/2010_09_21_railway_dream_berlin.pdf.

1.2 Objectives and approach

The aim of the study is as follows:

To identify the potential levels of modal shift from road to rail from several perspectives and the GHG savings that could thereby be achieved.

There are various ways to estimate the potential GHG reduction potential of a shift from road or air to rail transport, each of which has its limitations and problems. Several approaches have therefore been used in parallel and the respective results integrated in order to obtain relatively reliable estimates. The following approaches were adopted:

- Assessment of estimates from **existing studies on overall modal shift potential.**
- Estimation of potential modal shift per transport market segment, based on **extrapolation of illustrative case studies**.
- Estimation of potential modal shift per transport market segment, based on **infrastructure capacity analysis**.

The study covers both passenger and freight transport in the EU. The scope is medium- to longer-distance transport, including commuting (e.g. regional trains), but not light-rail transport within cities nor city distribution of freight. The potential of modal shift to rail transport is assessed for existing and already planned infrastructure as well as for scenarios with additional investments in rail. The analysis focuses on the period 2020-2050.

This study discusses the potential for modal shift from different perspectives. It is, however, not a full analysis that predicts how much modal shift is expected to occur, depending on policies, prices, infrastructure, service quality, reliability, speed and other factors. The information available was deemed too limited to draw conclusions on this issue. The study therefore recommends further analysis in this area.

The overall approach adopted in this study takes into account only the direct effect of modal shift measures. Although the potential impacts on overall transport demand, e.g. induced traffic in the case of new infrastructure development, are discussed, these could not be quantified.

1.3 Report outline

In Chapter 2 relevant market segments are defined and the specific emissions of the different modes are estimated, for use in GHG impact calculations later in the report. Chapter 3 contains a literature review of the drivers and barriers relevant for rail transport growth. Chapter 0 discusses available studies that have attempted to estimate the potential for modal shift to rail transport. Chapter 5 presents and discusses a number of cases that illustrate the potential for increasing the modal share of rail in specific situations, countries, transport links and markets. In Chapter 6 an analysis of infrastructure capacity is developed and used as the basis for an additional way of estimating the potential for modal shift. In Chapter 7 the GHG reduction potential of a modal shift is estimated, based on the results of the previous four chapters. Chapter 8 translates the vision presented by EU Commissioner Kallas into rail performance figures, their GHG impact and some of the requirements for realising such a vision. In Chapter 9, finally, the conclusions of the various chapters are summarised.

2 Sectoral review and assessment framework

2.1 Introduction

In this chapter we provide a general overview of the EU railway sector and develop the framework that will be used further on to assess infrastructure capacity (Chapter 6) and the GHG effects (Chapter 7) of a shift to rail transport. The first sections of this chapter provide an overview of trends in rail transport since the nineties, giving consideration to modal split, principal market segments and international transport. We also define the market segments that will be used throughout the study to structure the analysis.

To assess the effects of a modal shift, two sets of **baseline scenarios** were defined for the different market segments identified, on the basis of available scenario studies:
- Projected GHG emissions per unit performance (tonne-km, passenger-km) in 2020, 2030 and 2050.
- Projected transport volumes and GHG intensities for the years 2020, 2030 and 2050 of the modes competing in the various market segments defined.

In Chapters 6 and 7 these scenarios are used to assess future infrastructure capacity and the GHG reduction due to a modal shift.

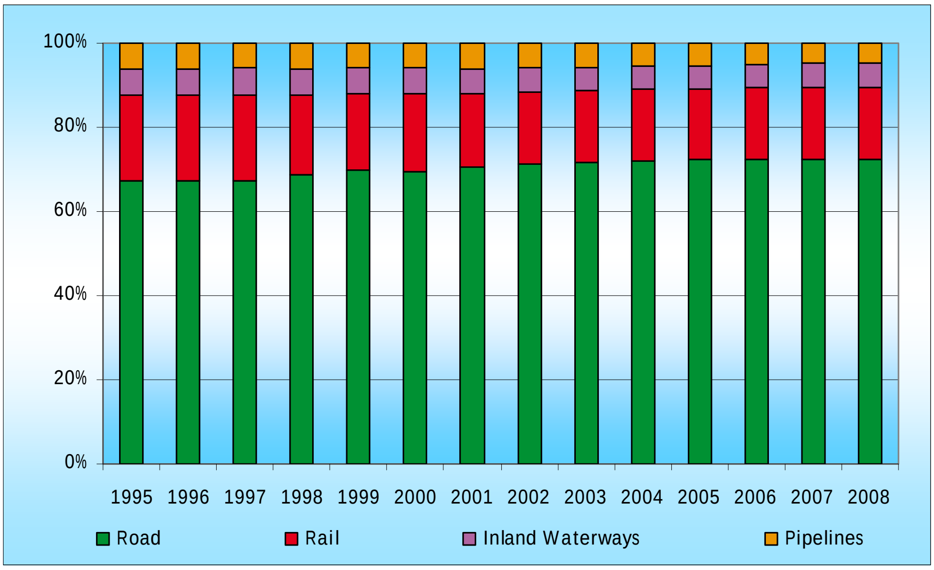
2.2 Past trends in modal split

Freight transport

Over the last decade the modal split between road and rail freight has remained relatively constant in the EU-15, with a slight shift towards rail in the second half of the period. In 2008 the share of rail was 11%. In the EU-12, however, the share of road transport increased over the same period from around 50 to over 70%.

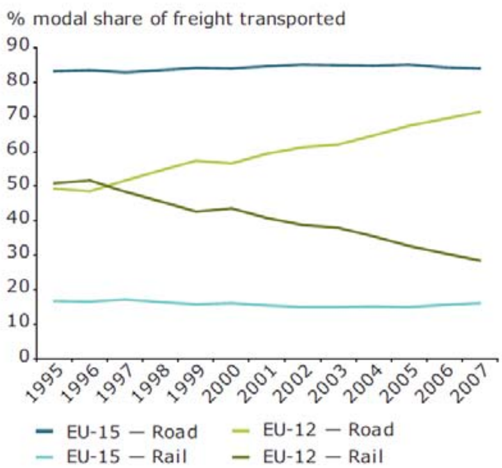
A change in the geographic orientation of the markets for the EU-12 (from east to west) has contributed to the shift, because the new markets are not well connected by rail infrastructure and offer far more flexible road transport as an alternative. For the entire EU-27 these two trends have resulted in a declining share of rail transport.

Figure 2 Modal split of freight transport performance (tonne-km) in the EU-27



Source: EC, 2010b.

Figure 3 Comparison of trend in modal split of freight transport in the EU-15 and EU-12



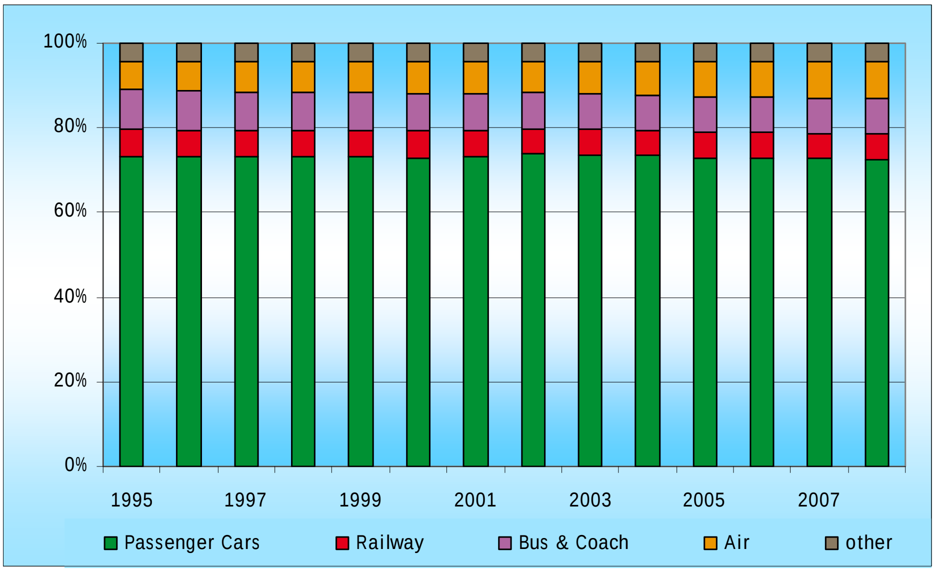
Source: Eurostat, 2009.

Note: This figure covers road and rail transport only, which thus sum to 100%.

Passenger transport

In recent years the modal split for inland passenger transport has been dominated by the private car in all EU member states. During the last ten years demand for rail has remained fairly steady or increased in all EU-15 Member States but one (Portugal). Within the EU-12, however, rail transport volumes have declined considerably in most countries, just as we saw for freight. Three countries (Estonia, Hungary and Slovenia) have experienced a slight improvement in rail demand since 1997.

Figure 4 **Modal split of passenger transport volumes (pass-km) in the EU-27**

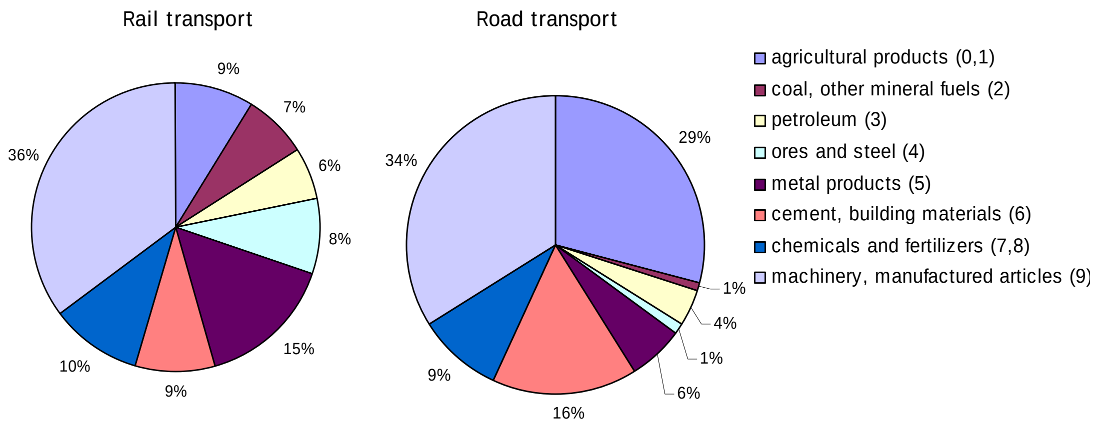


Note: 'Other' refers to powered 2-wheelers, tram/metro and sea transport.
Source: EC, 2010b.

2.3 Distribution of road and rail transport over NSTR classes

Given their nature, road and rail freight transport perform on different markets, but there are still substantial overlaps. Figure 5 shows that rail transport is more specialised in bulk transport of non-perishable goods, while the share of road is higher in the transport of final products. Figure 5 shows that the categories coal and other mineral fuels and metal products are important markets for rail transport, while these markets are less important for road transport.

Figure 5 **Distribution of road and rail transport over NSTR classification chapters (EU-15, 2001)**

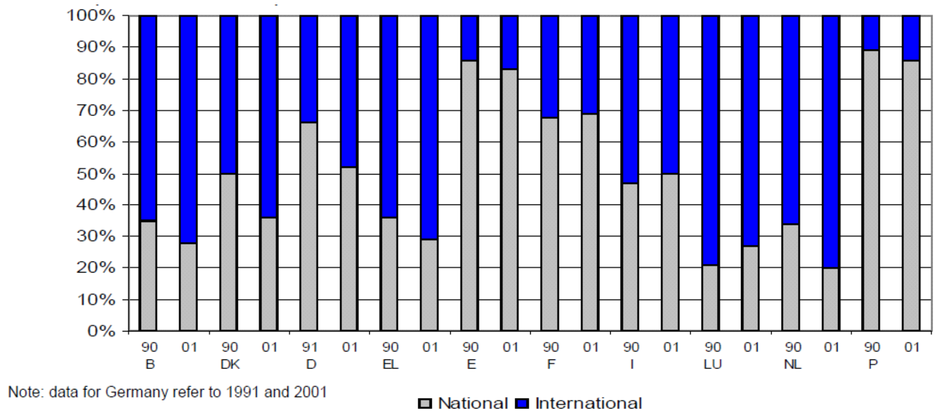


Note: 'Machinery and manufactured articles' also includes containers.
Source: Eurostat, 2003.

2.4 National and international rail freight transport

In many EU countries rail performs better in national freight transport than in international freight transport. The share of international transport is high for Luxembourg, owing to its small size, and for the Netherlands, because of its limited size and the major transport flows between the Port of Rotterdam and the European hinterland. In large countries like Spain, France and Germany the share of national transport is equal to or larger than that of international transport; see Figure 6. In terms of total tonne-kilometres, in 2001 the share of national transport was higher than that of international transport in the EU-15 (55 vs. 45%).

Figure 6 Split between national and international rail freight transport for various EU countries



Source: Eurostat, 2003.

In 2001 transit transport by rail was relatively limited, with only 22 billion tonne-km (10% of the total) passing through countries without being loaded, unloaded or transhipped.

The data presented above are relatively old, and a number of Directives to improve rail interoperability have since then come into force. However, there are still many barriers to full interoperability on international corridors (Walker et al., 2009) and the current situation may therefore not deviate significantly from that depicted above.

2.5 Definition of market segments

Table 1 shows the main market segments for both passenger and freight transport. This segmentation is based on the different markets for modal shift, as explained below.

Table 1 Definition of market segments in passenger and freight transport

Passengers		<100 km	100-500 km	>500 km
Train	Private			
	Business			
Car	Private			
	Business			
Aviation	Private			
	Business			

Freight	<500 km		>500 km	
	Rail	Road	Rail	Road
Container				
Bulk				
Miscellaneous goods				

For passenger transport we distinguish private and business trips. Business trips include commuter travel as well as travel for professional reasons. Private trips comprise all other travel, including shopping trips and holidays.

For passenger transport we then also distinguish short-, medium- and long-distance trips. Short-distance trips include commuter travel, business trips and personal trips for visits, shopping, etc. Long-distance trips are business trips to conferences, etc. and personal trips for holidays. We judged that the short-distance trips are typically below 100 km. The share of trips below 100 km is based on an expert guess for both road and rail transport. This has been estimated as 80% of total passenger-kilometres.

Trains only represent an alternative for a certain portion of passenger air flights in Europe. On longer and especially intercontinental flights there is no competition between trains and planes. The potential for modal shift is the highest for short trips. TREMOVE provides data on trips with a length of below and above 500 km. Because other sources with this kind of split between short- and long-term transport volume are lacking, we adopted this segmentation for passenger transport.

For freight transport, typical distances are longer than for passenger transport. Logistical characteristics differ for short- and long-distance trips and therefore the emissions per tonne-km, too. Furthermore, these characteristics are different for the various types of goods. This is why we distinguish short (<500 km) and long (>500 km) distance trips and three different types of goods, altogether resulting in six different market segments.

2.6 Future emission factors

2.6.1 Available scenarios

Emission factors were taken from the policy scenario tool SULTAN. This tool was developed by AEA Technology in the scope of the project 'EU Transport GHG: Routes to 2050', which can be considered a frontrunning project. The emissions in this tool are based on figures from several scenarios, with most figures derived from TREMOVE.

There are several reasons why we chose SULTAN as our source for emission factors:
1. It is the most recent projection available.
2. It provides information up to 2050.
3. It is an international scenario that covers the entire EU.

To check the robustness of the results obtained using the SULTAN figures we compared these with projections obtained using data from several other sources. This comparison is reported in Annex A.

On the basis of this comparison we conclude that SULTAN is a reliable source for all modes except rail transport, for which we have therefore used emission factors from TREMOVE.

Because we use projections from TREMOVE, which is also the basis for the SULTAN tool, a description of the TREMOVE model is included in Annex D.

2.6.2 Parameters and assumptions

Emission factors depend on numerous parameters and assumptions. To put the emission factors from SULTAN into perspective, we here present a brief description of the assumptions made in the SULTAN tool.

For the emissions of the different modes the following parameters are important:
- Vehicle energy consumption.
- Carbon intensity of electricity and fuels.
- Load factors.

Below, we describe the assumptions made with regard to the specific parameters in the SULTAN baseline scenario. All the reference scenario assumptions are based on literature that is documented in Hill (2010).

Vehicle energy consumption
Table 2 provides figures on the energy consumption of new vehicles.

Table 2 Average new vehicle fuel consumption (2010=100)

	2010	2020	2030	2040	2050
Car	100	88	84	80	76
Aviation	100	90	82	74	67
Passenger rail	100	98	92	85	78
Heavy truck	100	96	91	87	83
Freight rail	100	96	92	88	84

Source: Hill, 2010.

As Table 2 shows, the fuel consumption of the modes distinguished is projected to fall by 16-33% between 2010 and 2050.

Carbon intensity of power generation and fuels
Emission factors depend not only on vehicle energy consumption, but also on the carbon intensity of the fuel used. For fossil fuels there is no discussion about the carbon intensity, as it is a given property of the fuel. For electricity, however, there are major differences between power sources, as the value to be adopted depends on the shares of various kinds of energy production.

Emission factors for trains in 2020 were taken from TREMOVE, which means the TREMOVE assumptions on carbon intensity were also implicitly adopted. Trends on the decarbonisation of power generation in the EU are from SULTAN and were combined with the 2020 figures from TREMOVE to obtain values for 2030 and 2050. Table 3 presents an overview of the resulting carbon intensities.

Table 3 Projection of decarbonisation of EU power generation (g CO_2 eq./kWh)

	2020	2030	2050
Passenger transport	331	232	55
Freight transport	393	287	78

Note: Differences between freight and passenger transport are due to differences in the country mix for the two segments.

Furthermore, the projections assume:
- A share of 17% diesel traction in passenger transport and 30% diesel traction in freight transport in 2020.
- No correction factor for non-GHG emissions of aviation.

Load factors
Emissions per passenger- or tonne-kilometre depend on the load factor of the vehicle. As this parameter differs between segments and between countries, it is difficult to find an average value. Table 4 presents the load factors assumed in this study.

Table 4 **Occupancy rates and load factors**[1]

Modality		Unit	<100 km	100-500 km	> 500 km
Passenger car	Private	pass/veh	2.0	2.3	
	Business	pass/veh	1.2	1.1	
Passenger train	Private	pass/veh	128	147	
	Business	pass/veh	128	147	
Truck[2]	Containers	tonne/veh	4.7		6.2
	Bulk	tonne/veh	7.3		7.9
	Miscellaneous goods	tonne/veh	4.3		5.8
Freight train	Containers	tonne/veh	352		440
	Bulk	tonne/veh	379		470
	Miscellaneous goods	tonne/veh	352		448

Note: These load factor and occupancy figures differ from the Eurostat statistics. In the capacity study we stick to statistics, which we assume to be more reliable.

1 No occupancy rates are available for air transport.

2 Load factors are for 2020; there is a slight increase towards 2050.

Further notes

Rail transport cannot replace road transport one-to-one. If road is replaced by rail, the distance covered will probably increase. This is because the road network is denser than the rail network, which means shippers must often make a detour. In addition, the origin and destination of products are not always near a train station, so that products need to be transferred to and from trucks for further transport.

Detours and transport to and from loading points have a negative impact on rail transport emissions. The STREAM study (CE, 2008a) uses bandwidths for both factors. STREAM uses a detouring factor of 0-10% and assumes transport to and from loading points to represent 0-10% of the overall transport chain. We apply these figures when calculating the GHG effects of modal shift in Chapter 7.

The emission factors presented below are averages for the EU-27. There are major differences between countries, however. This is especially an issue with electric trains. The electricity production mix and therefore the GHG emission per kWh varies considerably from country to country. Average values are defined by the load factors assumed, moreover, which may deviate substantially from the average in specific cases. For these reasons it is wise to use country- and case-specific data for specific instances of modal shift.

2.6.3 Emission factors

The market segments defined in SULTAN and TREMOVE do not match those used in our segmentation and we could not therefore simply adopt their emission factors. We used figures on the relative distribution over market segments from sources such as Eurostat and TREMOVE to distribute the SULTAN figures over market segments. We distributed the overall transport performance in such a way that the (weighted) average over all categories per mode matches the emission factors in the preferred source. Annex B presents the sources used to obtain our emission factors.

Transport emissions have both a direct and an indirect component. Direct emissions are the emissions from combustion of fuel in the vehicle, while indirect emissions are those associated with fuel production and power generation. For vehicles running on diesel, indirect emissions are of minor importance. For electric trains, however, the indirect emissions of electricity production make up the bulk of aggregate emissions. Because we take diesel as well as electricity as an energy source into account, we use total emissions, i.e. the sum of direct and indirect emissions. Table 5 and Table 6 present the emission factors employed in our calculations. Annex B presents the emission factors for direct and indirect emissions separately.

Table 5 Total emission factors for passenger transport, average over the EU-27 (g/pas-km)

Passengers		2020			2030			2050		
		<100 km	100-500 km	>500 km	<100 km	100-500 km	>500 km	<100 km	100-500 km	>500 km
Train	Private	46	31	25	36	24	18	16	11	4.7
	Business	46	31	25	36	24	18	16	11	4.7
Car	Private	88	80		80	72		72	65	
	Business	150	159		135	143		122	129	
Aviation	Private	231		237	212		129	182		110
	Business	231		237	212		129	182		110

Note: Emission factors for trains are based on the assumption that trips <100 km are 50% regional trains and 50% IC trains, 100-500 km are ICs and >500 km are high-speed trains.

Table 6 Total emissions factors for freight transport, average over the EU-27 (g/tonne-km)

Freight	2020				2030				2050			
	<500 km		>500 km		<500 km		>500 km		<500 km		>500 km	
	Rail	Road	Rail	Road	Rail	Road	Rail	Road	Rail	Road	Rail	Road
Container	13	131	10	98	11	127	8	95	6	116	5	87
Bulk	12	84	10	78	10	81	8	75	5	74	4	68
Miscell. goods	13	141	10	105	11	137	8	102	6	124	5	93

Note: Emission factors for road are for trucks over 16 tonnes.

The average GHG reduction potential of a freight transport modal shift is higher than that for passenger transport, since the difference in emissions per unit of volume is higher for freight transport.

The differences between diesel and electric trains are currently limited (CE, 2008a). However, in the decades ahead electric trains will have a lower carbon intensity than diesel trains, because of the expected trend towards decarbonisation of power production.

2.7 Transport volume projections

As indicated, SULTAN is the preferred source for transport volumes. We cross-checked the figures from SULTAN with data from TREMOVE, Eurostat and the DG Energy and Transport Pocketbook. For passenger transport we found only minor differences.

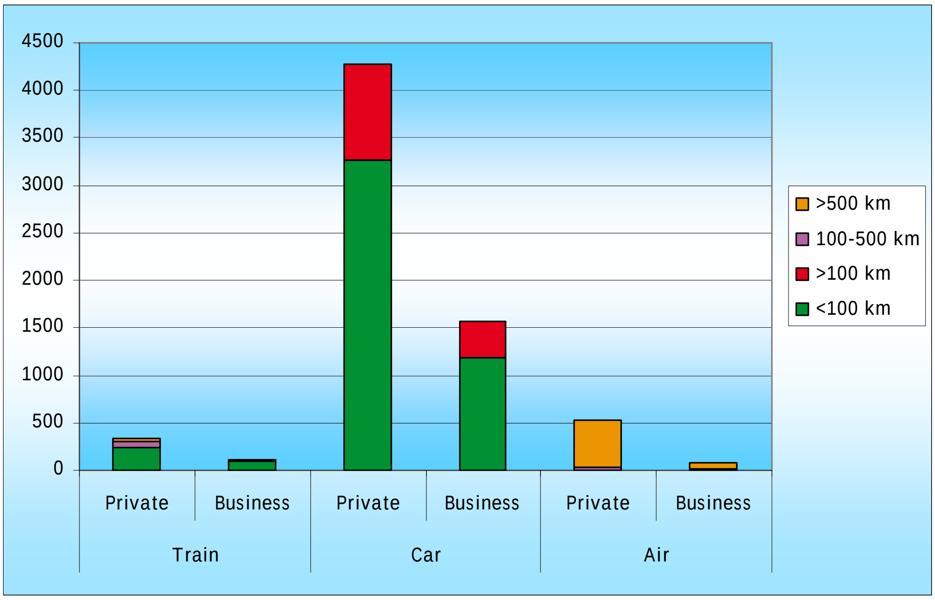
For freight transport, SULTAN is based on TREMOVE 2.7. However, we found major differences between SULTAN, more recent versions of TREMOVE and available statistics. We therefore used 2008 statistical data rather than the SULTAN figures. The figures for freight transport are based on 2008 statistics from the DG TREN Pocketbook (EC, 2010b). The volume growth rates subsequently used to arrive at 2020 and later are from the European Commission study *European energy and transport - trends to 2030* (EC, 2008a). Because the categories in SULTAN and in the DG TREN statistics do not match the categories in our segmentation, we used other sources to distribute over market segments, as we did for the emission factors. Annex C presents the sources used.

Both the scenarios used assume no future policy interventions, as the objective is to present a baseline scenario that can be set off against such future interventions.

Since rail competes with road and air transport in a limited number of markets only, the following assumptions were made:
- Freight rail only competes with the largest categories of truck; small distribution trucks (<16 tonne GVW) were therefore ignored.
- Inter-continental air traffic was ignored.

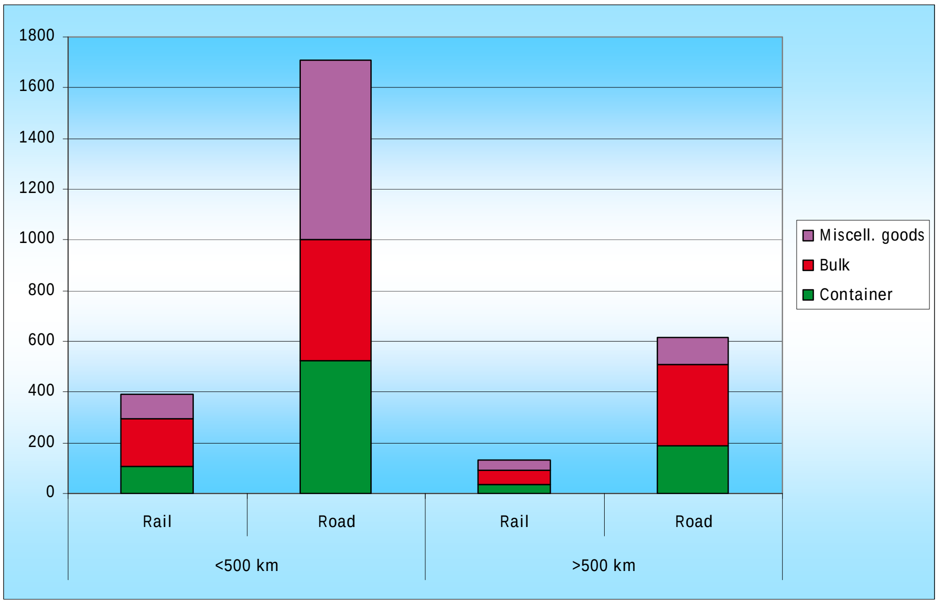
Figure 6 and Figure 7 and Table 7 and Table 8 present the projected volumes in passenger- and tonne-kilometres for the years 2020, 2030 and 2050.

Figure 7 **Projected transport volumes per passenger transport mode in 2020 in different market segments (billion pass-km)**



Note: Volume of aircraft transport includes all distances travelled by planes on intra-EU flights.

Figure 8 **Projected transport volumes per freight transport mode in 2020 in different market segments (billion tonne-km)**



Note: Road transport are volumes for trucks over 16 tonnes GVW.

Table 7 **Projected passenger transport volumes**

Passengers		**2020**			**2030**			**2050**		
		<100 km	**100-500 km**	**>500 km**	**<100 km**	**100-500 km**	**>500 km**	**<100 km**	**100-500 km**	**>500 km**
Billion pass-km										
Train	Private	243	61	34	263	66	37	302	75	43
	Business	89	22	5	96	24	5	111	28	6
Car	Private	3,260	1,014		3,584	1,144		4,234	1,402	
	Business	1,189	380		1,279	448		1,458	583	
Aviation	Private	34		497	37		550	41		657
	Business	9		75	11		105	14		166
Total market share (pass-km)										
Train	Private	4%	1%	0%	3%	1%	0%	3%	1%	0%
	Business	1%	0%	0%	1%	0%	0%	1%	0%	0%
Car	Private	47%	15%		47%	15%		46%	15%	
	Business	17%	5%		17%	6%		16%	6%	
Aviation	Private	0%		7%	0%		7%	0%		7%
	Business	0%		1%	0%		1%	0%		2%

Note: Projected volumes for passenger cars and passenger trains are based on the assumption that 80% of the trips below 500 km in TREMOVE are shorter than 100 km.

Table 8 **Projected freight transport volumes**

Freight	2020				2030				2050			
	<500 km		>500 km		<500 km		>500 km		<500 km		>500 km	
	Rail	Road	Rail	Road	Rail	Road	Rail	Road	Rail	Road	Rail	Road
Billion tonne-km												
Container	108	525	35	189	121	592	48	263	155	771	75	454
Bulk	189	479	57	319	206	539	69	418	254	699	97	674
Miscell. goods	95	705	39	109	107	818	51	151	137	1117	77	257
Total	*392*	*1,709*	*131*	*617*	*434*	*1,948*	*167*	*832*	*545*	*2,586*	*249*	*1,386*
Total market share (tonne-km)												
Container	4%	18%	1%	7%	4%	17%	1%	8%	3%	16%	2%	10%
Bulk	7%	17%	2%	11%	6%	16%	2%	12%	5%	15%	2%	14%
Miscell. goods	3%	25%	1%	4%	3%	24%	1%	4%	3%	23%	2%	5%
Total	*14%*	*60%*	*5%*	*22%*	*13%*	*58%*	*5%*	*25%*	*11%*	*54%*	*5%*	*29%*

The characteristics of the baseline scenarios can be summarised as follows:

Passenger:
- 1% annual growth of private car transport, 0.8% growth of rail transport and 1.3% growth of air transport as a result of 2% average annual growth in GDP as well as slight population growth up to 2020, with no further increase thereafter.
- A 6.6% market share of rail in 2020, decreasing slightly to 6.2% in 2050.
- The market share of rail concentrated mainly in private transport for shopping, holidays, etc. (4.9% market share in 2020).
- The strongest position of rail on distances below 100 km (market share of 6.9%), where it competes only with cars. On longer distances aviation is also a competitor, and the market share of rail is 5.7% in 2020, decreasing to 5.1% in 2050.

Freight:
- 1.8% annual growth of road transport and 1.4% growth of rail transport as a result of 2% average annual growth in GDP as well as slight population growth up to 2020, with no further increase thereafter.
- An 18.4% market share of rail in 2020, decreasing to 16.7% in 2050 (waterborne modes and trucks below 16 tonnes excluded[5]).
- The highest market share of rail on distances below 500 km (13.8 vs. 4.6% on distances over 500 km).
- The strongest position of rail in shipment of bulky goods (23.6% market share over all distances, 28% market share over short distances and only 15% market share on distances over 500 km).

[5] Including inland shipping reduces the market share of rail to 16%, while the share of trucks (>16 tonnes GVW) becomes 73% and inland shipping has a market share of 10% in 2020.

3 Key drivers for increasing the modal share of rail

3.1 Introduction

The key drivers and constraints for modal shift from road to rail can be derived from case studies, literature (Woodburn, 2004; Freightwise, 2007; EC, 2010c) and practical experiences with modal shift projects. Various research projects in Europe provide ample insight into the challenges of a modal shift from road to rail. In the following chapters we discuss some of the key drivers for increasing the modal share of rail in freight and passenger transport.

3.2 Freight transport

Key drivers and constraints can be considered from three different perspectives:
1. The user: haulier, shipper.
2. The supplier: the logistics service provider, transport operator.
3. The authorities/society.

Table 9 presents an overview of the most important drivers and constraints for each of these three perspectives, with a distinction made between the key driver and underlying drivers and constraints.

Table 9 **Overview of key drivers and constraints in rail freight transport**

Perspective	Key driver	Drivers/constraints
User	Costs	Transport costs
		Inventory costs
		Handling costs
	Time	Transport time/speed
		Lead time
		Just in time
	Quality	Reliability
		Flexibility
		Information/traceability
		Transparency/simplicity
		Security
	Cargo	Physical characteristics
		Transport requirement
Supplier	Services and network	Frequency
		Destinations
		Service orientation
		Price
	Infrastructure	Terminals
		Interoperability
		Capacity
Society	Accessibility/mobility	Congestion
		Safety
	Environment	Air quality
		GHG emission
		Noise emission
	Cost	Social cost (internal and external cost)

Source: Woodburn, 2004; Freightwise, 2007; EC, 2010c and own analyses.

It is difficult to prioritise the different drivers distinguished, as the exact situation will depend to a large extent on the specific characteristics of the logistics chain involved and, above all, on the framework conditions applying in each individual country. In virtually every case, though, costs are the predominant factor for users. When the total costs of alternative modes are similar, the mode with the highest time and quality performance will be preferred. It is important to note, that costs are dependent on political instruments such as EU ETS, energy taxation or VAT. Unfortunately, taxes and levies are not distributed according to the environmental performance of transport modes.

For many commodities and practically all distances below (roughly) 200 km, road transport is superior to rail transport in terms of cost and feasibility. In particular, the combination of flexibility, speed, transparency, simplicity and trouble-free border crossing makes road transport, especially on short distances, a modality difficult to compete with. The huge share of road in total inland transport performance in many European countries is a clear illustration of its market dominance.

In the freight sector there is still a large gap between the demand and supply of rail services. The main causes of this gap can be summarised under the headings of three major constraints.

The balance of market power

Due to the capital-intensive nature of rail transport, many railway operators are still very large organisations with substantial market power. Even large rail transport users (companies like Shell and Unilever and logistics service providers) are not always in a dominant position when negotiating with rail organisations. Also, complex network systems like the Single Wagonload system necessitate a critical mass that only large operators can offer.

Insufficient rail offer

Compared with the road network, the density of railway infrastructure is relatively low. In recent decades the number of shippers having direct access to the rail network has declined considerably, and during the past few decades many direct rail links have been discontinued, limiting the capacity of rail operators to provide a comprehensive and robust transport offer.

Partly as a result of this, many rail companies are still relatively weak, although improving, on key supply-side factors that meet the everyday needs of shippers, in particular with respect to:

- Frequency, speed and reliability of shipments.
- Offering transport for both large and small volumes.
- Covering the entire transport chain: door-to-door service and in various countries.
- Fast and easy contracting.
- Availability of value added services, e.g. tracking and tracing, packaging, stock management.
- Availability of conditioned containers.
- Competitive and transparent prices.

Lack of 'readability' of the offer and tariffs

Because of the complex structure of railway services, the readability and variety of prices and services is limited compared with road transport and inland shipping. This lack of readability can be seen by some shippers and forwarders as potentially hampering efficient decisions on transportation mode.

A factor also hampering greater use of the potential offered by rail transport is the lack of widespread knowledge of the possibilities that rail does already offer. As long as this lack of knowledge remains, shippers will tend to stick to ingrained patterns.

Another constraint relates to information on current cargo status. In this respect, further ongoing developments in information and communications technology, such as tracking and tracing systems, will enable rail transport to catch up with road transport.

A number of trends can also be distinguished that can be seen as opportunities favouring a larger modal share of rail. Two, in particular, are important:

- Growing awareness of the environmental impacts of transport and decisions by ever more businesses to factor these into their transport decisions. Because of its low environmental impact rail is also attracting government interest, particularly in environmentally sensitive areas like the alpine regions.
- Growing congestion on roads, making rail more and more competitive with road transport in terms of transport times.

Research comparing rail freight transport volumes in the US and Europe (Vassallo and Fagan, 2005) shows which segments of rail transport are strongest in Europe:

- Dry bulk:
  - Coal and ores.
  - Agricultural products.
  - Construction materials.
- Liquid bulk: chemical products.
- Containers: general cargo, manufactured products.

The fourth segment, that of wagon loads of large parts, semi-manufactured articles, paper rolls, steel coils, etc. has been in slow decline since the closure of many railway links (sidings and feeder lines) and marshalling facilities in the rail network from the nineteen-seventies onwards. In general, the share of rail transport has declined in those segments where overall economic activity has decreased: steel, building materials and chemicals (Railcargo, 2009).

3.3 Passenger transport

When assessing modal choices with respect to passenger transport, due allowance must be made for the purpose of the trip and the segment of demand involved. The drivers usually considered when analysing modal choice are cost, time, quality of transport, reliability, accessibility and availability of the network and flexibility of services.

For most users the cost variable is generally the key factor inducing a choice for rail, with the time aspect weighing less heavily in the balance. This holds in particular for segments of demand involving travel for leisure (tourists, students), for personal affairs and in general for low-income groups.
For business trips travel costs are less relevant, but the travel time is deemed all the more important, together with the availability of services, the timetable, the accessibility of terminals, punctuality and comfort.

Rail transport is a popular mode for (sub)urban and inter-city transport. As a result of increased congestion on roads and the availability of new high-speed links, rail offers services that score comparatively well in terms of reliability, security and punctuality. However, the passenger car offers opportunities that explain its strong position and can not be offered by rail.

The rising share of the passenger car can be explained by the (real and perceived) advantages of private transport over public and alternative transport modes. Private transport is generally perceived as faster, more flexible (in particular outside urban areas), more door-to-door and more comfortable and cheaper than public transport (EEA, 2006).
The main reasons behind the growing share of passenger cars are thus:

- Increased car ownership, particularly in the new EU member states.
- The need for people to combine tasks at a growing number of locations, driven by the increasing participation of women in the labour market and a growing amount of time spent on leisure activities. This calls for more flexible and faster door-to-door means of transport, a demand that is generally better met by private rather than public transport.
- The current structure of transport costs (with a high share of fixed vehicle costs rather than variable costs associated with actual usage) does nothing to remove the perception of private transport being cheaper than public transport. When deciding on a trip, motorists generally only take the

- Physical planning: on the outskirts of urban areas, where public transport is far less accessible, accessibility to basic services by public transport, cycling or walking decreases. This leads to more car usage and consequently traffic bottlenecks in and around cities. Hence, urban sprawl – the expansion of cities – may lead to greater car dependency and usage.

The described trends are all expected to continue, although there may be a slowing down of the rise in car ownership as saturation levels are reached. One of the main drivers of future developments will be trends in the average travel speed of the various modes.

4 Literature survey of studies on modal shift potential

4.1 Introduction

Various studies have endeavoured to estimate the potential for a shift from road or air transport to rail. These vary widely in methodology, assumptions and results. In this chapter we provide an overview of the available studies that have tried to estimate the potential for modal shift in the EU. This analysis covers both passenger and freight transport. In Section 4.3 we consider the conclusions that can be drawn on the basis of these studies.

4.2 Overview of the most relevant studies

This section reviews the available studies on modal shift for both freight and passenger transport. Our analysis is based on the following criteria:

- Scope/conditions.
- Modal shift effects.
- Is the study transferable to an EU figure?

In analysing the different studies, we refer to several different kinds of percentages:

- Percentage points, representing percentages of the entire transport market. One percentage point thus refers to 1% of all tonne-kilometres or passenger-kilometres performed.
- Percentage of rail transport volumes, referring to the relative change in rail transport volume,
- Percentage of road transport volumes, referring to the relative change in road transport volume.

4.2.1 Freight transport

Vassallo and Fagan (2005)

In the United States the share of rail freight transport is 40%, which is four times higher than in Europe (EU-15 in this section). This difference is remarkable, because both started from a share of 45% in 1960[6]. There are significant differences between the US and Europe that influence the share of rail. The three key differences are:

- Competition from water and pipeline transport.
- Shipment distance.
- Commodity mix.

Coastal and inland waterway transport carry 45% of all goods in the EU, compared with 20% in the US, a difference that can be explained by Europe’s far longer coastline. The importance of coastal and inland shipping also contributes to the fact that pipelines carry only 3% of freight in the EU, compared with 12% in the US. Many commodities that are carried by pipeline in the US are transported on coastal and inland waterways in the EU.

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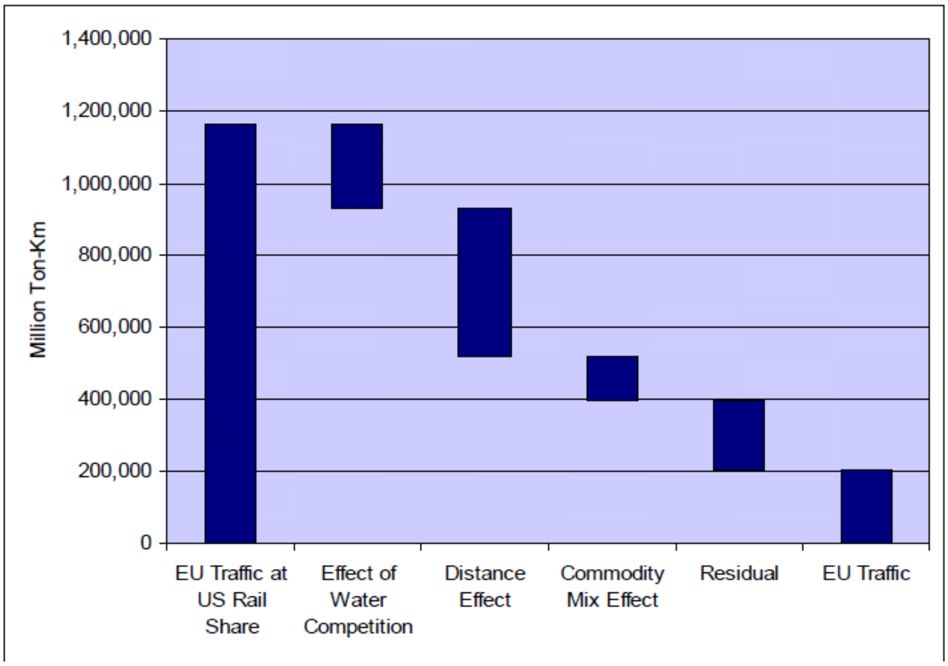
6 EU-15 share.

In the US the average shipping distance is significantly higher than in Europe for every major category of goods. On longer distances, rail transport becomes more competitive. This holds particularly in the US, where there are none of the interoperability issues that characterise the numerous borders within the EU. In the US the average distance for rail and road freight transport is 400 km, while in the EU it is around 150 km. In the US the share of rail is especially high in the category above 1,000 km, while the share of rail in the EU in this category is smaller than in the category 500-1,000 km.

The commodity mix in Europe is similar to that in the US, with two important exceptions. Coal accounts for 23% of all rail and truck tonne-km in the US, but only 1% in the EU[7]. Manufactured goods, by contrast, account for only 10% in the US, but for 34% in the EU. Since railroads are generally more competitive in carrying bulk and lower-value commodities, these differences in commodity mix favour rail transport in the US and disadvantage it in the EU.

Figure 9 below illustrates that the 'distance effect' (see above) is the greatest, followed by competition from waterborne modes and the difference in commodity mix. Based on the differences with the US, the analysis also concludes that the share of rail in the EU could be twice as high as at present. The residual volume can be regarded as the net effect of a combination of policies and rail sector service supply.

Figure 9 Explanation of differences in traffic volumes between US and EU-15 (2000)



Source: Vassallo and Fagan, 2005.

[7] This is because only a limited amount of coal is used for power generation in the EU, while in the US substantially greater volumes are used for this purpose as well as exported.

In addition to supply and demand factors, several policies are mentioned as being of influence on the share of rail in Europe (Vassallo and Fagan, 2005; OECD, 2010):
- Insufficiently open markets.
- Lack of interoperability.
- The national focus of European railways.
- Allocation of railway capacity in favour of passenger transport.
- Lack of productivity-enhancing infrastructure. Trains in the US are often twice as long as in the EU. In addition, double-stack container services are widely used, while in Europe they are not.

The aforementioned factors contribute to the price differences between rail freight transport in Europe and the US. Rail freight transport is two to three times more expensive in France, Italy, Spain and Germany than in the United States (The Economist, 2010).

The differences from the modal shares of the 1960s are also due to the fact that the quality and supply of road transport has increased significantly since then.

ZEW (2008)
The ZEW study calculates the GHG emission reduction potential of two policy measures to stimulate modal shift from road to rail in Germany:
- Road infrastructure charging.
- A bundle of measures to achieve an average rail speed of 80 km/h.

In Germany a road user charge in the range of 9-14 Eurocents was implemented in 2005 for trucks with a gross vehicle weight of over 12 tonnes. The ZEW study, based on an econometric analysis of an empirical survey among 500 German forwarders encompassing a long range of attributes shows that the charge led to a 7% increase in road transport costs and a 0.8% increase in the costs of combined transport. The study shows an increase of the share of combined transport in the sample by 1-2 percentage points.

The low average speed of rail services, especially on international corridors, is often seen as the main reason for the relatively low share of rail in the modal split. The ZEW study assumes that the EU White Paper measures aiming to improve rail transport quality will indeed lead to an average speed of 80 km/h. This higher speed will reduce the time span of the main haulage by rail by about 52% and by about 24% for the overall combined trip. On average for all observations in the study, the probability of choosing combined transport increases by 8 percentage points. Although this analysis focuses on Germany, the results can be used for an EU analysis, since the price and speed impacts were estimated to impact the whole rail part of the trips.

Öko-Institute (EEA, 2008)
Using a theoretical approach to estimate the potential for modal shift, this study estimates that the transport volume that can be shifted from road to rail within Europe may be 19% of the current (2006) transportation volume by road (in tonne-km)[8]. This amounts to an increase in rail freight by 362 billion tonne-kilometres, which is an increase by a factor 1.7 in 2020. A note is made that in certain EU countries this would require a very substantial effort, including massive infrastructure investments, and it is therefore unlikely to be

[8] Based on Section 2.2, this is equal to around 14 percentage points. Rail would thus be able to increase its share by 14 percentage points.

achievable by 2030. In the long term (2050) this maximum potential might be obtained, but would again require major investments.

The analysis is based on TRANSCARE estimates of the traffic volumes that are physically amenable to modal shift.

Table 10 **Volumes of goods physically suitable for shift to rail transport in Germany, 2005**

	Share of volume suitable for modal shifting	Freight traffic volume in Germany (2005)	Volume suitable for rail transport in Germany
	%	Mln. tonne	Mln. tonne
Agricultural products and live animals	25	141	35
Foodstuffs and animal fodder	35	304	106
Solid mineral fuels	0	12	0
Petroleum products	37	105	39
Ores and metal waste	10	29	3
Metal products	35	72	25
Crude and manuf. minerals, building materials	15	1,361	204
Fertilisers	30	20	6
Chemicals	63	210	132
Machinery, transport equipment, manufactured articles	68	474	322
Total	**32**	**2,728**	**873**

Source: EEA, 2008.

These figures do not take into account factors like costs, distance, access to rail infrastructure and services and quality. In Table 11 we report the assumptions made by Öko-Institute with respect to the potential for modal shift in different distance classes.

Table 11 **Modal shift potential in different distance classes**

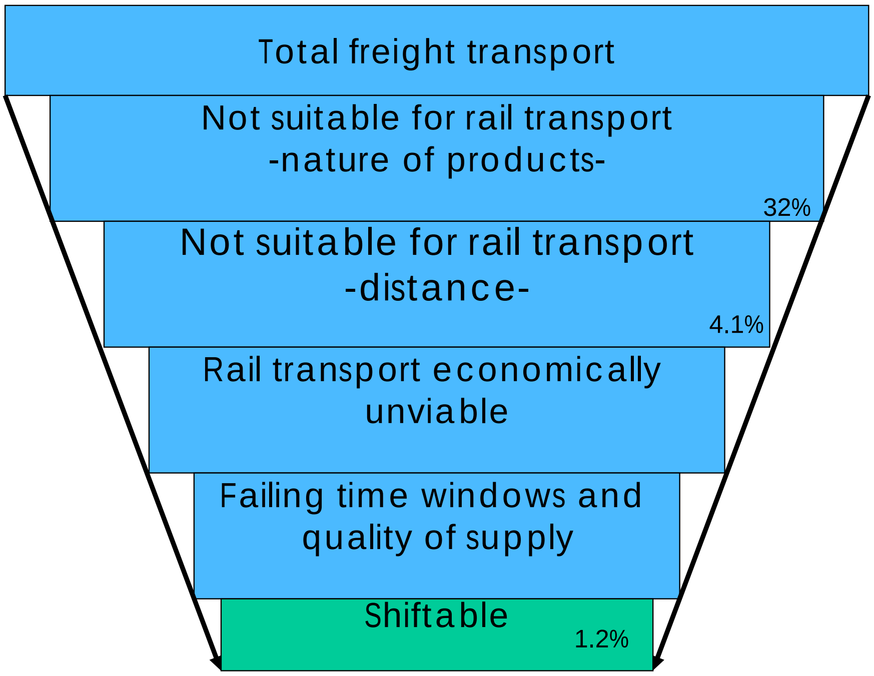
Distance class	Modal shift potential per distance class as percentage of current road transport volume	Resulting modal shift potential (% of tonnes)
50-150 km	5%	6.6%
150-500 km	40%	50.5%
>500 km	100%	42.9%
Total		**100%**

The calculated theoretical potential for modal shift implies a possible increase in rail transport volumes by a factor 3 to 5. As a conservative estimate the theoretical potential was therefore recalculated using a doubling of rail transport volumes. This led to a reduction of the theoretical modal shift potential, resulting in a potential for modal shift of 362 billion tonne-km. This corresponds to 14 percentage points.

This theoretical estimate includes not only road transport, but also cargo that is currently shipped by inland barge.

Öko-Institute also refers to estimates that make allowance for factors like distance, costs, quality of supply and rail access. On the basis of figures from the German Road Federation (BGL) it is concluded that in that case only 1.2% of road freight transport volumes can be shifted to rail; see Figure 10.

Figure 10 **Factors limiting the potential for modal shift (figures refer to % of road tonne-kilometres that can be shifted)**



Source: EEA, 2008, referring to German Road Federation (BGL).

The study shows that the theoretical potential for modal shift is significant, but that several criteria currently limit the use of rail as a means of transport. Furthermore, this study also illustrates that within the current context, the modal shift potential is limited.

The study is useful for drawing conclusions on an EU level.

FERRMED Great Axis (2009)

FERRMED[9] is a non-profit association promoting the so-called FERRMED Great Axis, a rail network interconnecting the EU's major sea and inland ports as well as the main East-West axes. One of the organisation's activities has been to define a package of standards aimed at expand the freight links between the mainports and their respective hinterlands as part of a drive to improve the functioning of the EU rail grid.

The association has developed a concept for a network that would interconnect key maritime and fluvial ports, the most important economic regions and the main East-West axes of the European Union, spanning over 3,500 kilometres from Stockholm and Helsinki to Algeciras (Spain) and Genoa,

9 FERRMED stands for Promotion de grand axe Ferroviare de Marchandises, www.ferrmed.com.

crossing 13 countries (Belgium, Denmark, Finland, France, Germany, Italy, Luxembourg, Netherlands, Spain, Sweden, United Kingdom, Norway and Switzerland), and encompassing the North Sea and Baltic Sea basins and Western Mediterranean coasts. The FERRMED Great Axis would directly affect an area encompassing 54% of the EU's population and 66% of its GDP. In addition, it would link the EU to Russia, through the connections with the western end of the Trans-Siberian railway in St. Petersburg and Finland, and with the north of Africa.

The construction and upgrading of this network would provide a solid stimulus to rail freight transport in the EU. The FERRMED association has undertaken a study that calculates the costs and effects of different scenarios.

Table 12 Costs and effects of different FERRMED scenarios

	Medium	Full/Full+
Investments (1,000 mln Euro)	131	178-211
Modal share of rail vs. reference (change in rail tonne-km in study area)	+8.4%	+15.6%
Modal share of road vs. reference (change in road tonne-km in study area)	-1.4%	-2%

Note: A 2% decrease means a 1.4 percentage point change in the modal split. The 15.6% growth for rail represents 4 percentage points. In the full scenario, the share of coastal shipping will also decline, which explains the difference between the absolute road and rail growth reported.

A socio-economic cost-benefit calculation shows that all investments are balanced by benefits. Travel time benefits play a significant role in this analysis. All currently planned policy measures (e.g. the Eurovignette revision and the railway liberalisation package) are part of the reference scenario.

FERRMED standards

The FERRMED Great Axis is a reticular and polycentric network with a major socio-economic and intermodal impact (comprising three great North-South and three great East-West Trans-European axes, together with their corresponding subsidiary main feeder lines).

The main branches of the great axes are characterised as follows:

- Electrified (preferentially 25,000-Volt) conventional lines with double track, giving priority or exclusiveness to common freight traffic and suitable for trains with a per-axle load of 22.5-25 tonnes.
- High-performance parallel lines available for exclusive or preferential use of passenger and light, fast-moving freight transportation properly connected with the main airport network.
- Width of the tracks: UIC.
- UIC C loading gauge.
- Train lengths of up to 1,500 metres and from 3,600 to 5,000 tonnes loading capacity.
- A maximum slope of 0.012 and limitation of ramp lengths.
- Availability of a network of intermodal polyvalent and flexible terminals with high levels of performance and competitiveness, based in the harbours and main logistic nodes of the great axes.
- Usable length of sidings and terminals for 1,500 m trains.
- Unified management and monitoring systems by main branches of every great axis.
- ERTMS system along the tracks.
- Availability of capacity and traffic schedules for freight transportation '24 hours a day and 7 days a week'.
- Harmonisation of administrative formalities and social legislation.
- Transport system management shared among several rail operators (free competition).
- Favourable fees for the use of infrastructures, bearing in mind the socio-economic and environmental advantages of rail.
- Reduction of the environmental impact of the freight transportation system (particularly noise, vibration and GHG emissions) through retrofitting of old railway rolling stock, infrastructural solutions where needed, and an increase in the share of rail in long-distance land transportation by up to 30-35%.

Since this study is EU-wide in scope, it can be used to draw conclusions at the EU level. Although it focuses on an area smaller than the EU as a whole (54% of population, 66% of GDP) an EU-wide figure would not be much higher, since the study is explicitly concerned with increasing the share of rail in EU international freight transport. This study is particularly relevant for estimating the potential of rail in the long-distance freight market.

UBA (2010)

Based on a range of supply-side measures, this study estimates that a doubling of rail capacity and transport volumes in Germany in 2025 would be possible. One-third of the growth of the rail volume is due to better use of the current infrastructure. The rest of the capacity increase is due to infrastructure construction. Optimisation measures include:

- Differentiated pricing aiming at increased capacity (train length).
- Improvement of signalling and safety systems.
- Improved planning.
- Speed harmonisation.
- Passing lane tracks.

Overall, 11 billion Euro is needed to finance the envisaged infrastructure update and expansion.

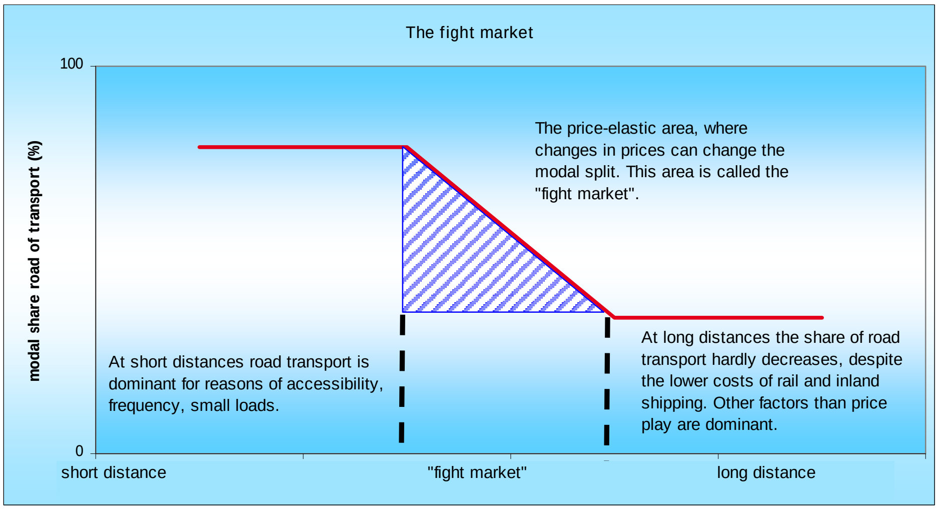
This study shows that German rail capacity could be increased at significantly lower cost than assumed by FERRMED. However, the FERRMED standards are more challenging than the optimisation measures in the UBA study.

Forced modal shift (PRC, 2007)

The Dutch government commissioned a study to investigate the scope for reducing the number of truck kilometres by 10-20% by means of fiscal measures like road pricing.

The study concludes that price increases can induce a 3% shift of the total freight transport market to alternative modes. This will occur in the so-called 'fight market': transport distances between 400 and 600 km, where the share of road transport is gradually declining and the shares of rail and inland shipping are on the rise. The required price increase differs per market segment, ranging from 20% to nearly 400%. With price increases in the order of magnitude of the German MAUT charge for heavy trucks (10-20%), the modal shift effects have been estimated at around 0.4 to 0.6 percentage points.

Figure 11 Definition of the fight market



The study concludes that under the conditions studied the social costs are higher than the social benefits. Raw materials and end products, agricultural bulk products and containerised goods are the most price-sensitive product categories. According to this study these comprise 13% of the Dutch national freight transport market.

TEN STAC (NEA et al., 2004a)

Projected changes in traffic volumes as a result of the TEN network have been studied by NEA on behalf of the European Commission. The study concludes that, compared with a reference scenario, an additional 107 million tonnes of freight will be shipped by rail in 2020. The total volume of road freight in that year is estimated at 6,200 million tonnes, of which 1,200 million tonnes is international carriage. These figures imply that almost 10% of international freight traffic in the EU will shift to rail[10]. This corresponds to around 2% of overall road transport, or 1.4 percentage points.

[10] Since tonne-km figures are lacking, an exact estimate cannot be made.

Dutch Ministry of Transport study (TNO, 2006)

TNO has investigated which flows of goods are in principle amenable to transportation by rail, inland barge or coastal vessel, using five criteria to assess the feasibility of alternative modes.

Table 13 Factors limiting the potential of alternative transport modes

Limiting Factors	Potential left for alternative modes *(mass %)*
Connection (Is there a transhipment terminal available near the destination?)	87
Distance (minimum 200-250 km for rail)	61
Product characteristics (Less than 12 packages per m^3, value < 6,000 Euro per m^3)	50
Size of shipment (>1 tonne)	35
Speed (>2 days)	34

The study concludes that 34% of all mass to be moved in the Netherlands can be transported by alternative modes, with 18% suitable for rail transport. This is well above the current share of rail in the Netherlands. The study concludes that if certain bottlenecks are removed, there is certainly scope for rail to increase its share. TNO explains the currently relatively low share of rail transport compared with the estimated potential by the lack of liberalisation and competition for capacity between passenger and freight transport.

Overall, the estimated potential for the alternative modes is 34%, while their current share is 41%. This implies that the market for transport by alternative modes cannot be readily increased.

These figures apply to the Dutch situation, which makes it difficult to transfer the conclusions to an EU context. However, since the study concludes that the alternative modes already have a market share 7% above the calculated potential, one can also question the research framework. For this reason and because of the limited scope of the research, this study has not been used in our analysis.

HOP! project (2008)

The HOP! project aims to assess the impact of high oil prices on the European economy and transport sector. Several alternative scenarios were simulated by means of two strategic tools: the ASTRA model and the POLES model. Each scenario assumes a combination of future higher oil price and investments in the energy sector (Martino et al., 2008). One of the impacts concerns the shift from road to alternative modes of transport. Since fuel is a significant component of truck operating costs, while only of relatively minor importance in the rail sector, common expectations are that in a future of more expensive energy, rail freight carriage should become more attractive. Although this expectation is confirmed by the outcome of the HOP! study, the projected shift to rail is in fact rather limited. With an oil price three times higher than in the reference scenario, the share of rail would merely increase from 15 to 16% in the year 2050. The impact should be larger for consignments within a range of 700 km, while for longer distances the competition of the maritime mode would limit the modal shift from road to rail.

IMPACT (CE, 2008b)
In the light of the Eurovignette Directive, the European Commission commissioned CE Delft, INFRAS and several other parties in 2007 to carry out a study on internalisation of the external costs of transport. The study, with the acronym IMPACT (Internationalisation Measures and Policies for All external Costs of Transport), assessed the available methods for estimating these costs and provided a consistent, scientifically sound framework for that purpose. In addition, the study analysed the impacts of various scenarios for internalising external costs in the EU.

The assessment of impacts of internalisation scenarios was based on model runs of TRANSTOOLS and TREMOVE. The results of these two models differed considerably. Deliverable 3 on the impacts of internalisation scenarios concluded that the results of the network model TRANSTOOLS indicate that a modal shift to rail and waterborne transport modes is likely to occur, particularly on long distances.

The scenarios with the greatest price increase for road transport included charging variable infrastructure costs and external costs on all roads and similar pricing for non-road modes. In those scenarios road transport demand decreases by 7% (tonne-km) and 2% (tonnes lifted). At the same time, rail transport demand increases by up to 10% (tonne-km) and 4% (tonnes lifted). It should be noted that the TRANSTOOLS model later proved to have a relatively low price elasticity, implying that the overall impacts of full internalisation of external costs may even be somewhat higher.

In these scenarios, maritime and inland shipping also showed significant growth rates, benefiting from the decrease in road transport demand.

Price sensitivity (Significance, 2009)
In addition to models, the impact of internalisation can also be estimated using the price elasticity figures reported in the literature.

Significance (2009) reports a price elasticity of 0.3 for the relation between the relative increase in the vehicle-km price of road transport and the share of road volume that is shifted to rail.

If both road and rail transport were charged for infrastructure use and their marginal external costs, the overall relative price increase of road transport would be in the range of 8 to 25%[11]. Such scenarios would result in a modal shift of between 2 and 8% of road transport volume (corresponding to 10 to 32% growth of rail volume).

These figures apply to the EU and the conclusions can therefore be directly used in the present study.

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11 Assumptions: in 2010 the sum total of infrastructure costs and external costs of large Euro-V trucks on motorways were in the range of 22 to over 40 Eurocent per vkm, depending on which costs are included, their valuation, the cost allocation applied, etc. Towards 2050 air pollution and accident costs are expected to decrease, but this will be off-set by a pronounced rise in climate costs. When existing kilometre charges on EU motorways (about 12 Eurocent per vkm on average) are taken into account and a total cost of 1.20 Euro per vehicle-km is taken, the net cost increase is in the range of about 8 to 25%. The price impacts of passing on the external costs of rail are already very low and assumed to be negligible in 2050, because of decarbonisation of electricity production.

Woodburn (2004)
This article documents considerable evidence on the potential for rail to attract new traffic. However, much of the potential is unlikely to materialise without improvements in rail capability and capacity and greater customer focus by rail freight operators.

This article is based on questionnaires and interviews and does not provide any figures on potential growth, but merely identifies potential bottlenecks to growth.

4.2.2 Passenger transport

Öko-Institute study (EEA, 2008)
This study uses a theoretical approach to estimate the transport volume that could potentially be shifted from road to rail under 'optimised' conditions, viz. under four assumptions:
1. In all regions rail infrastructure is upgraded to the level of highly populated areas.
2. Travel time by train is shortened to a level equal to or better than by car.
3. Travel costs by train are decreased to a level lower than or equal to by car.
4. On any specific line, rail capacity cannot be more than doubled by 2030.

Under these assumptions the share of rail in passenger transport can increase from 10 to 17% of the combined volume of road and rail transport. This corresponds to over 200% growth relative to the baseline scenario defined. This increase is assumed to be feasible by 2030, albeit with considerable effort.

In the long term (2050) the maximum potential might be estimated by disregarding the fourth assumption. In that case, the maximum share of rail transport increases from 17 to 33% of the sum total of road and rail transport volume.

Steer Davies Gleave (2009)
Steer Davies Gleave have studied the potential for shifting air passengers to high-speed rail in the UK, using a model to estimate the effects of changes in oil price and travel time. The study provides two blocks of analysis:
1. Domestic.
2. UK to Europe.

The model used is based on generalised journey costs, consisting of the ticket costs plus the monetarised cost of travel times. The model was calibrated with current travel data. The study also shows that people tend to prefer rail travel to aviation. On trips with comparable generalised journey costs, the share of rail is around 80%.

Domestic
The study shows a slightly higher share of high-speed rail transport in 2025 under a £ 150 oil price scenario compared with 2008. This implies that a higher fuel price does not lead to any significant shift to high-speed rail. Creation of a high-speed line on the London-Manchester-Glasgow route, supplementing the existing Eurostar link to the European mainland, would cause a much greater shift from air to rail, particularly on Anglo-Scottish trips. The share of rail (versus air) could increase by 60 to 80% on certain routes.

UK to Europe

In the UK to Europe scenario, the following assumptions were made for the calculations:

- Shorter travel times, due to direct services.
- Competing rail services (lower prices).
- Rail access charges reduced by 50% on international links[12].
- Shorter check-in times (Eurostar).

The study shows that the greatest increase in the share of rail would result from a reduction in travel times. On various routes from the UK to the European mainland the share of rail would increase by a maximum of 40 percentage points. This holds for Amsterdam, Düsseldorf and Frankfurt, for example. As in the case of domestic travel, high oil prices have only a limited effect on the increase of the share of rail.

It is difficult to draw EU-wide conclusions from this study, since the spatial and national characteristics are of major influence on the outcome. Below we therefore only elaborate on the conclusion that travel times play an important role.

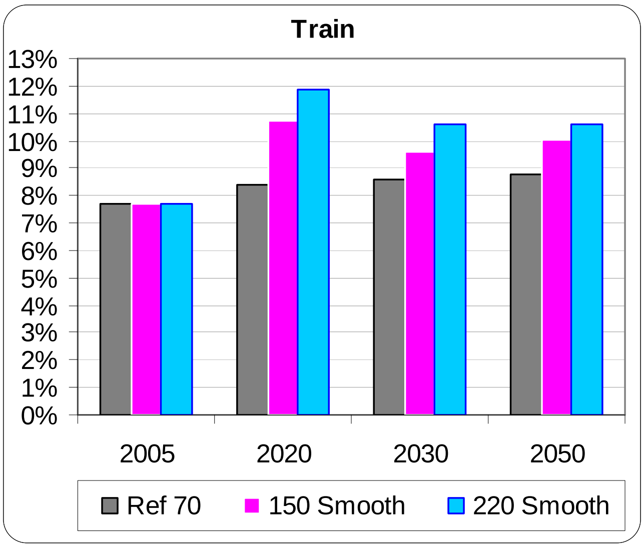
HOP! project (2008)

The HOP! project cited above for freight also examines passenger transport. According to this project, in high oil price scenarios passenger rail transport would gain some additional market share. In particular, with a doubled oil price (from 70 to 150 Euro/barrel), the share of rail passenger transport might grow from 8.5 to 10.5% in 2020. The gain is expected to be lower after 2020 because of improved fuel efficiency of cars. With a tripled oil price, the share of rail passenger transport could rise up to 12% in 2020, declining again in subsequent years.

According to HOP!, the sensitivity of rail demand to energy price increase is therefore greater than for freight. This could be explained by the relevance of transport costs, which are a determinant of choice for both types of transport but are much more significant for passengers, while freight forwarders require reliable and regular, rather than cheap services. Furthermore, rail is competitive on a wide range of distances for passenger transport, including short trips, while freight rail is not an alternative below several hundred kilometres.

[12] The rationale for this was that without this reduction there would no longer be any long-distance rail traffic.

Figure 12 Impact of high oil price on rail passenger market share



Source: ASTRA calculations in the HOP! project.

4.3 Summary and discussion

4.3.1 Freight

The studies discussed show significant differences in the potential growth of rail, as a result of their varying scope and methodology and the array of measures studied. Vassallo and Fagan (2005) and EEA (2008) are the only two studies that assess the maximum potential, while the others consider only single measures that do not provide an assessment of the full potential that can be achieved.

In addition, the studies concentrate on the short and medium term, with none of them providing a package of measures that apply to the period after 2030.

Table 14 Overview of measures and their effects

Study	Measures studied	Scope	Rail growth
Vasallo and Fagan (2005)	Full market opening, interoperability, international focus and productivity-enhancing infrastructure	EU	100%
EEA (2008)	a Theoretical potential based on trip length and the assumption that the share of rail can rise significantly on longer distances b Potential from a practical perspective (BGL)	EU	a 90% b 7%
FERRMED (2008)	131-211 billion Euro investment in infrastructure provision and quality of supply (FERRMED standards); improvement of the core EU network	Core network in EU (54% of population and 66% of GDP)	8-15%
NEA (2004a)	TEN network construction	EU	12%
ZEW (2008)	a Road pricing based on MAUT b Improvement of quality of supply by speed increase of 24% of combined trip.	Germany	a 14% b 60%
PRC (2007)	Road pricing based on MAUT	Netherlands	3-4%
IMPACT (2008)	Full internalisation of external and infrastructure costs	EU	10%
Significance (2009)	Full internalisation of external and infrastructure costs	EU	10-32%
HOP! (2008)	Doubling and tripling of oil price	EU	6%

Note: A 6% growth in rail transport volumes is equivalent to 1% growth in the share of the entire market for rail and road transport. The percentages cannot be summed, since the different studies cover the same or comparable measures.

Theoretical potential

The theoretical potential for modal shift is considerable, since a significant fraction of the goods shipped over long distances are transported by road (EEA, 2008; Vassallo and Fagan, 2005). Other sources, however, indicate that the potential for modal shift in this market is limited, since shippers have reasons - other than price - for not using rail.

We now look more closely at the various types of measure that would engender growth of rail transport.

Infrastructure capacity increase and quality of supply

Comparing the situation in the US with that in the EU and correcting for key differences shows us that rail transport volumes might be able to increase by 100% if steps were taken to resolve deficits in market functioning, inter-operability, international focus and productivity-enhancing infrastructure. One result of these improvements would be to increase the speed of rail transport – and its market share - through better integration of the rail networks and procedures across EU member states. It would also allow for growth in the long-distance market segment.

ZEW (2008) reports a 60% increase in the volume of combined transport as a result of a 24% reduction in trip duration in the combined transport chain[13]. FERRMED (2009) reports an 8-15% increase in rail by investing significantly (131-211 billion Euro) in new rail infrastructure and applying a set of EU-wide standards. Traffic forecasts made for the TEN network provide comparable results. KWC (2010), however, reports that a doubling of infrastructure capacity in Germany through optimisation measures and infrastructure investments can be achieved for less than 10% of the investments estimated by FERRMED.

Price measures in road transport

The projected impact of road pricing (based on the German MAUT scheme) varies significantly across the studies. PRC/NEA (2007) estimates the effect to be 3-4% growth for rail in the Dutch situation, while ZEW estimates 14% growth for Germany. Both these studies are national in scope, with no consideration given to the impact of EU-wide charging, and may therefore underestimate the EU-wide potential. However, analysing the study by PRC/NEA we conclude that the price elasticity they assume is significantly lower than the figures recommended by Significance (2009) in a meta-study on price elasticity. On the basis of this study we conclude that if road pricing (assuming a 10% increase) were applied across the EU, the increase in rail transport volume would be 13-19%. The IMPACT project estimates figures slightly below this estimate, but this can be attributed to the relatively low price elasticity figures in the TRANSTOOLS model.

A doubling or tripling of the fuel price relative to current levels would result in a 1% increase in the share of rail in aggregate freight transport.

Based on an analysis of both supply-side factors and government policies, we conclude that there is significant scope for increasing the share of rail. However, a strong package of policies and improved supply-side factors are required to achieve such growth. Full and detailed integrated analysis of various options for instrumentation of the scenarios is needed to predict the potential with greater precision.

4.3.2 Passenger

The information available on the future potential of rail passenger transport is more limited than for freight transport. The only study providing a full estimate of this potential is the Öko-Institute study (EEA, 2008). This shows that the potential for (high-speed) rail is significant. On longer-distance trips, rail could become more dominant in the long term. Overall, a modal share of 17% could be achieved, compared with a baseline projection of 6.6% in 2020. However, this significant growth is calculated solely from a theoretical perspective, under the following assumptions:

- Rail infrastructure in all regions is upgraded to the level of that in highly populated areas.
- Travel time by train is shortened to a level equal to or better than by car.
- Travel costs by train are decreased to a level lower than or equal to by car.
- On any specific line, railway capacity cannot be more than doubled by 2030.

[13] Assuming an average train speed of 80 km/h.

A study by Steer Davies Gleave (2009) concludes that the share of high-speed rail on European links could increase if travel times to the main destinations were shortened. Direct links without transfers would reduce travel times between European cities and increase the share of rail significantly on these links.

A doubling of the oil price (from 70 to 150 Euro/barrel) would lead to the share of rail in passenger transport growing from 8.5 to 10.5% in 2020.

To arrive at the potential indicated by Öko-Institute, significant efforts are needed with respect to both transport policies and rail service provision. Additional research is required to study the feasibility of the scenario described.

5 Illustrative case studies

5.1 Introduction

In this chapter we present several case studies embodying a successful modal shift to rail transport as well as cases illustrating the potential for rail in Europe. The goal here is to supplement the information presented in the previous chapter by reporting on specific cases where the share of rail has been or can likely be increased.

5.2 Transport of fresh produce

Rail is not commonly used for transporting fresh produce. There are several reasons why suppliers do not opt for rail for these products, in particular:
- Habits: Wholesalers are loyal to their established transporters and changing mode may be complicated. In the absence of need or incentive they will not switch to another mode.
- Prices: On various corridors rail transport prices are not competitive with those of road haulage.
- Volumes: Rail is specialised in large volumes, while in this business volumes are fragmented among several smaller suppliers. Besides, certain suppliers only have the products concerned in a particular season.
- Time: Products are sensitive to temperature, moisture and long periods in the dark, which means transport needs to be as rapid as possible.
- Cooling: Refrigerated 'reefer' containers need electricity to stay cooled, and this is unavailable on today's freight trains.

Several recent cases show, however, that rail may still be a suitable modality for the transport of fresh produce. Below we describe these cases and identify the critical success factors and existing barriers.

GreenRail[14]

GreenRail is an initiative of the Dutch flower auction FloraHolland and the Dutch branch organisation for wholesalers of flowers and plants. They organise rail transport of ornamental plants on existing intermodal rail shuttles from Rotterdam to Italy and Romania. Not all segments of the flower and plant market are suitable for rail transport. In this pilot they focused on action/ discount products and the so-called iron rations (fixed stock). These flows are predictable and can therefore be planned ahead. They make use of shuttle trains according to a set timetable. The most important means deployed to achieve a modal shift from road to rail are:
- 4th party logistics: A logistics chain coordinator is the spider in the web of the intermodal logistics chain, serving as the contact for both the wholesalers and transporters. He oversees the complete chain, is in a position to combine the loads of competing wholesalers and keeps track of the situation in the case of calamities.

[14] http://www.greenrail.nu/en/

- Conditioned containers: Initially a standardised 45-feet reefer container ('Unit45') was used in the pilot. A second phase consisted of the development of a dedicated FloraHolland container with a capacity of 43 flower containers ('Danish cars') rather than the 37 containers that can be stored in a standard 45-foot container. State-of-the art cooling technology ensures a high level of autonomy. The temperature and geographical position of the containers can be determined remotely using GPS and other ICT technologies.

The pilot concludes that communication is essential for success. If calamities are communicated in an early stage, the various actors can come up with suitable options to rectify the delay. In this, the chain coordinator plays a pivotal role. The pilot started in 2009 and will continue with a phase dealing with rail shipment of flowers, next to ornamental plants.

Transport of fruit and vegetables from Spain to UK

DB Schenker and the Stobart Group have introduced a weekly train service carrying refrigerated fresh produce from Spain to the UK (for Tesco supermarkets). This initiative is very successful and the service is scheduled to operate three times a week from the autumn of 2010 onwards. The reasons behind the success are as follows:

- By working together, DB Schenker and the Stobart Group are able to provide a fully integrated road and rail service. For customers, there is a single contact point.
- Containers are equipped with a track and trace system and the temperatures are constantly monitored and can be adjusted en route.
- Because rail transport is organised by a single rail freight operator, the connection is very fast.
- Previously, customers needed contracts for rail transport. This was very expensive because they only had small volumes during a certain time of the year. In the shuttle concept customers do not need contracts, but they can book regular loads and pay only for the space they use. The high level of utilisation enables a commercially sustainable door-to-door solution.

Multimodal transport of meat from the Netherlands to Italy

In 2007 the VanDrie Group implemented a pilot project for transporting meat by rail. Ten despatches took place. The three-day cooling autonomy of their reefer containers was sufficient. The containers could be traced by a track and trace system. The main stumbling block and the reason why this pilot was not followed up is that rail transport was not reliable in this case, because of unacceptable delays (five out of ten transports had significant delays).

The VanDrie Group concluded that, as a concept, rail transportation of meat is a good way to reduce costs and the environmental impact of transport. The present unreliability means that it is not yet a suitable option for this commodity, however.

Overall recommendations

The cases discussed share a number of success factors that can be regarded as recommendations for a future modal shift of fresh produce from road to rail. These factors are:

- Single point of communication: A single customer contact point seems very helpful. This may be a new party or a derive from cooperation among logistics service providers.

- Shuttle concept: This creates flexibility for customers who do not have a fixed flow of products or sufficient volume for dedicated transport, which is often the case in this market segment.
- Containers equipped with their own cooling facilities and a track and trace system provide a clear picture of transport status.
- Reliable travel times and services are important preconditions for rail to be a true alternative to road.

In 2009 the transport of food, food products and tobacco in the EU-27 was responsible for 232 billion tonne-km by road, of which 98 billion tonne-km on trips over 500 km. Agriculture, hunting and fishing are responsible for a further 153 billion tonne-km by road, of which 66 billion on trips over 500 km. This corresponds with a share of road transport of around 8%. This figure cannot be taken as the overall potential, but illustrates that a stronger position of rail transport in this market might contribute to a significant modal shift.

5.3 Modal shift in Switzerland

In 2006 over 25 million tonnes of freight crossed the Swiss Alps by rail, a modal share of 66%. This is by far the largest share for railways on any European transport corridor, reflecting Switzerland's concerted move towards rail transport in the vulnerable Alpine ecosystem.

The Swiss people enshrined modal shift in their Constitution in 1994, voting for the 'Alpine Initiative'. The measures adopted include:

- Construction and financing of new and improved rail infrastructure, as approved by federal decree on November 29th, 1998 by the Swiss population and Parliament.
- Two new transalpine rail links: the Lötschbergtunnel, in operation since December 2007, and the Gotthardtunnel, due for completion by 2017. The overall project (NRLA: New Rail Link through the Alps) is planned to cost CHF 18.5 billion (11 billion Euro), which is about 1% of the Swiss GDP. The Gotthard and Lötschbergtunnels will raise annual rail freight capacity from 20 to 50 million tonnes.
- Open access to the Swiss rail network for cargo traffic.
- Introduction of nationwide mileage-related Heavy Vehicle Fees in 2001 and stepwise increase of the charge levels thereafter, generating revenues of 900 million Euro in 2007.
- Revenues from the Heavy Vehicle Fee are spent on improvements and extensions of the rail infrastructure.

The Heavy Vehicle Fee (HVF) was introduced in January 2001, as the final step of a long political debate that began in 1978.

All domestic and foreign heavy vehicles and trailers for goods transport with a gross weight of over 3.5 tonnes are subject to the distance-indexed fee. The HVF calculation depends on the kilometres driven within the borders of Switzerland (on any road), the permissible gross vehicle weight (GVW) and the emission standard of the vehicle.

The HVF is considered an important instrument to encourage a shift in freight transport from road to rail, but the choice of transport mode – especially in international transport – depends on a number of factors, such as reliability and ease of transportation, which are regarded as at least as important as the price.

The impact of modal shift measures on transalpine traffic through Switzerland is clear:

– Between 2000 and 2008 the number of truck journeys through the Swiss Alps decreased from 1.4 to 1.27 million, a 9% decrease. Without introduction of the HVF and the accompanying measures, this figure would currently be around 1.6 million[15]. However, the current figure still falls short of the ambitious goal of 650,000 trucks per year.
– Over the same period, 2000 to 2008, the railways increased the volume of freight carried by 25%.

The reported modal shift has been observed in both domestic and international traffic. Switzerland's policies and perhaps also its well-operated rail system are thus yielding very good results in the short-distance market, too, as shown in Table 15.

Table 15 **Goods traffic at Gotthard, by road and rail, classified according to direction of flow and type of relation served (2004, million tonnes)**

Flow direction		Road	Rail WL[1]	Rail CA	Rail CNA	Total
North-South	Import	0.116	0.249	0.005	0.006	0.377
	Export	0.731	0.392	0.004	0.240	1.366
	Transit	2.854	3.447	0.234	5.486	12.020
	Internal	0.874	0.610	0.000	0.093	1.577
Total North-South		**4,575**	**4.699**	**0.242**	**5.824**	**15.341**
South-North	Import	1.369	0.220	0.005	0.209	1.804
	Export	0.116	0.015	0.001	0.000	0.132
	Transit	3.312	0.642	0.226	3.447	7.627
	Internal	0.512	0.398	0.004	0.182	1.095
Total South-North		**5.310**	**1.275**	**0.236**	**3.838**	**10.659**
Total		**9.884**	**5.974**	**0.479**	**9.662**	**25.999**

Source: TRT elaboration on CAFT.

[1] WL = wagon load; CNA = combined, not accompanied; CA = combined, accompanied.

Other interesting results recorded in the above table are that the vast bulk of the traffic is transit traffic and that overall traffic is unbalanced in the two directions, but different for rail and road. While road traffic volumes are substantially balanced , the unbalanced flow recorded in rail - the result of different type of goods being exchanged between the north and south of the Alps - represents a weakness of rail transport, as it means suboptimal use of available infrastructure.

To promote transalpine combined transport, the Swiss Parliament has moreover approved funds of CHF 1,600 million as payment parameters. The granting of all subsidies is based on legally binding agreements between the Federal Office of Transport (FOT) and the operators concerned. These agreements specify the numbers of trains and consignments planned and the maximum subsidies payable.

A distinction is made between different regions, to make due allowance for the differing cost and revenue situations among the contractual operators.

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15 The decrease in truck-kilometres is partly explained by the HVF and partly by the increase in maximum allowed vehicle weight for trucks that was implemented as a parallel move.

Summary

In Switzerland a combination of factors has led to the present situation that is strongly in favour of rail, compared with other EU countries. The following factors have contributed: the vulnerable Alpine environment, HGV charging and heavy investments - partly financed by cross-subsidies and operational subsidies. Switzerland can be considered as a laboratory to assess the potential for shifting goods from road to rail.

5.4 Port-hinterland transport

Throughout Europe the share of rail transport has declined in recent decades, owing to the fierce competition of road transport. Between 1970 and 2010 the share of rail in intra-EU freight transport decreased from 30% to less than 10%.

Generally speaking, one of the few segments where rail transport has retained - and in some cases expanded - its market share is the import and export flow via European seaports. Global economic developments have led to an enormous increase of transport flows from South-East Asia to Europe, entering the continent via the large mainports of Rotterdam, Antwerp and Hamburg. Container transport is the major growth sector not only at most European seaports, but also for European rail operators. Other port-related transport flows that have increased in recent years are those of ores and coal, oil and oil derivatives and food products. It is not only road transport with which rail is competing: at Europe's two biggest ports- Rotterdam and Antwerp - inland shipping has also been increasing its market share, mostly at the expense of rail.

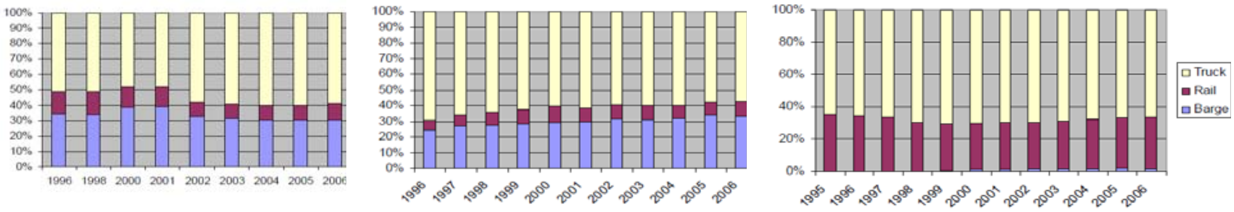
Nonetheless, port-related flows remain a very significant market segment for rail transport. In Belgium, over 50% of the imports and exports carried by rail have their origin in the port of Antwerp[16]. Including the other Belgian ports, this share could add up to more than 75%. For the Netherlands a similar share can be anticipated. Larger countries like France and Germany will have a lower share of port-related rail freight transport.

Modal split factors at seaports

At the mainports in the Hamburg-Le Havre range, the modal split varies substantially (NEA, 2004b). The share of road transport for containerised cargo varies from 40% (Bremen) to 85% (Le Havre), with the mainports of Antwerp and Rotterdam lying in between, at around 60%. The share of rail transport ranges from approximately 5% (Le Havre and Dunkirk) to over 50% at Bremerhaven. Rotterdam and Antwerp, by far the largest container ports in Europe, have a modest share of rail transport of approximately 9 to 11%. The share of barge transport varies from less than 2% (Zeebrugge) to over 30% (Rotterdam and Antwerp). Figure 13 shows trends in modal split for Europe's three largest mainports.

16 Source: Port of Antwerp.

Figure 13 Overview of modal shift in the Northern-range ports (container)



Rotterdam Antwerp Hamburg

Although rail infrastructure provisions at the three ports are comparable, it is obvious from these bar charts that when inland shipping infrastructure is available, this mode is preferred over rail. It is to be noted that, in contrast to the situation for bulk commodities, road haulage also has a very strong position in hinterland transport, with a share of around 60% at the three largest ports.

One port with good rail connections but without inland shipping infrastructure is the port of Barcelona. In 2009 the modal split between road and rail transport here was 95-5%. In the first half of 2010 the share of rail was slightly higher: 6%[17]. The low share of rail transport is probably due to a mix of economic and cultural factors. On this point no research data could be found.

This variation in modal split is due mainly to the following factors:
- The function of the port: regional port, international mainport or transhipment port.
- The availability of (rail) infrastructure and rail interoperability at national borders.
- The cargo concentration at the port and in the hinterland.
- The distance to the hinterland.

In general, ports with a regional function such as Zeebrugge, Gent, Le Havre and Dunkirk have a relatively high share of road transport, owing to the relatively short distances involved. The mainports of the European continent, on the other hand, serve a hinterland encompassing a very large geographical area. When inland navigation infrastructure is available, this modality proves to be a very strong competitor with rail transport.

Rotterdam: dedicated rail freight infrastructure and obligatory shift

To improve the accessibility of Port of Rotterdam, a dedicated rail freight link to the German border was constructed several years ago (Ribbink et al., 2004). This double-track line has a length of 160 kilometres and a capacity of 10 trains per hour in each direction at a speed of 120 km/h. As a result the travel time between Rotterdam and the Ruhr area has been reduced from 4.5 hours to less than 3 hours.

The line was opened in 2007. Forecasts were that about 160 trains per day would carry 37 million tonnes of freight by 2015. In 2010 capacity utilisation was still very limited - approximately one train every two hours - owing mainly to teething troubles with the ERTMS traffic management system, deficiencies in the connection to the German rail network and the economic recession. In 2010 capacity was increased to 50 trains a day. In due course this freight line

17 Source: Port de Barcelona.

is expected to capture 60% of the freight traffic between the Netherlands and Germany.

The Rotterdam port area is currently being extended with new land, the 2nd Maasvlakte, where new industries and deep sea-container terminals are planned. To limit the environmental impact of this development an obligatory modal split has been agreed, with the following targets set:

- Inland shipping: 45% (currently approx. 30%).
- Rail: 20% (currently approx. 10%).
- Road: 35% (currently approx. 60%).

As part of the sustainability paragraph of the contracting procedures, an enforcement system is being developed, with fines foreseen for shipping companies that fail to meet these targets, which is unique in the world. To facilitate this shift, a series of complementary policy measures are foreseen that focus mainly on inland shipping infrastructure, subsidies and pricing measures.

In the container segment the potential growth of rail transport is over 3 million TEU: from 0.6 million in 2010 to 3.7 million in 2035. This, together with the obligatory modal shift illustrates the scope for increasing the share of rail[18].

Overall recommendations

Policy measures to increase the share of rail transport to and from seaports can be subdivided into push and pull factors:

- Pull: infrastructure provision, subsidies.
- Push: obligatory shift, road pricing, environmental zoning.

In Rotterdam, a combination of push and pull policies is currently being applied, consisting of the following concrete measures:

- Obligatory modal split for containers to and from the 2nd Maasvlakte.
- Participation of the Rotterdam Port Authorities in inland rail (and barge) terminals.

5.5 Improved interoperability

'Interoperability' involves several sub-systems of the railway system, including:

- Infrastructure and energy.
- Command and control and signalling.
- Operation and traffic management.
- Rolling stock.
- Maintenance.

Interoperability is thus not only a matter of technical compatibility between the rolling stock and the network, but also involves a complex system of administrative procedures aimed at guaranteeing that rolling stock and railway lines have common or compatible characteristics. The most recent trend in interoperability is represented by developments in rolling stock and signalling. In particular, introduction of the ERTMS/ETCS systems represents a huge step in the direction of higher-level interoperability.

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[18] Port of Rotterdam.

The main driver of ERTMS (European Rail Traffic Management System) in the context of the European railway network is cross-border interoperability. Implementation of a common signalling system will remove barriers to trade and achieve seamless cross-border railway operations (see also Annex E).

The existence of more than twenty different signalling systems in Europe is the major obstacle to efficient international rail transport. This state of affairs is costly and significantly increases the technical and operational complexity of train sets. Various factors, including the constraints of having different on-board systems present and the 'non-standard' character of train sets produced in a small series for a specific route push up the costs of each train set by as much as 60%. Creating interoperability through deployment of ERTMS, together with further harmonisation of the traction-current supply, does away with the need to change locomotives, on the one hand, and reduces journey times and costs, on the other. A few examples may help illustrate the significance of interoperability for network transport volumes.

a **Corridor A – Genoa-Rotterdam**

Continuous installation of ERTMS along the whole transport corridor together with the train control system ETCS is a crucial element of interoperability. As the corridor with by far the largest transport volume in Europe, the Rotterdam-Genoa corridor is playing a pioneering role in this respect. As the first of the six corridors, Corridor A is to be fully fitted with ERTMS by 2015, insofar as the member states can provide the required funding. On those sections of the line where the system has already been installed (HST Olten - Rotstetten/Mattrist, Lötschbergtunnel, Betuwe line Kijfhoek - Zevenaar, Maasvlakte harbour line), it has achieved a level of reliability and transport volume capability that makes it suitable for sections of line with mixed traffic and higher loads.

Another key element of interoperability is a uniform traction-power supply, to eliminate the need for the time-consuming procedures involved in changing locomotives at borders. Moreover, basic operational regulations are being analysed, summarised and, wherever possible, simplified and harmonised.

b **Belgium**

The two most recent connections from Belgium to Germany (HSL 3) and the Netherlands (HSL 4) are already running in commercial service with ERTMS level 2.

HSL 3 connects the city of Liège to the German border at Aachen. The 56 km line (42 km dedicated high-speed tracks, 14 km modernised lines) came into commercial operation on 15th June 2009 and has cut the travel time between Liège and Cologne to an hour, while Liège to Aachen takes about 20 minutes at speeds of up to 260 km/h.

HSL 4 connects Antwerp to the Dutch border, where it meets the HSL Zuid (see c, below). The line is 87 km long, including 40 km of dedicated high-speed tracks and 47 km of modernised lines. It opened in June 2009 and since December 2009 trains have been running using ERTMS Level 2. Trains are now travelling at 200 km/h from Brussels to Antwerp (47 km), whilst reaching speeds up to 300 km/h on the 'dedicated' part of the line.

c **The Netherlands**
The HSL Zuid line (Amsterdam – Belgium border) is a dedicated 125 km high-speed rail link featuring state-of-the-art ERTMS Level 2 technology. While the northern part (from Amsterdam to Rotterdam) has been in commercial service with ERTMS Level 1 since September 2009, the southern section has been in commercial service with ERTMS Level 2 since December 2009.The Betuwe line (Rotterdam – German border, 160 km) has been in commercial service since July 2007 with ERTMS Level 2 without any fallback system. It is a dedicated freight route.

d **Switzerland**
A typical example of a high-capacity ERTMS line is provided by the Mattstetten–Rothrist line in Switzerland. The line is a strategic bottleneck for traffic from Bern to Basel, Bern to Zurich and Bern to Lucerne. Equipping only this section with ERTMS Level 2 has helped reduce the journey time between Zurich and Bern by 15 minutes (from 70 minutes to less than 1 hour). It has also reduced journey times between Bern and Olten, moreover, and consequently cut the travel times of both international North-South traffic through Switzerland (mostly freight) and East-West domestic intercity traffic. An estimated 242 trains (both freight and passenger) run on the line every day, at speeds of up to 200 km/h. The headway between trains has been reduced to less than two minutes (110 seconds), allowing for a considerable capacity increase. The SBB infrastructure manager reported a 15% capacity increase with ERTMS Level 2 on already optimised lines. In the case of lines with mixed traffic (passengers plus freight), a capacity increase of up to 25% was reported.

5.6 MAUT in Germany and in Austria

LKW-MAUT is the German law introducing motorway tolls for heavy goods vehicles. It empowers the government to set the toll level by regulation. The toll is charged on virtually every German motorway (‘Autobahn’), including city ring-roads. The tariff is based on the length and cost of the infrastructure concerned and is differentiated according to the number of axles on the vehicle and the engine emission category. The less polluting the truck, the less its driver pays. Since its introduction in 2005 the toll tariffs have been raised by over 40%.

The strategic objectives of the introduction of this distance-related user charge are that it allows more rigorous application of the ‘user pays’ principle, more efficient use of transport capacities, additional revenues for transport infrastructure financing and greater environmental protection due to the emission-related toll differentiation. All trucks with a permissible maximum weight from 12 tonnes upwards are subject to the toll. It is irrelevant whether these vehicles are registered in Germany or abroad and whether they are carrying goods or circulating empty.

Since 2004, use of motorways and expressways has been subject to toll payment in Austria, too. Here, all vehicles with a maximum permissible gross weight of over 3.5 tonnes are subject to tolling. Tolls are collected fully electronically without impacting the flow of traffic, using microwave technology. The technology applied is based on a Dedicated Short Range Communication (DSRC) system which meets the European DSRC Standards requirements.

The Austrian LKW-MAUT is designed to cover the infrastructure costs, including the debts of the state-owned road infrastructure company ASFINAG owed for earlier construction work. The kilometre charge is differentiated according to number of axles, type of road (with exceptional tolls in mountainous areas) and time (Brenner motorway day/night), with no differentiation by emission class.

These two existing distance-based road user charging systems have similar objectives: road infrastructure financing, environmental sustainability of the transport system and more efficient use of transport capacities.

In the first few months following introduction of the scheme, the German Ministry of Transport claimed there had been considerable shifts from road to rail. However, there is no factual evidence that the significant change in the modal split in Germany can be attributed to road charging schemes, as confirmed by the results of a survey by the German Federal Office for Goods Transport (BAG), the agency responsible for monitoring the market.

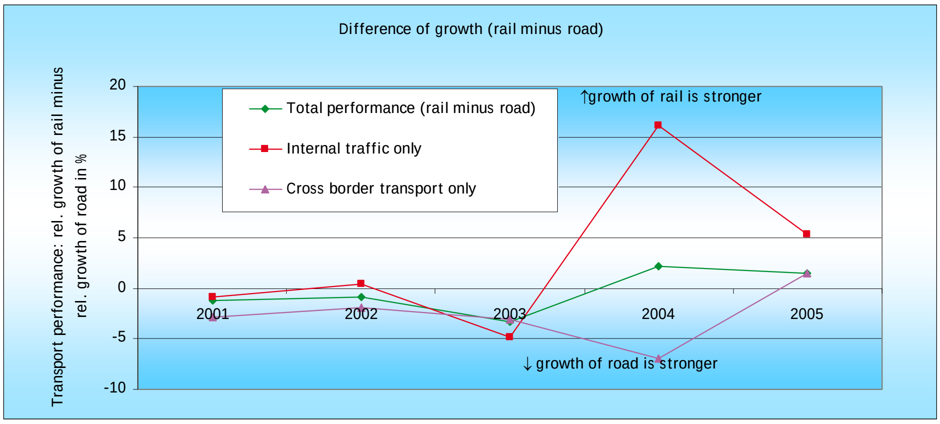
Recent research by Significance and CE Delft (2009) has found limited evidence for the effect of road pricing, as follows.

A 2005 industrial survey (BAG, 2005) provides some evidence of a modal shift as a result of the introduction of the German charging scheme:
- 3.1% of the companies surveyed answered that they use rail to a larger degree than before.
- 76.4% reported they had not changed anything.
- 19.3% have consolidated their use of road transport, thereby increasing utilisation.

Later research (Gernot, 2006) estimates modal shift effects indicating a 1.4% reduction of road transport volumes and a 4.4% increase of rail transport volumes.

In Austria, introduction of the MAUT in 2004 likewise led to a small modal shift to rail, as shown in Figure 14, with rail transport growing 2% faster than road transport.

Figure 14 Difference in growth (as % of previous year) between rail and road transport (rail minus road)



Source: Significance, 2009.

Long-distance international (i.e. cross-border) transport has remained largely unaffected by introduction of the MAUT, however, while internal transport by rail has gained a competitive edge over road haulage. It seems that road transport within Germany's borders was more sensitive to introduction of the MAUT. The reason for this might be that for long-distance (international) transport the price increase due to the MAUT was relatively low, since for international trips the distance with infrastructure charging is limited. In 2005, an advantage for long-distance rail traffic is also visible. This effect may have been triggered by the introduction of the German MAUT in 2005, as a large part of cross-border road transport in Austria passes through or comes from Germany.

Summary
According to the available data, the modal-shift effects of existing road tolls for HGV in Germany and Austria are relatively small, with demand patterns proving to be fairly rigid. The effects are likely to become more evident if the pricing system is extended across the entire European network. This could reduce or even avoid traffic diversion towards non-tolled countries and detours of traffic to secondary roads.

Furthermore, HGV pricing may have more visible impacts on modal shift if higher tariffs are applied that seek full internalisation of external costs, provided there are alternative modes offering a good and reliable service. It is evident that the magnitude of the impacts of any infrastructure pricing measure also depends on how much a competing alternative can substitute the priced transport mode. The better the alternatives, the more modal shift can be expected.

5.7 High-speed rail versus (low-cost) airlines

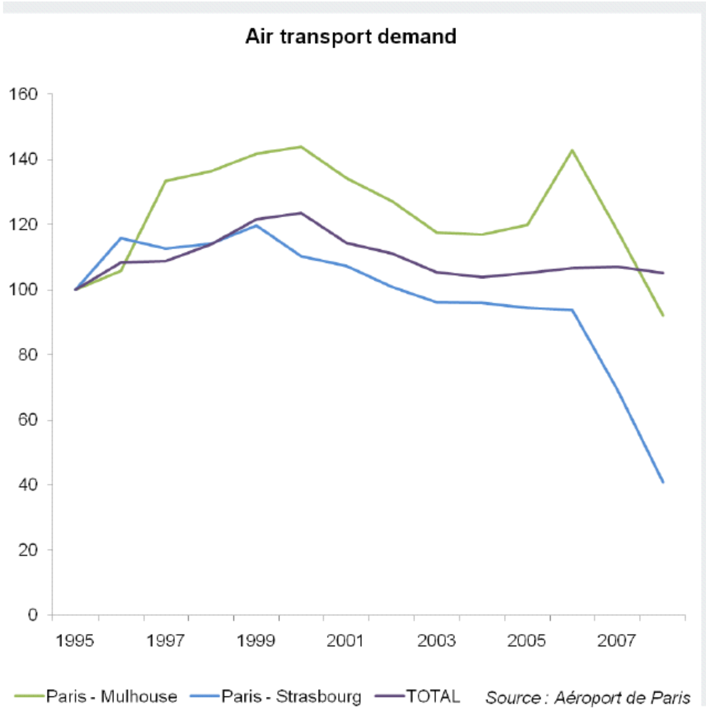
High-speed rail as an alternative for air transport
In Europe high-speed rail was first implemented in France at the beginning of the 1980s. Today the network comprises 1,800 km of track. Between 1996 and 2008 the share of passenger rail transport in France increased from 8 to 10%, owing mainly to the increase in demand for high-speed rail transport. In that country high-speed rail now accounts for 60% of total passenger rail demand.

On the links Paris-Brussels, Paris-Marseille and Madrid-Seville the share of rail transport has increased by a factor 2-3 following introduction of high-speed rail services. On the links Paris-London and Madrid-Barcelona rail had a share of respectively 70 and 60% in 2010. On some of the links (e.g. Paris-Brussels) air services were discontinued after introduction of the high-speed rail services[19].

High-speed rail is a proven alternative for air transport with travel times up to 4 hours. Data for the HSL-Est connection that was finished in 2007 show that air transport on the Paris-Strasbourg link has been reduced from 1 million flights to 400,000 flights.

[19] Data from SNCF.

Figure 15 Air transport demand on links with competition from HST



Source: Taken from Brunel, 2010.

A new high-speed rail link not only induces a modal shift from air to rail, however; it also attracts additional passengers. An analysis by Tractebel Engineering (2009) of passengers travelling on new HSR links shows that 32 and 28% of them originally travelled by car and air, respectively. However, 33% of the demand was induced by the new rail service.

Several studies have concluded that the share of rail in the EU can be boosted by construction of new infrastructure and optimisation of current services (OECD, 2009a; Steer Davies Gleave, 2006).

Environmental impact

A report by the OECD (2009b) reviews and analyses a number of studies that have examined the origins of shifts in demand. The OECD analysis shows that the share of induced transport demand is in the range of 24 to 26% (thus slightly lower than the 33% estimated by Tractebel). Diverted traffic from air to rail amounts to between 22 and 38%. This study also indicates that a considerable share of the passengers are pre-existing train passengers. A subsequent OECD study (2010b) shows that the net effect of investing in high-speed rail is limited. Based on the assumption that 25% of the passengers are from air, car and conventional train and that 25% are newly generated, the average emission of train passengers are 60 g/pass-km lower than in a situation without HST (infrastructure construction and maintenance excluded). This is illustrated in Table 16, the calculations for which are based on the figures from Section 2.6.3.

Table 16 Net emission effect of HST transport

	Emission reduction (g/pass-km) (initial mode-HST)	Share in number of passengers, by origin (%)
From car to HST	82	25
From air to HST	200	25
From conventional rail to HST	-5	25
Additional travellers	-37	25
Net emission reduction (g/pass-km)		**60**

Note: For car travel, an assumption of 50% business travellers and 50% private travellers was made. The emission factors from Chapter 2 were used.

The above figures show that an extension of the HST network might help to reduce the overall impact of transport on climate change. The study by Tractebel Engineering (2009) derives a relation between the length of the network and transport volumes. On the basis of statistics, it was concluded that every kilometre of HST infrastructure generates 17 million pass-km per year. If the HST network is seriously extended over the next decade to 20,000 km (UIC scenario[20]), it may have a significant potential if we assume capacity utilisation of 75-100% of current levels.

5.8 Transport to and from train stations

The choice between making a trip by car or train is often based on door-to-door travel time. Although trains are a quick and generally convenient way to travel between railway stations, transport to and from the stations can lengthen the trip considerably and thus affect the modal choice of travellers. It is therefore important to optimise the total trip and focus on the transport to and from train stations as well as the rail trip itself.

The Dutch Railways company (NS) has investigated which steps in the travel chain merit greatest attention (Haaijer, 2007). On the basis of questionnaires and workshops they identified and quantified the wishes and opinions of their customers.

The effect of a number of measures to improve factors of apparent influence on choices for a particular modality was quantified. Table 17 presents the measures investigated and their anticipated impact on the number of trips by train. For the quantitative measures they assumed an increase of 10%; if a 10% decrease is assumed, the effect is the same but in the opposite direction.

20 http://ec.europa.eu/transport/rail/studies/doc/2003_passenger_trafic_2010_2020_en.pdf.

Table 17 Impact of various measures on number of train trips in the Netherlands

Measure	Train trips/year
10% increase in train fares	-1.9%
10% increase in travel time by train	-2.3%
10% increase in car costs (excl. parking costs)	3.6%
10% increase in travel time by car	3.3%
10% increase in cost of transport to and from stations	-1.7%
10% increase in travel time to and from stations	-9.3%
10% increase in costs of total train trip	-3.6%
10% increase in travel time of total train trip	-11.4%
10% increase in cost of bicycle parking	-0.1%
10% increase in cost of car parking	-0.2%
Safer free bicycle parking	0.7%
Unsafer free bicycle parking	-1.0%
Paid parking places open 24 hrs.	0.0%
Camera surveillance at parking places	0.2%

Source: Dutch Railways.

At subsequent workshops a number of additional factors influencing modal choice were identified, viz.:
- Clarity of information at the destination station.
- Sense of insecurity at parking lots, in trams and subways and at (poorly illuminated) bus stops.
- Number of (free) parking places for cars.
- Interconnection between buses and trains.

The influence of these factors was not quantified, however.

The results in Table 17 clearly demonstrate the importance of trip duration. Cost measures appear to be less important, having only one-third of the impact of travel-time measures. It is therefore concluded that policy-makers should give due consideration to the entire travel chain in decisions concerning infrastructure and railways.

On many short-distance trips the travel time to and from stations has a significant impact on overall travel time. High-quality transport to and from stations combined with well-integrated timetables would therefore almost certainly have a significant impact on rail utilisation. For short-distance trips for leisure, business and commuting, the quality of transport to and from railway stations can thus influence modal choices.

5.9 Rail business card

Company cars are defined as passenger light-duty vehicles leased or owned by companies and used by employees for their personal and business travel. They account for roughly 50% of all new car sales in the EU. Company-car drivers often have free access to the vehicle as well as free fuel. For this group of travellers it is very uncommon to use other means of transport such as public transport. In the Netherlands the Dutch Railways and other mobility providers have introduced a concept that gives lease and company-car drivers free access to trains (and in some cases other transport modes) alongside their car. The providers claim that the extra costs for use of the train for business trips (or other modes) are (largely) offset by lower costs for car use.

In addition, there are benefits in terms of:
- More freedom in choice of transport mode.
- Scope for spending time in the train usefully (higher productivity/leisure).

Several specific cases have been reported on.

Following introduction of the so called NS Business Card (rail card) at the company *Cap Gemini* 1,500 of 3,400 lease drivers started using the train alongside their car, leading to less car use and 35,000 extra train trips per year (http://www.slimreizen.nl/: case Cap Gemini).

Introduction of the same card at the company *Twynstra Gudde* led to 250 out of 350 staff starting to use the train regularly. Car kilometres decreased by 7% and 1.2-1.4 million extra train kilometres were travelled (http://www.slimreizen.nl/: case Twynstra Gudde).

In a three-month pilot at *Deloitte*, with 350 employees, 23% of lease car drivers started using the NS Business Card (http://www.slimreizen.nl/: case Deloitte).

5.10 Estimated potential of upscaled cases

The illustrative cases presented above show that both policy measures and supply-side factors can help increase the share of rail transport. The cases of HGV road pricing and Swiss rail policy illustrate how political willingness can influence the competitiveness of the various transport modes. Furthermore, the case study on the transport of fresh produce shows that rail can serve the market for conditioned transport if there is adequate provision of the required services.

Below, we provide an overview of the potential impact on transport volumes.

5.10.1 Freight transport

In the different cases discussed in this chapter, we identified several factors of influence on the future growth of rail transport: improved interoperability, political willingness, obligatory modal shifts, improved quality of supply and road pricing.

Improved availability and quality of services

If the availability and quality of various services (e.g. reliability, cooling, tracking and tracing) are improved, rail has the potential to increase its market share in areas where volumes have been low in the past. Shipments of fresh produce has been identified as a market area where rail can increase its share. If rail can achieve a market share of 10-20% on distances over 500 kilometres, rail transport volume would be able to grow by roughly 15-30 billion tonnes, equivalent to 3-6% growth.

Political willingness and obligatory modal shifts

The case of Switzerland shows that strong political willingness to increase the share of rail, the provision of subsidies and the charging of trucks for infrastructure use have led to the highest share of rail on any single corridor. At the Port of Rotterdam, rail has been chosen as a preferential mode because of congestion and air quality problems. If other countries were to bring the same pressure to bear on use of rail as Switzerland does, rail transport volumes might well increase, but the example of the Betuwe line in the

Netherlands shows that increasing the share of rail is not simply equivalent to building new infrastructure.

At Rotterdam Port the modal shift criteria will apply to 4 million TEU. If the same criteria[21] were to be applied to 20 million TEU across EU ports (equivalent to container throughput at Rotterdam and Hamburg in 2008) almost the entire increase in container throughput projected for 2020-2050 would be transported by rail, boosting rail transport volumes in the EU by 100 billion tonne-km[22]. This corresponds to some 20% of the 2020 EU rail volume.

5.10.2 Passenger transport

For passenger transport, too, a mix of supply-side factors and government policy can lead to an increase in the modal share of rail. In concrete terms this means both new infrastructure and improvement of services.

High-speed rail

Under the assumption of an extension of the high-speed rail network over the coming decades to 20,000 km (UIC scenario[23]), the aggregate volume of passenger rail might increase significantly. If future-build HST infrastructure carries 75-100% of the passengers carried by current infrastructure, it would generate around 225 to 300 billion passenger-km annually. Assuming that 25% of these travellers were originally conventional train travellers, passenger rail volume increases by 50%.

Conventional rail

For short-distance trips the travel time to and from train stations is significant: an overall reduction of 10% in this time would result in 9.3% more short-distance trips. Assuming that 10% more trips results in an equivalent increase in the volume of rail transport under 100 km, the overall volume of rail transport would increase by 7.3%; see Table 18. The effect on overall rail transport is relatively high, since short-distance trips predominate. With a 15% reduction in travel time, the effect would be even greater.

Table 18 Increase of rail transport volumes through time savings

Reduction of travel time to and from train stations	Increase in short-distance trips (<100 km)	Increase in overall rail transport volume
5%	4.7%	3.7%
10%	9.3%	7.3%
15%	14%	11%

21 The Rotterdam criteria represent 20% rail and 45% inland barge. If applied across the EU, the share of rail would be higher, since inland shipping has a strong position in hinterland transport from Rotterdam.

22 200 million tonnes (10 tonne per TEU) * 500 km on average = 100 billion tonne-km.

23 http://ec.europa.eu/transport/rail/studies/doc/2003_passenger_trafic_2010_2020_en.pdf.

Rail business card

Proceeding from the Dutch figure of an 18% share of company cars in total mileage (CE, 2007) and a 7% reported shift to rail transport, the use of so-called rail business cards leads to an 1.2% overall reduction in car use. If these figures were applied to 50% of all company-car users in the EU, this would translate to 35 billion passenger-kilometres, implying an increase in passenger rail transport volume of 7-8% in 2020.

6 Infrastructure capacity analysis

6.1 Introduction

The objective of this chapter is twofold: to define the available residual capacity that can be exploited to support modal shift actions and identify potential measures for upgrading network performance in terms of capacity. The demand projections presented in Chapter 2 and the modal shift potential estimated according to the analysis carried out in Chapter 4 imply that a growing share of the rail network capacity will be utilised.

In this chapter the capacity of the whole network, broken down into primary and secondary networks and with a focus on the main European corridors, is quantified and compared with projected demand.

6.2 Methodology

In order to quantify the potential modal shift, an analysis of aggregate capacity and free capacity is paramount. Proceeding from the baseline level of capacity utilisation (current and forecast), in the following the capacity available for accommodating additional demand is estimated on the basis of an optimal and realistic target of network use. Given the influence of a range of factors such as type and geographical patterns of rail demand, the overall target for capacity utilisation is set below the theoretical 100%.

The analysis is carried out separately for two supply scenarios
A **baseline scenario** corresponding to no evolution of the current network at all.

An **upgraded scenario**, so called in comparison with the baseline scenario, which takes into account the planned development of the network. The main component of this development is constituted by the TEN-T implementation programme. In this scenario the following assumptions were made for 2020 and 2030:

- Of the TEN-T projects, 41% completed in 2020 and 100% in 2030.
- A 10% increase in the length of the main six-corridor network by 2020 and a 14% increase by 2030, compared with 2008.
- In EU-27, 6,252 km upgrading of lines from single track to double track by 2020 and 14,853 km by 2030, compared with 2008.
- Capacity increase due to ERTMS deployment on priority corridors: 5% in 2020 and 15% in 2030.
- No further growth of the overall network.

These assumptions are further elaborated in Section 6.4.

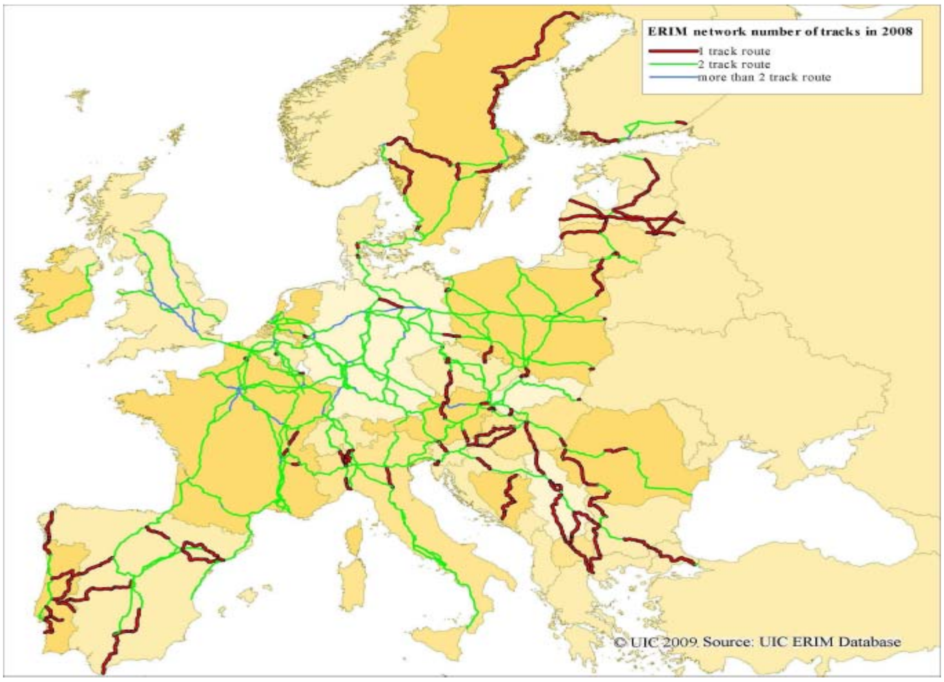
On any single stretch of line capacity is measured in trains/day, while at the network level other units are more appropriate for this purpose, viz. the train-km parameter. The potential modal shift is measured in units of demand, moreover, and for this reason it is important to also quantify capacity in terms of the additional demand that can accommodated on the network.

The residual capacity available on the European network, or by country, can be estimated by means of two methods:
- A bottom-up approach, aimed at quantifying the total capacity to be compared with the total demand in order to obtain a capacity utilisation rate. Proceeding from the network characteristics, by attributing to each subnetwork a standard capacity it is possible to calculate the total theoretical supply. The estimated average utilisation rate is based on the traffic (and the average load, either tonnes/train or passengers/train according to the type of traffic).
- A top-down approach, by deriving from existing studies the average utilisation rate (e.g. related to specific corridors). This average can then be extended to the whole network.

In this study the first method has been applied, while the second has been used to check the consistency of results.

The analysis has been performed for different levels of aggregation:
- On a geographical basis: homogeneous aggregates are represented by the EU-27, EU-15, EU-12 and 'Europe', defined as the EU-27 plus Croatia, Norway, Switzerland and Turkey.
- On a hierarchical basis: the overall network is broken down into a primary network, corresponding to the ERIM network, and a secondary network, encompassing the remainder(Figure 16). The ERIM network is part of the TEN-T network. The primary network indeed represents the routes which are most important on the basis of their potential to maintain and enhance the volume of national and international rail traffic.

Figure 16 ERIM network



Source: UIC, 2009.

The results of an analysis of planned interventions and quantification of anticipated capacity improvements (consistent with the geographical classification adopted above) enable an analysis to be carried out for the years 2020, 2030 and 2050.

For each year, demand figures are translated into train-km, in order to produce comparable variables and calculate the average utilisation rates for different aggregates and different time thresholds.

The average utilisation rate and its comparison with the analogue outcome provided by other studies for specific parts of the network (e.g. UIC Atlas 2009) provide the input for quantification of the residual capacity in units of demand (i.e. passenger-km or tonne-km based on current demand patterns).

Additional data on available capacity are derived from the study of the capacity-enhancing measures that might be implemented to increase network capacity, beside new line construction.

6.3 The present network

Today, the total length of rail line in the 31 countries is about 231,000 km, of which 60% is single-track route, with the remaining 40% constituted by double or more tracks.

Over half the single-track route is concentrated in the EU-12, where 71% of the network has single track and 29% double or more.
In the EU-15, by contrast, the 151,000 km of rail line is split nearly equally between single-track route (53%) and double- or multi-track route (47%).

In terms of length, the primary network represents about 20% of the whole network, the secondary about 80%. The whole ERIM rail route can be broken down as follows:
– About 25% single-track route.
– About 70% double-track route.
– About 5% more than double-track route, concentrated mainly in and around major cities and in some cases between cities (UIC, 2009).

Table 19 summarises the total lengths of the defined networks.

Table 19 Network length

Aggregate	Total line length (km)	Single-track lines (km)	Double-track lines (km)
Europe	230,776	138,842	91,934
EU-27	212,108	122,794	89,314
EU-15	150,569	79,253	71,316
EU-12	61,539	43,541	17,998
Primary	48,464	12,116	36,348
Secondary	182,312	126,726	55,586

Source: EUROSTAT database; UIC, 2009.

6.4 Network development

Projections of network development constitute the main input for the upgraded scenario. Over the last 20 years the European Commission has been very active in restructuring the European rail transport market in order to revitalise rail freight transport and give it a more European dimension.

Commission efforts have concentrated on three major areas, which are all crucial for developing a strong and competitive rail transport industry:
a Opening of the rail transport market to competition.
b Improving the interoperability and safety of national networks. And
c Developing rail transport infrastructure.

Looking at the past evolution of the rail network, a slightly decreasing trend over the last 10-15 years can be observed. According to the European Commission's statistics, aggregate network length was about 245,200 km in 1995 and about 236,100 km in 2000, which are both higher than today's figures. This trend is a consequence of peripheral lines being abandoned, mostly in the EU-12. Another contributing factor is the fact that many network interventions have involved a doubling of existing lines or renewal of such lines.

Given this *de facto* evolution, the main assumption (i.e. boundary condition) regarding network development is that there is **no further net growth of the overall network**.

For this reason, the projected changes were transferred to two aspects:
- Development of the primary network, implying a decrease in the length of the secondary network.
- A shift from single-track to double- or multi-track lines, realised in both the primary and secondary network.

The combined effect is synthesised in Table 20.

Table 20 Network length development in 2020 and 2030

Aggregate	2008			2020			2030		
	Total line length (km)	Single-track lines (km)	Double-track lines (km)	Total length (km)	1 track (km)	2 tracks (km)	Total length (km)	1 track (km)	2 tracks (km)
Europe	230,776	138,842	91,934	230,776	132,407	98,369	230,776	123,553	107,223
EU-27	212,108	122,794	89,314	212,108	116,542	95,566	212,108	107,941	104,167
EU-15	150,569	79,253	71,316	150,569	74,261	76,308	150,569	72,835	77,734
EU-12	61,539	43,541	17,998	61,539	42,281	19,258	61,539	35,556	25,983
Primary	48,464	12,116	36,348	52,341	9,421	42,920	55,482	8,479	47,002
Secondary	182,312	126,726	55,586	178,435	122,985	55,450	175,294	115,074	60,220

Source: TRT elaboration; UIC, 2009.

From Table 20 the following growth can be derived:
- In the EU-27 the total length of double-track sections increases by 17% from 2008 to 2030, by almost 15,000 km. The opposite trend is expected for single-track sections.
- In the EU-12 network upgrading proceeds faster than in the EU-15.

– The upgrading is concentrated mainly in the primary network, but a certain increase in the length of double-track lines is also assumed in the secondary network.
– On the primary network there is net growth in total line length, while on the secondary network a reduction is expected.

These hypotheses are coherent with the development forecast for the TEN-T network, the length of which is projected to grow from 98,000 km in 2005 to 107,000 in 2020[24].

In 2030 the assumption is that the actual TEN-T programme has been completed, while the 2020 situation can be seen as partial completion according to the latest update on TEN-T development.

With regard to the primary network, as it attracts more than 50% of passenger traffic and almost 60% of freight traffic, it is expected here that the main investments in capacity improvement are concentrated. As also stated in UIC (2009), the length of the ERIM network will increase by 8% by the year 2020, in contrast to what is expected in Europe as a whole, where most interventions will involve a doubling of existing singel-track route rather than construction of new lines.

Convinced that action must be taken at a European level, the Commission is now giving priority to a corridor-based approach. The development of technical interoperability and interconnection as well as the construction of key infrastructure for the continent are objectives of the Trans-European Transport Network (TEN-T) programme, in which a number of European Coordinators are tasked with facilitating the implementation of certain multi-country rail projects that are seen as a high priority for the network.

The updated **investment** sum required for the ongoing 18 rail priority projects that are part of the TEN-T programme is about 330,000 million Euro, 37% of which has already been spent on completing 40% of the works. This means that around 207,000 million Euro remains to be spent over the years to 2030 to finish the priority projects (EC, 2010d).

For the primary network a total investment budget of 202,407 million Euro has been identified as necessary to cover all the infrastructure investments planned by the railways, upgrading of key infrastructure parameters to minimum target level and addressing capacity-constrained sections. This figure excludes investments in terminals and major nodes, which were not part of the UIC study (UIC, 2009).

According to UIC, the 202,407 million Euro budget estimated are split as follows:
– 61,331 million Euro for the planned investments in ERTMS corridors.
– 141,076 million Euro for other plans.

TEN-T details financial instruments to fill in the ‘missing links’ and expand existing rail networks in the EU by 2020. The first action plan of this long-term programme was launched back in 1990, with legal stipulations laid down in the Treaty of Maastricht in 1992. TEN-T is a multimodal network comprising approximately half of all freight and passenger movements in Europe. Its scope

[24] http://ec.europa.eu/transport/infrastructure/networks_eu/rails_en.htm.

is based on a pre-selection of infrastructure projects. To date, TEN-T has grown from 14 to 30 priority projects, 22 of which are rail projects.

The approach proposed by the Commission was to create rail corridors for freight based on good business cases. This means these axes were identified by evaluating existing and potential traffic flows, by assessing the needs of freight operators in terms of infrastructure and services and by establishing the socio-economic impact of the measures to respond to these needs.

This led to identification of six main corridors, which currently carry around a fifth of Europe's rail freight traffic (EC, 2008b). On these corridors the EU's objective is to deploy ERTMS[25] systems by 2012-2015, to achieve cross-border harmonisation of infrastructure systems, as a prerequisite for successful competition with road. The six corridors are as follows:

- Corridor A: Rotterdam – Genoa.
- Corridor B: Stockholm – Naples.
- Corridor C: Antwerp – Basel/Lyon.
- Corridor D: Valencia – Ljubljana.
- Corridor E: Dresden – Budapest.
- Corridor F: Duisburg – Terespol/Medyka.

While the primary aim of creating ERTMS was to ensure trans-European interoperability, the system also offers considerable benefits in terms of infrastructure capacity, influencing the number of trains on a given line and the distance between them, and has therefore become a crucial element of railway competitiveness.

Initial implementation of ERTMS on the European rail network is scheduled for these six main corridors. This should turn into a capacity increase by 15% by the year 2030 (and by 5% by 2020).

This can be seen as a mid exploitation of the ERTMS benefits.

According to the latest studies, a very slight increase in available capacity is in fact already achievable by means of ERTMS Level 1 and Level 2 without optimised block sections (only high-speed lines benefit of it). On the other hand, application of Level 2 with optimised block sections should allow a strong increase in capacity (up to +30-40% on conventional main lines and HS lines). In practical applications the SBB infrastructure manager reported a 15% capacity increase with ERTMS Level 2 on already optimised lines. In the case of lines with mixed traffic (passengers plus freight) a capacity increase of up to 25% was reported (UNIFE, *Increasing infrastructure capacity*, 2010).

The assumption of envisaging a deployment of 5-15% in 2020-2030 seems acceptable, implying an effort to optimise block sections on part of the corridor lines.

6.5 Rail network capacity

The capacity of an individual rail line or entire network depends on a broad array of variables. It is not only the infrastructure as such, but also the rolling stock, motive power, staffing and operating strategies (e.g. size, speed, and timing of trains) that are part of the equation. The reality is that, much of the

[25] European Rail Traffic Management System.

time, plenty of capacity is available on most of the track network; however, around urban areas, key junctions and other choke points, congestion may worsen during certain periods of the day or on certain days of the week. Although laying more tracks may seem the obvious solution, this may not be the best course of action, for once in place, it is costly to move such resources elsewhere. A less costly and risky solution may therefore often be to adopt a better optimised operating strategy, by changing schedules or powering up some or all of the locomotives, for example.

As said, rail capacity is affected by numerous factors. Of these, the following are the most relevant:
- Mix of trains (local, regional, international, etc.).
- Length/carrying capacity of trains.
- Train weight (both the rolling stock itself and the maximum weight it can carry).
- Direction of train travel.
- Acceleration and deceleration (braking characteristics).
- Train stopping protocols.
- Location and length of crossing loops.
- Location of signals.
- Length of sections.
- Dwell times.
- Sectional running times.
- Quality of maintenance.
- Functionality of pedestrian areas in railway stations (passenger).
- Capacity of freight terminals (freight).

In Annex E, capacity improving measures are discussed in greater depth.

Transportation firms can never utilise a railway 100% of the time, for reasons relating, among other things, to the following: maintenance, weather, peak traffic volumes, disruptions and recoverability, and normal variability in operating conditions. Industry practices call for standards to maintain fluidity of operations and avoid major issues at chokepoints. Utilisable (effective) capacity is 70 to 80% of the maximum (theoretical) capacity: utilising the capacity buffer between effective and maximum capacity results in deferred maintenance, reduced ability to react to variability with increasing recovery time and significantly reduced reliability.

After collecting data on the length of the network and the number of passengers and amount of freight transported (derived from the EUROSTAT database and the statistical Pocketbook of the European Commission), the first step in calculating the average capacity utilisation rate is to determine the average total number of train-km travelling through the network in a year, by summing the number of passenger train-km and freight train-km.

The expression used to calculate the theoretical capacity of the network (in train-km per year) is the following, in which, in line with the assumptions adopted in the UIC (2009) study, the number of trains running daily on single- and double-track routes has been taken as 60-80 and 200, respectively, and 330 as the average number of full days per year:

(Single-track length*70 trains/day)+(double-track length*200 trains/day) * 330 days.

These figures reflect capacity in the baseline scenario. Compared with other sources (e.g. Kessel and Partners, 2004) our assumptions are relatively cautious[26]. This was deemed justified, because in the present study the aim was not to focus on local bottlenecks, but to estimate overall network capacity. However, these assumptions may have a limiting effect on projected network capacity.

Current capacity utilisation is then calculated as the ratio between the average number of annual train-km and the theoretical capacity of the corresponding line sections.

Despite the network being extended by doubling certain parts of it, resulting in an increase in theoretical capacity, the strong growth in transport demand for both passenger and freight at rates outstripping the trend in available capacity leads to an increase in projected average capacity utilisation rates in 2020 and 2030.

The capacity growth projected for 2020 and 2030 is based on the network development generated by current projections of renewal, upgrading and investment programmes. Table 21 summarises the total capacity assumed for assessing available capacity.

Table 21 Capacity forecasts (million train-km/year)

Aggregates	2008	2020	2030
	Theoretical capacity (train-km)	Theoretical capacity (train-km)	Theoretical capacity (train-km)
Europe	9,275	9,551	9,931
EU-27	8,731	8,999	9,368
EU-15	6,538	6,752	7,046
EU-12	2,194	2,248	2,322
Primary	2,679	3,050	3,298
Secondary	6,596	6,501	6,633

Source: TRT elaboration.

6.6 Capacity utilisation

6.6.1 Current and future capacity utilisation in the baseline scenario

In the base year for the present study, 2008, aggregate rail passenger transport in the EU-27 stood at 409.2 billion pass-km and rail freight transport at 443 billion tonne-km. The corresponding volumes for Europe (EU-27 plus four other countries, as stated above) are 438 billion pass-km and 473 billion tonne-km. These flows correspond to 4.1 billion train-km in the EU-27 and 4.3 billion in Europe, as reported in official European statistics (EUROSTAT).

Current average capacity utilisation can therefore be estimated as 47% relative to the 100% capacity estimated above.

Within the European Union, data shows that old Member States make far greater use of rail than new Member States: indeed, for passenger transport the EU-15 accounts for almost 90% of EU-27 passenger transport demand, while for freight this share is 66%. This pattern is also reflected in the average capacity utilisation rate, which in the case of the EU-15 is much higher (51%) than in the EU-12 (33%).

[26] The cited source assumes 288 (2002) and 346 (2015) trains per day on an electrified double-track line.

Following a similar approach, average capacity utilisation in the primary network can be estimated as 58% and in the secondary network as 42%.

From the EUROSTAT data the average load factors of operational trains can be calculated as about 530 tonnes/train for freight and 125 pass/train for passengers. On the primary network and especially on the main corridors these load factors are estimated to be higher: 180 for passengers and 600 for freight. On the secondary network the figures will consequently be 96 pass/train and 468 tonnes/train, respectively.

For the 2020 and 2030 thresholds no changes in load factors have been assumed in either the baseline or upgraded scenario.

Table 22 Average capacity utilisation in 2008 in the baseline scenario

Aggregate	Network		Demand		Used capacity (mln train-km/year)	Total capacity (mln train-km/year)	Capacity utili-sation
	1 track (km)	2 tracks (km)	Pass-km (millions)	Tonne-km (millions)			
Europe	138,842	91,934	437,190	472,520	4,345	9,275	47%
EU-27	122,794	89,314	409,200	442,700	4,077	8,731	47%
EU-15	79,253	71,316	359,900	292,400	3,358	6,538	51%
EU-12	43,541	17,998	49,300	150,300	719	2,194	33%
Primary	12,116	36,348	200,910	262,870	1,554	2,679	58%
Secondary	126,726	55,586	236,280	209,650	2,791	6,596	42%

Source: TRT elaboration; UIC, 2009.

To determine average capacity utilisation rates for 2020-2030 in the baseline scenario, growth rates were assigned for both passenger and freight demand, while on the supply side the capacity of existing lines was assumed to remain unchanged. In the year 2020, passenger demand is assumed to have grown by 11% and freight demand by 18%. The corresponding projected growth in traffic in terms of train-km in Europe is 15% (an increase in average capacity utilisation of 7 percentage points, from 47 to 54%).

As a cross-check on these estimates, according to values reported in the ERIM Atlas (UIC, 2009) capacity utilisation on the ERIM network in 2020 should be around 65%.

Table 23 Average capacity use in 2020 in the baseline scenario

Aggregate	Network		Demand		Used capacity (train-km/year)	Capacity (train-km/year)	Capacity utili-sation ratio
	1 track (km)	2 tracks (km)	Pass-km (mln)	Tonne-km (mln)			
Europe	138,842	91,934	484,745	558,360	4,979	9,275	54%
EU-27	122,794	89,314	453,710	523,122	4,654	8,731	53%
EU-15	79,253	71,316	399,048	345,518	3,849	6,538	59%
EU-12	43,541	17,998	54,663	177,604	802	2,194	37%
Primary	12,116	36,348	222,764	310,624	1,755	2,679	66%
Secondary	126,726	55,586	261,981	247,736	3,223	6,596	49%

Source: TRT elaboration; UIC, 2009.

The above traffic growth rates have also been applied to current transport demand on the primary and secondary networks, which, assuming the same load factors and average theoretical capacity of double- and single-track sections as for the base year, yields relative increases in average capacity utilisation of 8 and 7%, respectively.

According to UIC (2009), the following general remarks can be made:
- On line sections operating at below 70% of capacity, residual capacity is currently sufficient, certainly over a given 24-hr period.
- On line sections operating at between 70-85% of capacity, there may be some flexibility for carrying extra traffic at certain times of the day.
- Line sections running at over 85% of capacity are likely to be operating at optimum operational efficiency in terms of train throughput, based on the current configuration of the infrastructure and train patterns.

According to forecasts defined in Chapter 2 for the year 2030, there will be 20% growth in passenger demand and 36% growth in freight demand compared with the base year, with a corresponding increase in traffic in train-km on the European network of 26%. This means an average capacity utilisation rate of 59% on the network as a whole, implying ample potential for accommodating additional demand. In theory, in 2030 an extra 3.8 billion train-km should be available for both passenger and freight traffic (compared with projected demand of 5.5 bln).

Residual capacity is not uniformly distributed, though. Given the concentration of demand along the main networks, on selected routes capacity use in 2030 could be close to the limit and, as previously explained, this could potentially lead to periods of congestion during the daytime.

Table 24 Average capacity use in 2030 in the baseline scenario

Aggregate	Network		Demand		Used capacity (train-km/year)	Capacity (train-km/year)	Capacity utilisation ratio
	1 track (km)	2 tracks (km)	Pass-km (mln)	Tonne-km (mln)			
Europe	138,842	91,934	524,636	641,643	5,459	9,275	59%
EU-27	122,794	89,314	491,047	601,504	5,102	8,731	58%
EU-15	79,253	71,316	431,886	397,055	4,215	6,538	64%
EU-12	43,541	17,998	59,161	204,095	886	2,194	40%
Primary	12,116	36,348	241,096	356,956	1,934	2,679	72%
Secondary	126,726	55,586	283,540	284,687	3,525	6,596	53%

Source: TRT elaboration; UIC, 2009.

6.6.2 Current and future capacity utilisation in the upgraded scenario

The fundamental difference between the baseline scenario and the upgraded scenario is that the former assumes solely an increase in transport demand, with aggregate network capacity remaining unchanged, while the latter assumes that the growth in demand for both passenger and freight transport is accompanied by upgrading of existing lines, construction of new lines and implementation of the ERTMS signalling system on priority corridors. As explained above, the upgraded scenario is based on the TEN-T investment plans.

Table 25 **Average capacity utilisation in 2020 in the upgraded scenario**

Aggregate	Network		Demand		Used capacity (train-km/year)	Capacity (train-km/year)	Capacity utilisation ratio
	1 track (km)	2 tracks (km)	Pass-km (mln)	Tonne-km (mln)			
Europe	132,407	98,369	484,745	558,360	4,979	9,551	52%
EU-27	116,542	95,566	453,710	523,122	4,654	8,999	52%
EU-15	74,261	76,308	399,048	345,518	3,849	6,752	57%
EU-12	42,281	19,258	54,663	177,604	802	2,248	36%
Primary	9,421	42,920	222,764	310,624	1,755	3,050	58%
Secondary	122,985	55,450	261,981	247,736	3,223	6,501	50%

Source: TRT elaboration; UIC, 2009.

For the decade from 2020 to 2030 a further enhancement of rail infrastructure is foreseen as well as an extension of double-track routes, with the aim of accommodating further growth in demand for both passenger (8%) and freight (15%) transport.

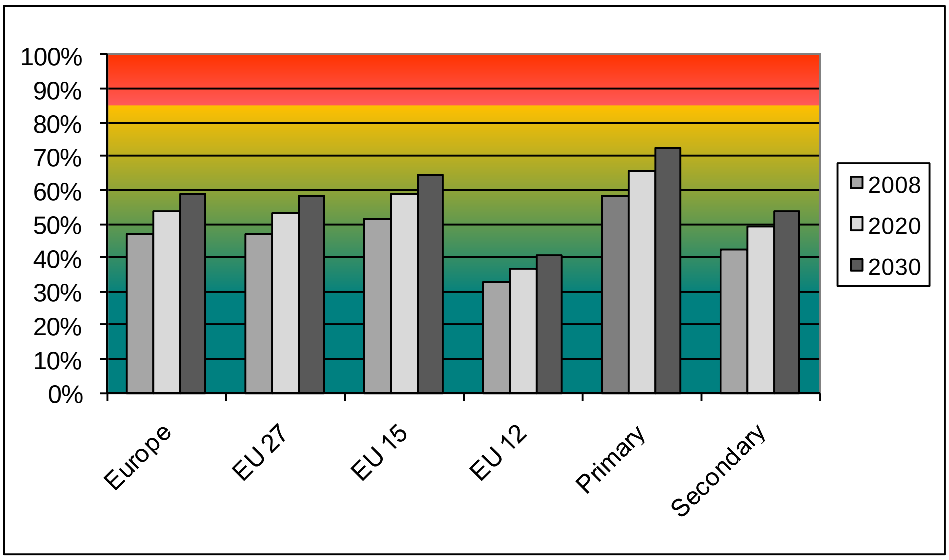
Table 26 **Average capacity utilisation in 2030 in the upgraded scenario**

Aggregate	Network		Demand		Used capacity (train-km/year)	Capacity (train-km/year)	Capacity utilisation ratio
	1 track (km)	2 tracks (km)	Pass-km (mln)	Tonne-km (mln)			
Europe	123,553	107,223	524,636	641,643	5,459	9,931	55%
EU-27	107,941	104,167	491,047	601,150	5,102	9,368	54%
EU-15	67,393	83,176	431,886	397,055	4,215	7,046	60%
EU-12	40,548	20,991	59,161	204,095	886	2,322	38%
Primary	8,479	47,002	241,096	356,956	1,934	3,298	59%
Secondary	115,074	60,220	283,540	284,687	3,525	6,633	53%

Source: TRT elaboration; UIC, 2009.

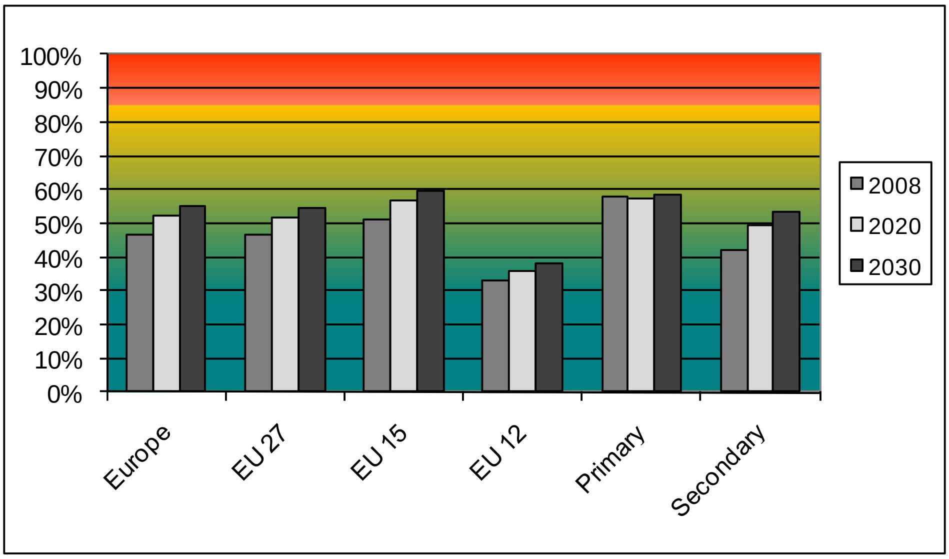
As shown in Table 25 and Table 26 and Figures 17 and 18 below, despite the increase in capacity due to the doubling of lines, in the upgraded scenario average capacity utilisation rates increase, but less markedly so than in the baseline scenario.

Figure 17 **Evolution of average capacity utilisation in the baseline scenario**



Source: TRT elaboration.

Figure 18 **Evolution of average capacity utilisation in the upgraded scenario**



Source: TRT elaboration.

Analysing the evolution of the primary network, it transpires that the increase in transport demand on the one hand and the extension of double-track routes, with the resulting increase in available capacity, on the other, mean that average capacity utilisation remains virtually unchanged from 2008 to 2020, while in the following period from 2020 to 2030 there is a slight increase of 2%.

6.7 Snapshot of priority corridors

Construction of the trans-European Transport Network (TEN-T), based on the interconnection and interoperability of national transport networks, including rail, is of great importance for the EU's economic competitiveness and its balanced and sustainable development.

ERTMS corridors have been identified based on the ERIM network study, the criteria of high freight traffic flow and wide coverage of EU states. The length of all six rail corridors represents 6% of the TEN-T network and as much as 20% of European freight traffic. The expected result of ERTMS deployment on these corridors is a significant improvement in the competitiveness of rail freight transport.

The total length of the main six-corridor network is expected to increase by 10% by the year 2020 and by 14% by 2030. Rail traffic on these corridors is expected to grow faster than average, at an average annual rate of 2.3% for passengers and 2.9% for freight (EC, 2008b). Given the major appeal of the corridors, compared with 2010 these values have been taken about 1% higher than those used for the network as whole.

Other sources (e.g. CER, 2007) report even higher growth rates. The values adopted in the present study are more conservative and partially internalise the effects of the recent crisis, for which reason it was also assumed that demand in 2010 was approximately the same as in 2005.

Table 27 Projected traffic in the six ERTMS corridors

Corridor	Tot. length (km)	2005 Train-km (mln)		2020 Train-km (mlm)		2030 Train-km (mln)	
		Pass	Freight	Pass	Freight	Pass	Freight
A	2,548	73	46	92	61	115	80
B	3,467	96	34	121	45	152	59
C	1,680	34	22	43	29	54	39
D	2,220	69	18	87	24	110	32
E	1,621	17	15	21	20	26	26
F	1,934	30	44	38	58	47	77
Total	13,470	319	178	401	236	505	313

Source: EC, 2010b; TRT elaboration.

Table 28 Average capacity ustilisation in the six ERTMS corridors (baseline scenario)

Corridor	2005			2020			2030		
	Pass-km (mln)	Tonne-km (mln)	Capacity utili-sation	Pass-km (mln)	Tonne-km (mln)	Capacity utili-sation	Pass-km (mln)	Tonne-km (mln)	Capacity utili-sation
A	13,112	27,455	78%	16,504	36,399	101%	20,773	48,257	129%
B	17,277	20,252	63%	21,746	26,850	80%	27,372	35,597	103%
C	6,150	13,237	56%	7,741	17,549	72%	9,743	23,266	93%
D	12,487	10,865	66%	15,717	14,405	84%	19,783	19,097	107%
E	2,978	8,957	33%	3,748	11,875	42%	4,718	15,744	54%
F	5,386	26,155	64%	6,779	34,676	83%	8,533	45,972	108%
Total	57,390	106,921	62%	72,236	141,753	80%	90,923	187,933	102%

Source: EC, 2010b; TRT elaboration.

Compared with the other selected aggregates, the ERTMS corridors turn out to have the highest average capacity utilisation rates. In particular, Corridors A, D and F prove to be among the most congested, which means demand is significantly concentrated along the main corridors. Again, these average

capacity use rates are in line with the values reported in the CER study (CER, 2007).
Based on the same hypothesis as for the ERIM network, these main corridors not only show significant growth in average capacity utilisation, but in fact in many cases exceed the critical threshold of the lines in or after 2020.

In the event of any of the measures designed to increase network length not being implemented, corridor A in particular will be unable to accommodate the transport demand projected for 2020.

The six major corridors will require investments to create sufficient capacity in line infrastructure and intermodal terminals, to harmonise the infra-structure across borders and to improve productivity. This will enable longer and therefore more heavily loaded trains and boost aggregate infrastructure capacity by around 72% by 2020 (CER, 2007). The investments will bring the following benefits:

- Through bottleneck relief and terminal extension, sufficient infrastructure capacity to accommodate the 30% projected growth in rail cargo demand by 2020.
- Through ERTMS investments, cross-border harmonisation of infrastructure systems.
- Productivity gains through optimised infrastructure parameter upgrades will provide a further capacity increase of around 11%.

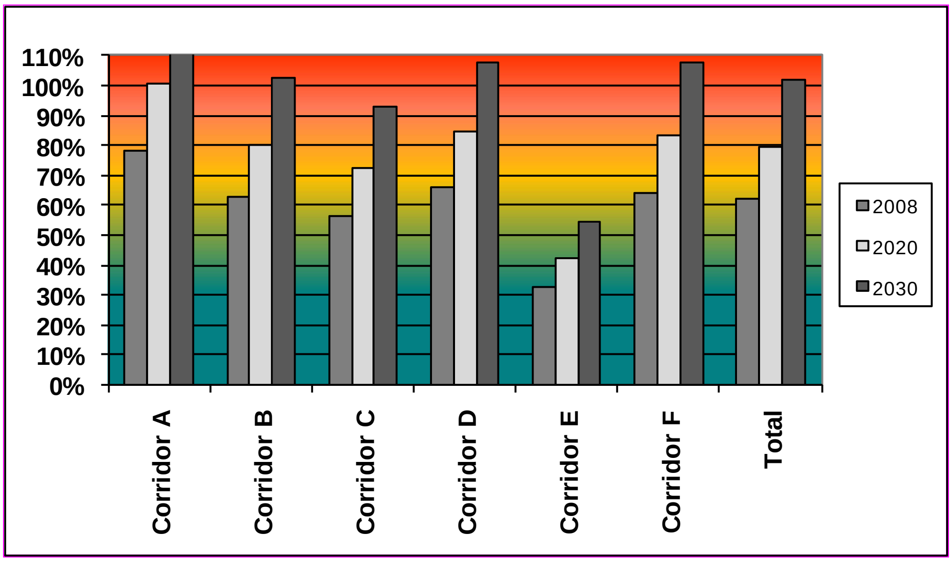
As a result of ongoing investments in the upgrading of lines and introduction of the ERTMS system, capacity should increase as assumed above by a further 15% in 2030. For the six corridors considered, the upgraded scenario brings the capacity utilisation rate up to an acceptable level, proving that investments on these routes should not be smoothed.

Table 29 Average capacity utilisation in the six ERTMS corridors (upgraded scenario)

Corridor	Length (km)	2020			2030		
		Pass-km (mln)	Tonne-km (mln)	Capacity utilisation	Pass-km (mln)	Tonne-km (mln)	Capacity utilisation
A	2,548	16,504	36,399	87%	20,773	48,257	99%
B	3,467	21,746	26,850	70%	27,372	35,597	78%
C	1,680	7,741	17,549	63%	9,743	23,266	71%
D	2,220	15,717	14,405	73%	19,783	19,097	82%
E	1,621	3,748	11,875	37%	4,718	15,744	42%
F	1,934	6,779	34,676	72%	8,533	45,972	82%
Total	13,470	72,236	141,753	69%	90,923	187,933	78%

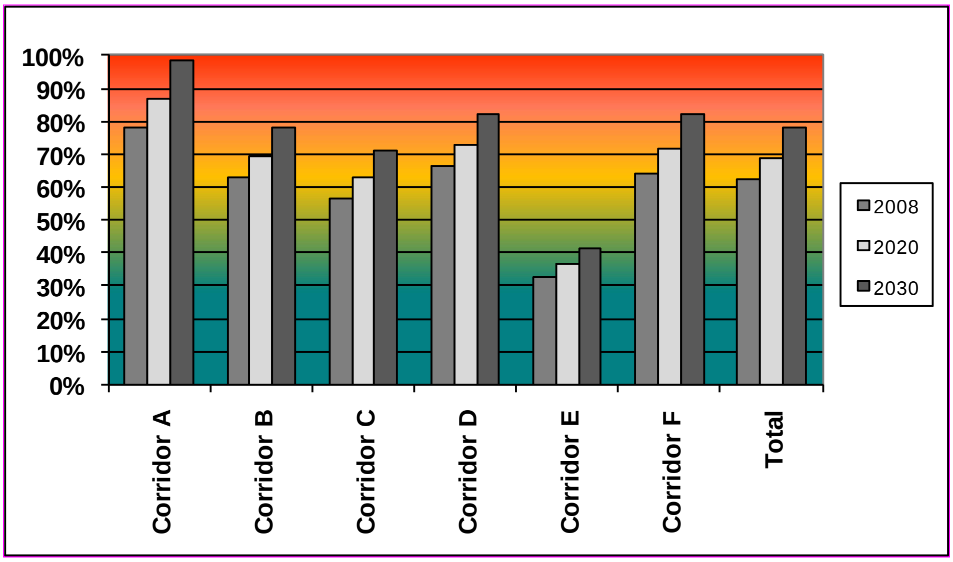
Source: TRT elaboration.

Figure 19 **Evolution of average capacity utilisation in the baseline scenario (six corridors)**



Source: TRT elaboration.

Figure 20 **Evolution of average capacity utilisation in the upgraded scenario (six corridors)**



Source: TRT elaboration.

6.8 Estimate of available capacity

As highlighted in the previous section, the availability of additional capacity is not spread uniformly across the network but is concentrated mainly in the secondary network.

The purpose of the analysis of the corridors, the backbone of the primary network, was to provide an illustrative snapshot of available capacity. As explained, traffic is concentrated mainly on the primary network, with a further concentration observed along the main corridors, especially for freight. For this reason it is not possible to exactly assess the residual capacity, since it is unknown how future demand will be distributed over the network.

Table 30 summarises the available theoretical capacity on the various networks in the baseline and upgraded scenarios.

Table 30 Theoretical free capacity (million train-km)

	Baseline scenario		Upgraded scenario	
	2020	2030	2020	2030
Whole network	4,078	3,629	4,346	4,266
Primary Network	936	764	1,276	1,340
Secondary Network	3,142	2,865	3,070	2,927
Corridors (total)	236	176	360	424

Source: TRT elaboration.

Even though it is very difficult to argue in detail the geographical distribution of future demand, it may reasonably be assumed that new demand will not show significantly different patterns, compared to today.

The existence of severe bottlenecks on the primary network is currently a obstacle to full exploitation of the high capacity available. On the main corridors, for example, various sections are already operating close to full capacity, while others can still accommodate additional demand. Besides the characteristics of the infrastructure itself, this uneven use of capacity is also due to the distribution of demand, aggravated by other factors such as the different standards in force along the various routes.

The combined effects of bottlenecks, demand distribution and line characteristics are very difficult to estimate across the board, as they will often depend on local circumstances.

The following assumptions can be made with respect to achievable capacity utilisation targets:

- Capacity along the main corridors can be exploited up to 90%; this can be achieved by operating a high density of long-distance trains, and through robust interventions to address bottlenecks, especially close to major urban centres. As explained above, bottlenecks represent a real physical limit to the exploitation of theoretical capacity.
- On the primary network optimum utilisation can be set at 80%, given the lower density of long-distance trains. In this case there are relatively fewer bottlenecks.
- On the secondary network a target of 65% for average utilisation can be taken as an upper limit. On this network, the problem lies in the distribution of demand and the scope for attracting additional flows on a network that is often characterised by lower technical standards. Although lower than the other two targets, this target can be regarded as the hardest to achieve.

Based on these values, the additional traffic that can be accommodated in upgraded scenarios in the EU-27 is as follows:

Table 31 **Useable capacity in EU-27 (2020, million train-km), upgraded scenario**

	Total capacity	Capacity utilisation	Residual capacity	Max. capacity utilisation ratio	Usable capacity
Whole network	8,999	52%	4,346		1,647
Primary Network	2,964	57%	1,276	80%	682
Secondary Network	6,035	49%	3,070	65%	965
Corridors (total)	924	69%	287	90%	194

Source: TRT elaboration.

Table 32 **Useable capacity in EU-27 (2030, million train-km), upgraded scenario**

	Total capacity	Capacity utilisation	Residual capacity	Max. capacity utilisation ratio	Usable capacity
Whole network	9,368	54%	4,266		1,408
Primary Network	2,964	63%	1,340	80%	544
Secondary Network	6,404	51%	2,927	65%	864
Corridors (total)	1,049	58%	231	90%	126

Source: TRT elaboration.

As the tables show, in 2020 there appears to be around 30-40% residual capacity in terms of train-km, with the exact figure depending on the network involved. In 2030 these figures are a few percentage points lower. In Table 33 the usable capacity is allocated to freight and passenger transport for three different scenarios.

Table 33 **Potential growth of total freight and passenger transport under three allocation scenarios in EU-27 on different networks (2020, upgraded scenario)**

70% allocation to freight		**Freight**		**Passenger**	
	Train-km (mln)	**Tonne-km (bln)**	**% growth**	**Pass-km (bln)**	**% growth**
Corridors	194	81	16%	12	3%
Primary	682	286	55%	37	8%
Whole network	1,641	609	116%	62	14%
50% allocation to freight		**Freight**		**Passenger**	
	Train-km (mln)	**Tonne-km (bln)**	**% growth**	**Pass-km (bln)**	**% growth**
Corridors	194	58	11%	19	4%
Primary	682	205	39%	61	14%
Whole network	1,641	435	83%	103	23%
Allocation on basis of 2020 transport volume		**Freight**		**Passenger**	
	Train-km (mln)	**Tonne-km (bln)**	**% growth**	**Pass-km (bln)**	**% growth**
Corridors	194	20	4%	32	7%
Primary	682	70	13%	102	22%
Whole network	1,641	148	28%	170	38%

Note: allocation on the basis of 2020 transport volume implies a 17% allocation to freight.

The growth potential depends very much on capacity allocation. The data show that under equal distribution of capacity or allocation in favour of freight transport, rail freight can grow significantly, but that growth potential for passenger transport is then limited. When allocation is based on the transport volume projected for 2020, the potential growth figures are 28 and 38%, respectively. If growth will be concentrated on the corridors only, the growth potential is limited.

When assessing rail network capacity, it is not enough to consider only the capacity of the lines, as the capacity or terminals is also important. There are numerous options available for improving the efficiency of use of existing terminals, including improving train service punctuality, reducing container storage periods, extending terminal opening times, coordination and control of terminal operations by a single party, implementation of an IT-based terminal management system, continuous communication/information exchange among all relevant operators.

6.9 Conclusion

Rail network capacity utilisation is very different for lines in the primary and secondary network. Utilisation of the current network is highest in the six defined TEN-T corridors and the primary network. In the upgraded scenario estimated capacity utilisation in 2020 amounts to 52% for Europe, 57% for the primary network and even higher on the corridors. With the planned investments and the installation of ERTMS signalling systems on these corridors, capacity can be expanded; see Table 34.

Table 34 Usable capacity in EU-27 (2020), upgraded scenario

	Capacity utilisation	Max. capacity Utilisation rate
Whole network	52%	
Primary Network	57%	80%
Secondary Network	49%	65%
Corridors (total)	69%	90%

The analysis shows that growth figures of around 30-40% can be accommodated by the current infrastructure in terms of train-km, compared with the baseline scenario, with the exact figure depending on the utilisation rate on the secondary network. Obviously, in the short term local bottlenecks will need to receive more attention than massive programmes of infrastructure construction. However, for growth beyond the cited 30-40%, additional infrastructure will be needed.

The potential for growth of freight and passenger transport depends on the allocation of available train-km. Under 50/50%[27] allocation, rail freight transport can grow by 39% on the primary network and 83% on the network as a whole and passenger transport by 14 and 23%, respectively. When allocating on the basis of 2020 transport volume, the relative growth of passenger and freight transport amount to 22 and 13%, respectively, on the primary network.

27 Passenger transport growth will be accommodated partly by newly constructed high-speed rail infrastructure and partly by defining the networks primarily for freight.

7 GHG reduction potential

7.1 Introduction

The goal of this chapter is to estimate the greenhouse gas (GHG) reduction potential of shifting freight carriage from road and air to rail. The precise impact of modal shift will depend on two factors:

- The climate impact of the transport modes concerned, possibly in specific market segments (see Chapter 2).
- The (policy) measures employed to encourage the modal shift: certain measures may lead to increased demand, limiting the GHG reduction potential (see Section 7.5).

7.2 Approach

When calculating the GHG reduction potential of modal shift, two questions arise: what is the autonomous trend, and to what extent are the measures studied part of baseline scenarios.

TREMOVE and the scenarios of the European Commission are all baseline scenarios that are used to estimate the effect of policies under study. We therefore assume that the effects identified in the cited studies are additional to the impacts of the baseline scenarios described in Chapter 2. In this analysis we thus assume that the growth of rail transport in the baseline does not yet require the measures discussed. However, there may be a limited amount of double counting.

Below, the GHG impact of modal shift is calculated by multiplying the sum total of tonne-km shifted by the difference between road and rail emissions per tonne-km. In doing so, it has furthermore been assumed that in the case of modal shift only 90% of the tonne-km involved can be shifted; the other 10% is assumed to remain served by road because of transport to and from loading points. In addition, we assume that the distance by rail is on average 10% longer than the equivalent trip by road. Finally, we calculate using a bandwidth because of differences in load factors and to account for empty trips.

In the case of passenger transport, transport to and from stations is assumed to be by bus and tram/metro, which have emissions close to those of trains.

7.3 Freight transport

7.3.1 Baseline scenario

Table 35 summarises the baseline scenario for freight transport GHG emissions by road and rail transport in 2020.

Table 35 2020 baseline estimate of GHG emissions (Mtonne CO_2 eq.)

Distance	<500 km		>500 km	
	Rail	Road	Rail	Road
Container	1	69	0	19
Bulk	2	40	1	25
Miscellaneous goods	1	100	0	12
Total	5	209	1	55

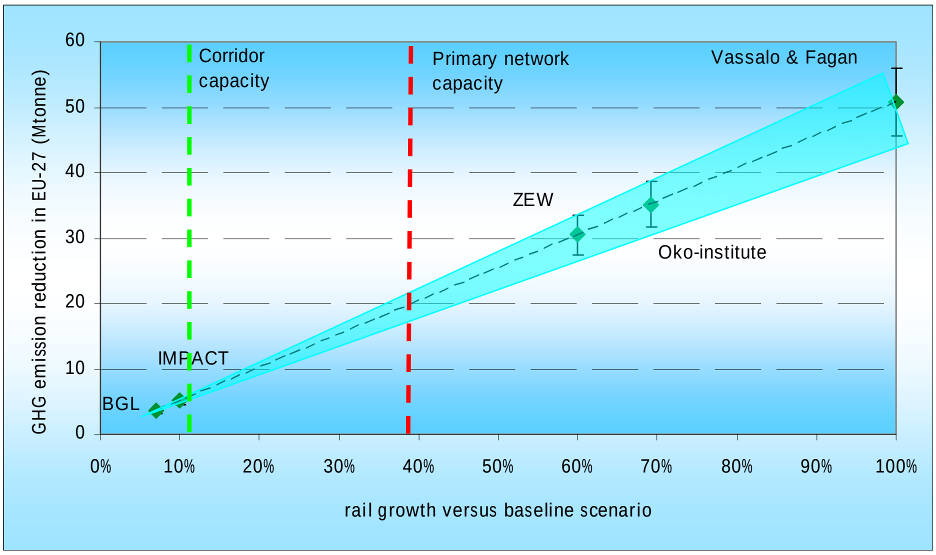
Note: The projection represents well-to-wheel emissions and EU-average figures for electricity production.

As Table 35 shows, the aggregate emissions of rail transport are very low compared with those of road transport. This reflects not only the lower share of road in total transport volume, but also the lower GHG intensity of rail transport.

7.3.2 Emission reduction potential

Figure 21 shows the GHG reduction impact of the scenarios in some of the studies discussed in Chapter 0. The depicted GHG reduction represents the reduction in the entire market defined in Chapter 2, the GHG emissions of which are presented in Table 35. The green and red dashed lines are thresholds that apply if growth can only be allocated to the corridors and primary network, respectively.

Figure 21 GHG reduction as a result of the increase of rail freight transport and decrease of road transport (2020) in the EU-27



Note: The different studies depicted are described in detail in Chapter 0. The corridor and primary network capacity are based on a 50% allocation of additional available network capacity (upgraded scenario) to freight. Allocation based on the 2020 transport volume would lead to lower growth rates for freight (see Chapter 6).

The ranges in the figures are the result of uncertainties associated with modal shifting and the different characteristics of road and rail transport. The following factors are of influence on GHG reduction potential:
- Load factor.
- Empty running.
- Transport to and from loading points.
- Detouring.

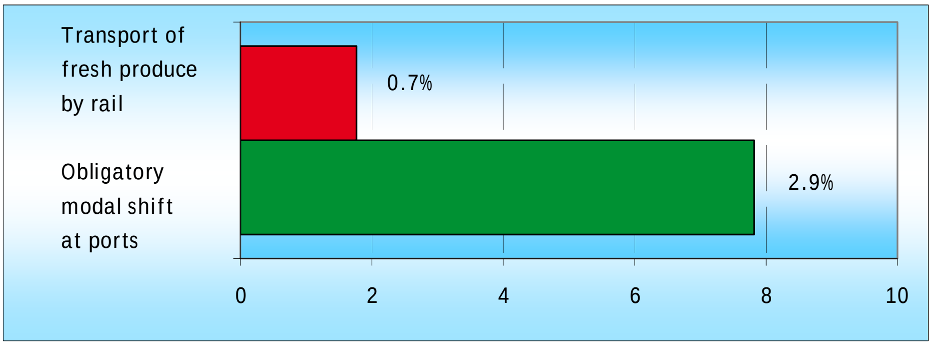
Figure 21 shows that a pronounced shift to rail transport (as estimated by Öko-Institute and by Vassallo and Fagan) would result in a reduction in GHG emissions by 32-39 and 45-55 Mtonne CO_2 eq., respectively. The latter estimate corresponds with 19% of the emissions of the market in which rail and road transport compete. Other estimates, based on single measures and policies that assume a significant improvement of the quality of supply (ZEW) and EU-wide road pricing (IMPACT) result in a GHG reduction of 27-33 and 7-8 Mtonne CO_2 eq, respectively.

The figure shows, furthermore, that around 20 Mtonne CO_2 eq. can be reduced by utilising the primary network in 2020, under a scenario of 50% allocation of unused capacity to rail. Utilising the secondary network, too, GHG savings could in theory be even greater. However, this potential seems to be small because the secondary network is associated with smaller transport flows.

Market segments

The effects of the measures from the case studies (see Chapter 5), are dictated by their selection as an illustrative case study. It is therefore difficult to draw conclusions on overall GHG reduction potential. The combined effect of both measures depicted below is equal to the effect of a 20% increase in rail transport volume due to a shift from private car transport. For each 10% increase in rail transport volume due to a shift from road transport, the climate effect in the EU-27 in 2020 is 3 Mtonne CO_2 eq.

Figure 22 GHG emission reduction potential (in Mtonne CO_2 eq.) of measures targeting specific market segments



Note: The case studies are described in detail in Chapter 5. The percentages refer to the reduction in the overall market defined. See Chapter 2 and Table 35.

7.4 Passenger transport

7.4.1 Baseline emission scenario

Table 36 shows the baseline scenario for passenger transport emissions by road, rail and air transport in the year 2020.

Table 36 Baseline estimate of GHG emissions (2020, Mtonne CO_2 eq.)

Distance		<100 km	100-500 km	>500 km
Rail	Private	11	2	1
	Business	4	1	0
Car	Private	288	81*	
	Business	178	60	
Aviation	Private	8*		118
	Business	2		18
Total		482	154	137

* These emissions are calculated under the category 100-500 km.

As with rail freight transport, rail passenger transport accounts for only a limited share of aggregate emissions. Again, this is due both to the low share of rail in overall passenger transport and the limited climate impact per train-kilometre.

7.4.2 Emission reduction potential

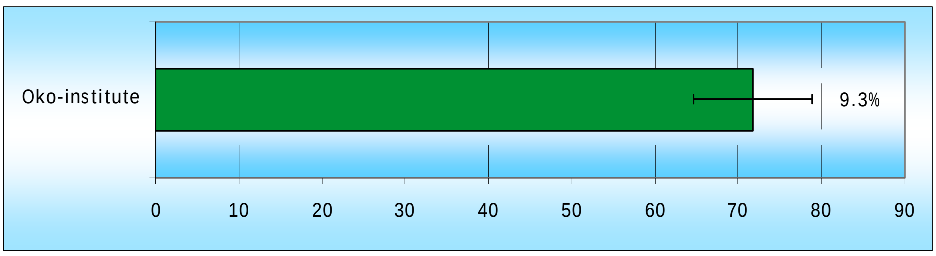
Conventional rail

The potential for modal shifting of short-distance passenger transport is not well documented in the literature. By far the greatest potential has been identified by Öko-Institute (EEA, 2008). However, this study had a theoretical framework that assumed significant quality improvements:

– Upgrading of all rail infrastructure to the quality in highly populated areas.
– Travel time reductions to levels comparable with private car transport.
– Reductions in travel costs to the level of private vehicles.

The study assumes that a significant fraction of medium- and long-distance trips can be shifted from car to train, leading to more than a doubling of the modal share of rail, but it is not clear whether the scenario can be underpinned with policies and measures. Furthermore, the capacity analysis (Chapter 6) showed that the growth potentials cannot be accommodated by the current infrastructure.

Figure 23 GHG reduction as a result of the increase of conventional rail transport and a decrease of road transport (2020, Mtonne CO_2 eq.) in EU-27

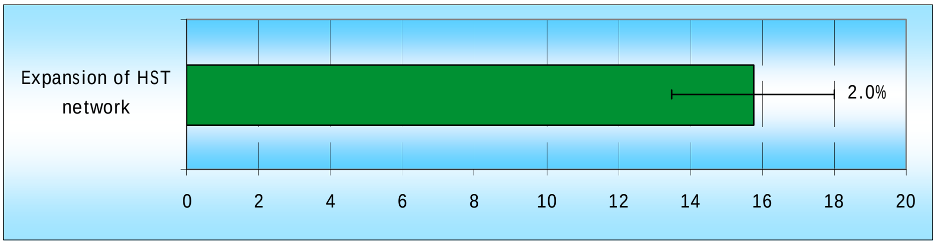


Note: The percentage refers to the reduction in the overall market defined; see Chapter 2 and Table 36.

Under 50% allocation of the free capacity to passenger rail, an emission reduction of 2 to 7 Mtonne CO_2 eq. could be achieved on the corridors and primary network, respectively, in 2020. On the basis of allocation of projected performance in the baseline scenario in 2020, these figures would increase to 4 and 11 Mtonne CO_2 eq.

High-speed rail
As can be seen from Figure 24 high-speed rail transport also has significant GHG reduction potential, although the current share in the EU is still limited, as discussed in Chapter 2. The potential GHG reduction of high-speed rail is 14-18 Mtonne CO_2 eq. in 2020, compared with a scenario where aircraft, cars and conventional rail are used for these trips.

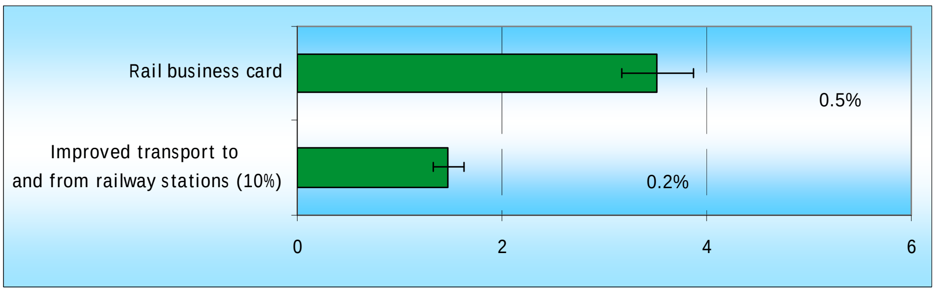
Figure 24 GHG reduction as a result of the increase of high-speed rail transport and a decrease of road and air transport (2020, Mtonne CO_2 eq.) in EU-27



Note: The percentage refers to the reduction in the overall market defined; see Chapter 2 and Table 36.

Market segments
The effects of the measures from the illustrative case studies (see Chapter 5), are dictated by their selection as an illustrative case study. Therefore, it is difficult to conclude on an overall GHG reduction potential. The combined effect of both measures depicted below is equal to the effect of a 20% increase of the rail transport volume due to a shift from private car transport. For each 10% increase in rail transport volume due to a shift from road transport, the climate effect in the EU-27 in 2020 is 3 Mtonne CO_2 eq.

Figure 25 GHG reduction resulting from application of measures from case studies (2020, Mtonne CO_2 eq.)in EU-27



Note: The percentage refers to the reduction in the overall market defined; see Chapter 2 and Table 36.

7.5 Rebound effect

It is above all measures that increase the speed of rail transport and/or reduce its costs through increased transport efficiency that make rail transport more attractive to transport users. Cost reductions and higher speeds have also a demand-increasing effect, however. This is known as the rebound effect.

Some of the cases studied illustrate the effect of more attractive rail transport. For example, high-speed rail attracts new travellers. And if resistance to rail travel is reduced through improved tram links to train stations, not only will people who previously travelled by car start using the train, but people might also consider making additional trips. The same is true for speed and capacity measures in rail freight transport. If transport capacity is increased, rail will not only attract freight from road transport, but also generate additional transport demand, through longer transport to and from loading points and an increase in rail freight transport due to changes in production locations.

As an example, the theoretical modal shift potential calculated by the Öko-Institute study was calculated mainly from a supply-side perspective, assuming that all rail transport was originally road transport. If a tonne-km is additional rather than shifted, however, the climate impact is the impact of both the additional rail demand and the non-shifted road transport in the calculations above. This illustrates the importance of taking into account.

The rebound effect does not play a role in the case of measures that increase the prices of transport. Internalisation of external costs therefore reduces the rebound effect to some extent.

In the present study it is difficult to take this effect into account, however, since the impact of measures on prices and speeds is unknown, and the same holds for the elasticity of changes in speed and reliability. The effect will therefore be illustrated by means of an example.

Rebound effect

In our present context the rebound effect is defined as rail growth that does not correspond to a reduction in road transport. Since the effect of measures (relating to interoperability and speed) on transport prices is unknown, this rebound effect cannot be quantified, but obviously exists, as described in this chapter.

The rebound effect of high-speed rail introduction is well-documented and amounts to around 25%. This is included in the analyses. We estimate that the rebound effects for freight transport are lower than for passenger transport, owing to more limited options for modal shift in the former.

We can estimate the effect when 10-15% of growth is additional rather than shifted. Under the assumption of 60% growth of rail transport (ZEW study), 6-9% would be additional rather than shifted. The climate effect would then not be 30 Mtonne but 20-24 Mtonne, which is 20-30% lower than initially.

The conclusion of this tentative analysis is that if rebound effects play a significant role, the climate impact of rail-promoting measures may be significant.

8 The 2050 perspective

8.1 Introduction

In the previous chapters potential future rail transport volumes were estimated from a demand and a capacity point of view, thereby focusing mainly on the period 2020-2030. Longer-term views are required, however, in order to prepare for radical changes in the context of an 80-95% reduction of transport GHG emissions in 2050. Parts of a speech given by the current EU Transport Commissioner Mr. Siim Kallas highlight the potentials of railway transport in this longer term.

> **The Single European Railway Area – Mr. Siim Kallas**
> **Quotes on the transport volume of the railways in 2050:**
>
> **"Railways should play an essential role in reducing the dependency of Europe on fossil fuels and the reduction of our emission of greenhouse gases".**
>
> **"In this vision, railways will be dominating freight transport over distances of more than 300 km – compared to today, where, measured in tonne-km, 50% of road freight is on journeys longer than 350 km".**
>
> **"Passenger railways will carry a majority of passengers (compared in particular to air) over medium distances of less than 3 hours journey time. (400-1,000 km). For passengers there must be high quality services, comfort and attractive and competitive prices."**
>
> **"And we will have a well functioning network of commuter and regional passenger services, which provide high quality punctuality and safety, making them an attractive choice encouraging people not to use private cars."**
>
> **Source: Speech of EU Commissioner Siim Kallas, Berlin 21-9-2010.**

In the following sections we translate this vision of Mr. Kallas to rail transport volume figures and estimate the potential impacts on transport GHG emissions on the one hand and the required infrastructure capacities, investments and policy measures on the other. The analysis is thus restricted to a translation to rail transport volumes, GHG reduction potentials and infrastructure needs. Economic efficiency has not been analysed and policy instruments are dealt with only superficially. Further study on the latter point is recommended to achieve more detailed insight into the impacts for society at large, for policy-making and for the rail sector.

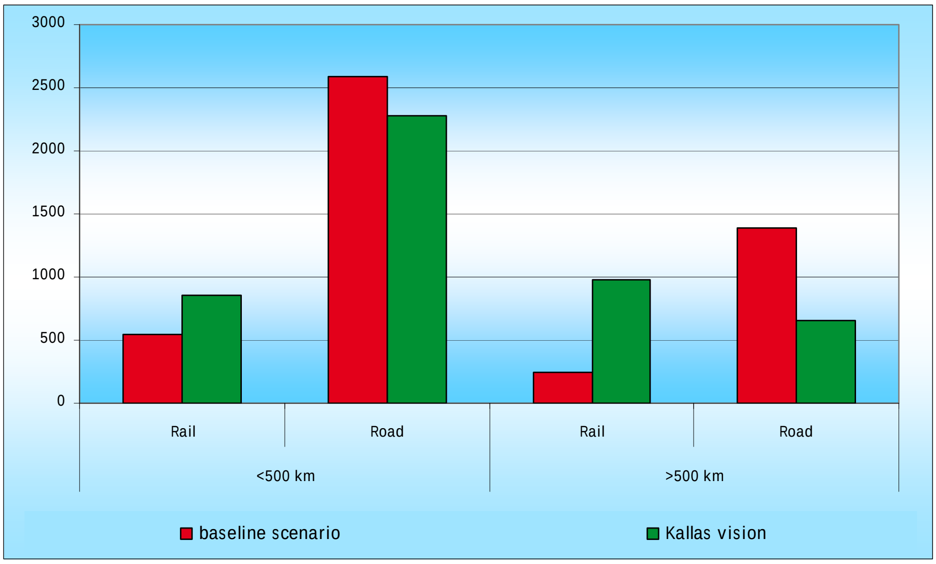
8.2 Translating the vision to rail transport volume

Freight transport

In the vision of Mr. Kallas rail will become the predominant mode of land-based freight transport in the EU. We translated this into a 60% market share (in tonne-km) on distances over 300 km. Our framework distinguishes between trips below and above 500 km. Because of a lack of information, as a rough estimate we assume that 20% of the transport volume below 500 km is over 300 km.

Figure 26 shows the resulting tonne-km of road and rail transport in this scenario compared with the baseline (Table 8). Overall, rail has a modal share of 38% in this scenario. This is similar to the theoretical modal shift potential calculated by Öko-Institute, which also assumes a major role for rail on long distances (EEA, 2008).

Figure 26 Freight transport volumes in the 2050 scenarios (billion tkm)

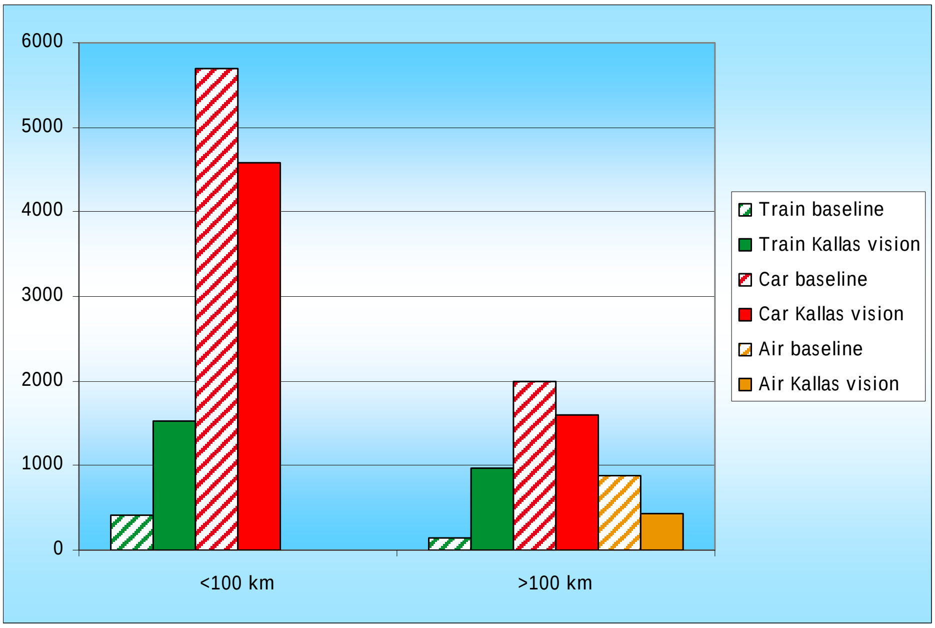


In absolute terms, road transport will still be the dominant mode, since its volume on shorter distances is high. However, the volume of rail increases significantly in the market segment above 500 km.

Passenger transport

For passenger transport we assume that in the 2050 vision of Mr. Kallas 50% of the EU air market in the baseline scenario will be served by the rail sector (by high-speed rail). Furthermore, we assume that the well-functioning commuter and regional passenger network will be able to accommodate a modal share of 25% on all other trips. This is a very challenging tripling/quadrupling of the market share in the baseline scenario. Compared with the baseline scenario (Table 8), rail and road would have the volume shown in Figure 26. In this scenario rail achieves a 27% share in passenger transport.

Figure 27 **Passenger transport volumes in the 2050 scenarios (billion pkm)**



8.3 Climate impact of the 2050 scenario

For passenger transport the baseline emissions in 2050 are slightly lower than in 2020. This is due mainly to energy efficiency improvements for all transport modes, which more than compensate for demand growth. For freight transport, the growth figures are higher and decarbonisation options more limited, resulting in significant emissions growth between 2020 and 2050.

Table 37 reports the baseline emissions, based on the assessment framework described in Chapter 2.

Table 37 **Baseline GHG emissions in 2050 (Mtonne CO_2 eq.)**

Passengers		**<100 km**	**100-500 km**	**>500 km**	**Total**
Train	Private	5	1		
	Business	2	0		
Car	Private	304	91		
	Business	178	75		
Aviation	Private	7		72	
	Business	3		18	
Total		498	167	91	756

Freight	**<500 km**		**>500 km**		**Total**
	Rail	**Road**	**Rail**	**Road**	
Container	1	89	0	39	
Bulk	1	52	0	46	
Miscellaneous goods	1	139	0	24	
Total	3	280	1	109	394

In the 2050 vision scenario, the strong modal shift towards rail saves 150 Mtonne CO_2 eq. (20%) for passenger transport and 86 Mtonne CO_2 eq. (22%) for freight transport, as depicted in Figure 28 for passenger transport and in Figure 29 for freight transport.

Overall the emission reduction potential of such a high modal shift is 236 Mtonne CO_2 eq, or 21% of the combined emissions of passenger and freight transport. It needs to be emphasised that these figures are based on crude assumptions which do not reflect possible changes in load factors or rebound effects.

Figure 28 Overview of the GHG reduction potential of strong growth of the share of passenger rail in the 2050 scenario (Mtonne CO_2 eq.)

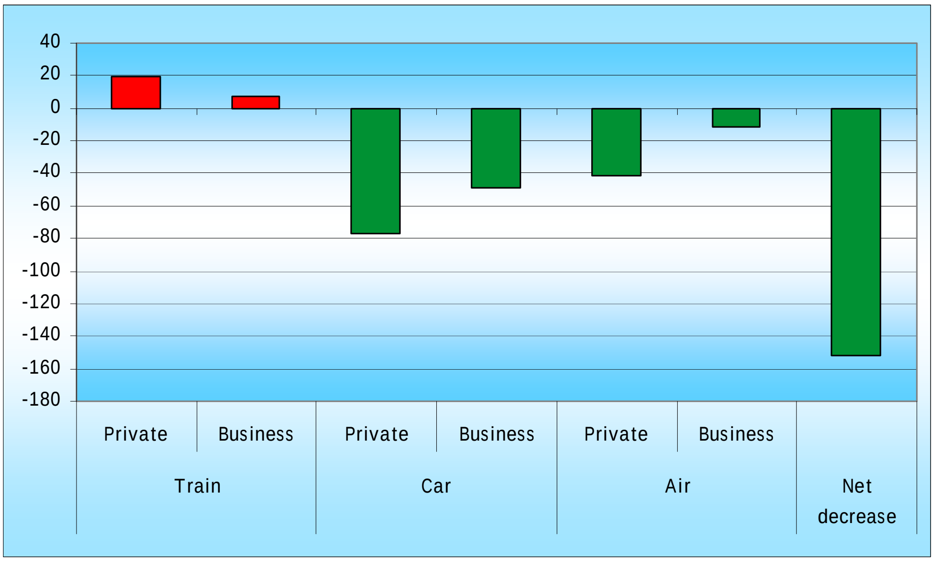
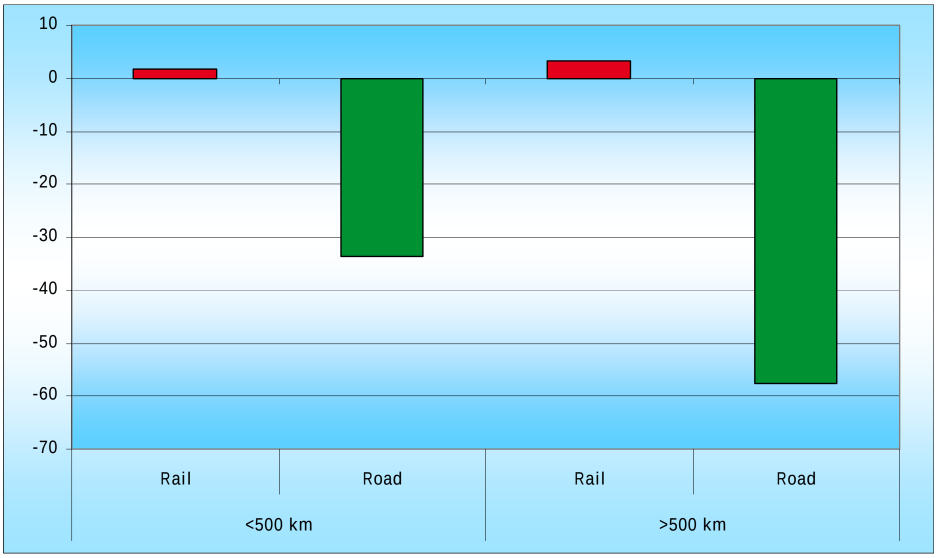


Figure 29 Overview of the GHG reduction potential of strong growth of the share of freight rail in the 2050 scenario (Mtonne CO_2 eq.)



8.4 Required infrastructure capacity

Under the 2050 scenario, the current capacity of the rail network will not be sufficient to accommodate the projected growth. Table 38 shows the amount of train-km needed to accommodate all demand in this scenario. If we compare the demand in this scenario with the available capacity in the upgraded scenario in 2030 that assumes full realisation of the TEN network (Table 32) we conclude that the available rail capacity of the whole network is much lower than the projected demand. Assuming that the primary network would above all be used, the capacity shortfall will be even greater.

The transport volume projections shown in Table 38 encompass an increase of load factors to 775-900 tonne/train and 140-160 pass/train. This should be achieved through longer trains and less empty running.

Table 38 Overview of rail transport volumes in the 2050 scenario

	Billion tonne-km	Billion pass-km	Billion train-km
Freight	1,836		2.0-2.3
Passenger		2,498	15-17
Total			17-19

The reported increase in demand implies almost a doubling of EU rail capacity. However, capacity demand is concentrated on the corridors, especially for freight transport and the cited increase in the capacity of the corridors will therefore probably be insufficient to accommodate all freight transport in this scenario. In addition, high-speed rail will also need significant network expansion.

Apart from the allocation of future demand, infrastructure needs to be built anyway to accommodate transport volumes going far beyond current levels. The current road infrastructure is also insufficient for accommodating 2050 demand. The need for additional infrastructure depends on the efficiency improvements that can be achieved by improving the capacity of the present infrastructure by increasing train length and speed and decreasing block length.

To assess the extent to which the projected rise in demand can be accommodated, it is important to estimate what kind of improvements can be envisaged for the network. To maintain good levels of service, average capacity utilisation must be kept at or below the acceptable threshold of 80%. This means that to accommodate the forecast 17-19 billion train-km a theoretical capacity of around 21-24 billion train-km is required.

If the network is assumed to consist of 30% single-track route and 70% double- or multi-track route, the required capacity can be achieved with a total network length of a little over 400,000 km. Compared with the 2030 situation, then, the required infrastructure development comprises, at the EU-27 level, around 140,000-170,000 km of completely new double-track lines. This estimate is based on an average standard capacity of 255 trains/day on double-track lines and 105 on single-track lines, which are higher figures than those adopted in Chapter 6 These higher volumes, achievable through efficiency gains, both on the network side through ERTMS systems deployed on major parts of the network and on the operational side through more balanced flows and higher load factors, may reduce the need for new infrastructure.

Proceeding from these figures, the required investments would range between 1,300 and 2,000 billion Euro. This range is based on investment costs of slightly less than 10 Million Euro/km, considering the actual expenditure forecast for the ongoing TEN-T projects that are based on a mix of technology improvement, upgrading and new lines. The overall investment is equivalent to between 4 and 6 times the total TEN-T programme and would therefore have to be supported by exceptionally strong political will and a strong push towards major improvements to the rail network. The upper limit might even be higher still if it is assumed that network expansion through to 2050 should consist mainly of completely new lines.

The table below summarises the theoretical required increase of network capacity.

Table 39 Overview of rail transport volumes in the 2050 scenario

Network today	Additional network required in 2050		Network increase in 2050	
	Min	Max	Min	Max
212,000 km	140,000 km	170,000 km	+65%	+82%

8.5 How to instrument such a strong modal shift?

The vision of Mr. Kallas is very ambitious indeed in terms of the magnitude of the modal shift to rail transport envisaged and is entirely at odds with the trends we have seen in recent decades. Such a massive shift to rail transport would clearly require a broad range of policy instruments and probably also a sea change in people's preferences and habits.

In this section we sketch some of the key policies that could contribute to changes in this direction. Clearly, due anticipation from the rail sector is also required.

Infrastructure capacity: a precondition

As explained in the previous section, the vision scenario for 2050 would require a virtual doubling of total rail infrastructure capacity. On corridors and the primary network even higher growth rates would be needed. This implies very high investments in rail infrastructure: an estimated 1,300 to 2,000 billion Euro. In addition, it would lead to higher operating and maintenance costs for rail infrastructure.

In his speech Mr. Kallas already indicated a number of possible policy measures and funding options; see the textbox below.

The Single European Railway Area – Mr. Siim Kallas
Quotes on the required measures:

"Before 2050 Europe must make substantial investments in railway infrastructure. We must invest in tracks, intelligent traffic control and management systems and to un-block bottlenecks."

"Budget money for infrastructure needs will be limited. The ageing population and other constraints will make the life of budgetary authorities difficult. We need bigger involvement of private capital. We need solutions to make infrastructure investments attractive to private money. "

"An essential element in separating business from political interference is the existence of strong independent regulators which must also execute efficient supervision on undertakings, enterprises. "

"Equally, we remain committed to ensuring that all external costs – pollution, accident costs etc – are "internalised" – so economic price signals truly reflect the real costs of each mode."

"We need high quality pan-European railway carriers."

Source: Speech of EU Commissioner Siim Kallas, Berlin, 21-9-2010.

As Mr. Kallas mentions, there may be limited public funding available for new infrastructure capacity in the future, implying a need to raise substantial sums of private capital. Funds for infrastructure investments might also be derived from transport pricing schemes, as discussed below.

Strong modal shift requires competitive travel times, prices and quality

A major expansion of rail infrastructure capacity is a precondition for achieving Mr. Kallas' vision of a modal shift to rail, but is not in itself any guarantee of such a shift. Modal shift will only occur when rail becomes the most attractive transport option for many more transport users and for many more transport relations than is the case today. This will require highly competitive door-to-door travel times, price levels and quality levels compared with the competing modes, in particular road transport.

Improving the competitiveness of rail transport in these three areas requires changes in the realms of both road and rail transport. There are various measures that can contribute to this aim:

- Removal of current bottlenecks, in terms of services offered[28] and interoperability.
- Improved geographical coverage of rail networks.
- Improved interconnectivity with other modes, to reduce door-to-door travel times.
- Spatial planning that focuses less on road and more on rail.
- Reduced car ownership.

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28 With respect to rail freight, services amenable to improvement include: frequency, speed and reliability of shipments, services for small volumes, door-to-door services, fast and easy contracting, value-added services, e.g. tracking and tracing, packaging, stock management, conditioned containers, transparency.

- Higher speeds on railway lines (with potential rebound effects on GHG emissions).
- Lower speed limits on roads and strict enforcement thereof.

There is also a broad pallet of other measures that could make rail transport more competitive. Although efficiency improvements within the rail sector may constitute a first step to reducing operating costs, it is pricing policies that are most important here. If road transport prices were to better reflect infrastructure costs as well as other external costs, rail prices would be far more competitive than they are today, since all these costs are higher for road than for rail. The precise impact of full cost internalisation on the relative price of rail compared with road depends on many assumptions, in particular:
- The valuation of externalities and cost of infrastructure provisioning and operation, management and maintenance. In this respect, there is particular uncertainty about the magnitude of CO_2 costs.
- Whether the full infrastructure costs are charged or just the variable costs.
- Assumptions regarding truck types, road types, energy consumption, emissions factors, load factors, etc.

For the period through to 2050, many of these assumptions become very uncertain. To assess the impact of pricing schemes we refer the reader to Section 4.2.1, where the impact of full internalisation of external costs was calculated. Full internalisation scenarios would result in a modal shift of between 2% and 8% of the current road transport volume, corresponding to 10 to 32% growth of rail volume. The vision scenario of Mr. Kallas implies a doubling of rail transport demand, corresponding to a decrease in road freight demand of about 23%. On its own, then, internalisation of external costs is certainly not sufficient for securing such a challenging objective. However, these figures do show that such a move can still make a significant contribution.

Last but not least, the quality of rail transport compared with road is also a key factor in long-term intermodal competition.

Besides improvement of supply factors, the future potential of passenger rail transport also depends very much on the extent to which existing cultural patterns can be changed. In short, societies need to be made less car-dependent. Measures that could contribute to this aim include:
- Abolition of subsidies that directly or indirectly promote car use (e.g. tax breaks for commuter trips and private use of company cars).
- Spatial planning designed in such a way that the various activities of living, working, services and so on can be accessed more readily without a car. Today, the need to combine a range of tasks increases the need for a car. New shopping malls are a particular case in point; today these are generally planned on city outskirts, thus necessitating private car use.

In freight transport, transport costs and supply factors will be important factors determining the modal split. In addition to internalisation of external costs, requirements of carbon footprinting of consumer goods and carbon labelling of logistical chains might help reduce the carbon intensity of freight transport and increase the share of rail. The same might hold if an emission ceiling were applied to the transport sector.

In the long term, the potential for rail will depend on the costs of decarbonising private car and truck transport. If more stringent targets of 80% decarbonisation compared with current levels were applied to cars and trucks, rail might become a more favourable transport mode.

9 Conclusions and recommendations

9.1 Introduction

In this chapter the main conclusions of the study are presented. The main findings from the different chapters are reiterated and elaborated into integrated conclusions.

9.2 Modal shift potential

Several measures have been studied, ranging from road pricing to improvement of interoperability and liberalisation and improvement of service quality.

Freight transport

The assessment of existing studies shows that the potential for an increase of rail freight transport is potentially high. Two projections that studied the maximum potential show a market share increasing from 18 to 31-36% in the relevant market[29]. This would require rail to be the dominant mode for long-distance transport. Other studies showed more limited effects, but these only took isolated (government or supply-side) measures into account. Some studies also show that the quality of services needs to be improved to achieve a higher market share. However, to what extent the maximum potentials could be achieved by government policies and measures by the rail sector requires further study on instrumentation of the potential.

Based on the market segmentation applied in this study, 80-100% growth would require rail to serve the entire market for long-distance transport. There is indeed scope for freight rail to increase its market share in market segments where its position is still limited:

- International containerised transport over long distances. The market share of rail in container transport is still low compared with road transport. The demand for containerised transport is set to increase significantly over the next decades however. If rail proves able to resolve problems concerning interoperability and national fragmentation, international rail transport over long distances will be able to boost its market share significantly. As shown by the case studies *'Transport of fresh produce'* and '*Port-hinterland transport'*, the scope for increasing the volume of long-distance containerised transport is promising.
- Inland non-port-related transport (chemicals, flowers, meat) is a market that today is hardly served by rail transport. The case study *'Transport of fresh produce'* shows that if rail is able to maintain a high level of service quality, its market share can increase in this segment.

In addition, political choices can increase the share of rail significantly. Examples are modal shift targets and heavy investments in infrastructure. Furthermore, intensified EU policies can help improve interoperability between countries by achieving harmonisation of technical systems and procedures.

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29 This market excludes inland barges and trucks below 16 tonnes GVW.

Passenger transport

The potential growth for passenger rail is not well documented in the literature. One study estimates a potential for a significant but theoretical increase in volume (more than doubling in 2030 compared with the baseline) based on heavy investments and significant improvements in service quality. However, this significant growth is only calculated under the hypothetical assumption that all rail transport achieves the highest quality available and that prices are lower than those of private car transport. For this potential, too, further research is needed to define the need for policies and increased services supply by the rail sector.

Passenger railways could increase their market share in market segments where the position is still limited:

- High-speed rail passenger transport is an alternative for air transport, and if rail succeeded in offering competitive prices and services, its market share in long-distance passenger transport would increase. This conclusion is underpinned by the case study '*High-speed train versus low-cost airlines*'.
- The case studies '*Rail business card*' and '*Transport to and from train stations*' show that improvement of rail accessibility and services for business car drivers could help increase the share of rail on short distances and in the market segment of business trips.

Generic climate policies such as internalisation of external costs, harmonisation of (carbon-based) energy taxes and application of uniform VAT regimes across all modes can help strengthen the position of rail transport.

9.3 Available additional infrastructure capacity

The assessment of infrastructure capacity indicates that in the upgraded scenario[30] capacity utilisation in 2020 is 52 and 57% for the primary network and the entire EU-27 network, respectively, while. on the main corridors the figure is higher; see Table 40. This implies that growth rates of around 20% (in terms of train-km) can be accommodated by the current infrastructure, compared with the baseline scenario. The exact figure depends on the extent of utilisation of the secondary network. In the short term local bottlenecks will obviously need to receive more attention than creation of new infrastructure. However, for growth figures exceeding the cited figure of 20%, additional infrastructure will be needed.

Table 40 Usable capacity in the EU-27 (2020), upgraded scenario

	Capacity utilisation	Max. capacity utilisation ratio
Whole network	52%	
Primary Network	57%	80%
Secondary Network	49%	65%
Corridors (total)	69%	90%

30 The upgraded scenario represents the TEN-T investment plan; see Chapter 6.

The potential for growth of freight and passenger transport volumes depends on how the available train-km are allocated. Under 50/50% allocation[31], rail freight transport can grow by 39% on the primary network and passenger transport by 14%. Future capacity allocation on the basis of 2020 transport volumes results in rail growth figures of 13 and 22% on the primary network for freight and passenger transport, respectively.

The current network can accommodate limited growth potentials, depending on the allocation of freight and passenger transport to the different networks.

9.4 Greenhouse gas reduction potential

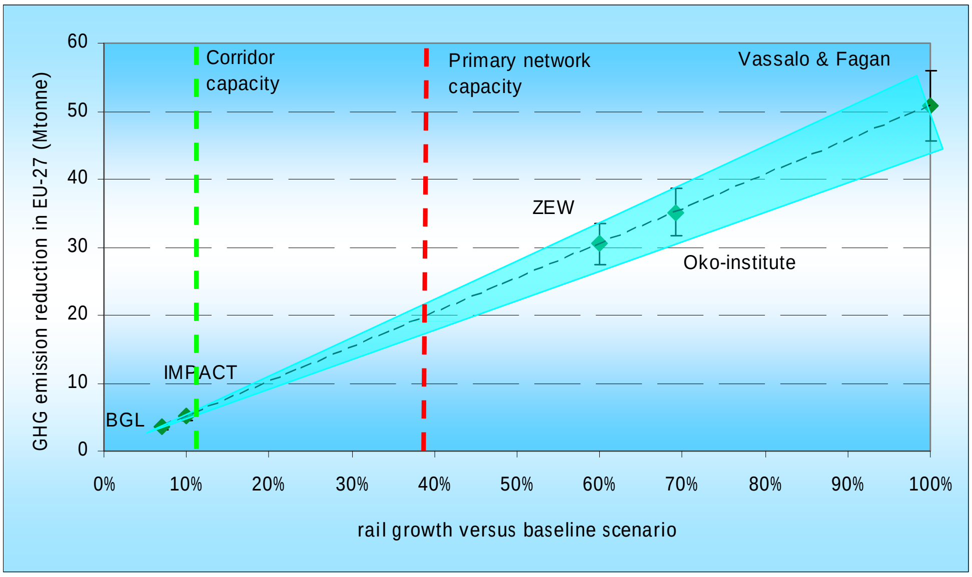
The average GHG reduction potential of freight transport modal shift is higher than that of passenger transport, since the difference in emissions per unit of volume are higher for freight.

For freight transport, estimates that assume single measures like a significant improvement of the quality of supply (ZEW) or EU-wide internalisation of external costs (CE, 2008b) result in a projected GHG reduction of 27-33 Mtonne CO_2 eq. (10-12%) and 5-6 Mtonne CO_2 eq. (2%), respectively. A significant shift to rail transport (Vassallo and Fagan) would result in a reduction of GHG emissions by 45-55 Mtonne CO_2 eq. This corresponds with 17-20% of the emissions from the market in which rail and road transport compete. These figures do not include rebound effects.

Figure 30 summarises the GHG reduction potential of a modal shift to rail freight, taking into account detouring, transport to and from loading points and other uncertainties like vehicle utilisation. The green and red dashed lines represent the additional capacity compared with the 2020 baseline scenario under the TEN-T investment scenario. They show that around 5-20 Mtonne of CO_2 eq. (2 to 7% in freight transport) could be reduced by fully utilising the corridors and the primary network respectively in 2020.

31 Passenger transport growth will be accommodated partly by newly constructed high-speed rail infrastructure. Furthermore, these networks have been defined primarily for freight transport.

Figure 30 **GHG reduction as a result of the increase of rail freight transport and decrease of road transport (2020, Mtonne CO_2 eq.) in EU-27**



Note: The different studies depicted are described in detail in Chapter 3. The corridor and primary network capacity are based on a 50% allocation of additional available network capacity (upgraded scenario) to freight. Allocation based on the projected volumes in 2020 would lead to lower growth rates for freight.

The potential for reducing the GHG emissions of passenger transport is harder to estimate unequivocally. The study by Öko-Institute (EEA, 2008) calculates scope for some 70 Mtonne CO_2 eq. reduction. If the required policy instruments and measures can be implemented, this would lead to a 9% emissions reduction in the defined passenger transport market in 2030.

Rebound effect

Some of the cases studied illustrate the effect of more attractive rail transport. For example, high-speed rail has been shown to attract new travellers. If rail travel is simplified, moreover, by improving tram and bus links to stations, not only will people accustomed to travelling by car shift to rail, but new transport demand will also be induced. The same holds for speed and capacity measures in rail freight transport. These rebound effects do not play a role in the case of measures that increase the prices of competing transport modes. Internalisation of external costs and lower speed limits for road vehicles will therefore have no rebound effects, but even co-benefits in reducing overall transport demand growth.

In the present study it proved hard to take this effect into account, since the impact of price and speed measures on the one hand and the elasticity of changes in speed and reliability on the other are both unknown. An illustrative example demonstrated, however, that a 10% rebound effect corresponds with 20% less CO_2 reduction. This implies that the effects to be expected might be smaller, but still significant.

9.5 The 2050 perspective

In a vision sketched by EU Commissioner Kallas, rail will be the dominant mode on long-distance transport and have a strong position in regional passenger transport. This vision has been translated into a 38% modal share in freight transport and a 27% modal share in passenger transport. The scenario results in a GHG reduction of 238 Mtonne CO_2 eq., which is a reduction of 21%. This scenario would require a massive investment in rail infrastructure (1,300-2,000 billion Euro) and optimal rail supply factors. Full internalisation of external and infrastructure costs could also contribute significantly, with a potential shift of 2 up to 8% of the road transport volume (corresponding to 10 to 32% growth of rail volume). Although internalisation of external costs alone is certainly not sufficient for achieving a doubling of rail transport demand (a decrease in road freight demand of about 23%), it can make a significant contribution.

9.6 Recommendations for further study

This study has identified several topics that require further research in order to better understand the potential of a modal shift to rail transport. The most interesting of these are:

- Assessment of the extent to which the maximum modal shift potential can be instrumented by government policies on the one hand and supply-side measures on the other, and analysis of the costs and benefits of these respective approaches.
- The climate impact associated with construction of new (high-speed) infrastructure.
- The magnitude of rebound effects to be accounted for in the case of travel cost decreases and higher average rail travel speeds.

In addition, the potential for modal shift could be further elaborated by means of:

- A social cost-benefit analysis of specific modal shift policies, particularly those focusing on improved use of existing rail network capacities.
- A study to assess the potential for decarbonising the EU rail sector in relation to cost decrease as a result of increased transport volumes due to better interoperability and the projected increase in the price of road transport.
- A study to assess the options for future financing of (rail) infrastructure and efficient allocation of the required funds.

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Annex A Comparison of sources used for projections

A.1 Description of sources

SULTAN
The SULTAN (**SU**stainab**L**e **T**r**AN**sport) Illustrative Scenarios Tool was developed by AEA as part of the project *EU Transport GHG: Routes to 2050*, carried out in the context of the EU Commission's long-term objective for tackling climate change. SULTAN is a high-level calculator (not an in-depth model) to help provide indicative estimates of the possible impacts of EU transport policies. The purpose of the tool is to permit quick scoping of a wide range of transport policy options.

TREMOVE
TREMOVE is a policy assessment model for studying the impact of transport and environment policies on the transport sector emissions. The model was developed by the Catholic University of Leuven and Transport & Mobility Leuven and is now managed by the JRC-IPTS of the European Commission.

EcoTransIT
The Ecological Transport Information Tool (EcoTransIT) calculates the environmental impacts of freight transport modes. In particular, it can be used to determine the energy consumption and CO_2 and exhaust emissions of any combination of rail, road, ship and air transport. EcoTransIT was developed by the Institute for Energy and Environmental Research (IFEU), Heidelberg and the Rail Management Consultants GmbH (RMCon). The project was originally initiated by a number of European railway companies in 2000 and several more rail companies have subsequently joined.

STREAM
STREAM stands for Study on TRansport Emissions from All Modalities. It is a Dutch database, established in 2009, providing emissions data per passenger-km and tonne-km. The underlying research was performed by CE Delft. It presents data for 2005 and estimates for 2010 and 2020 on the basis of expected policy and trends.

A.2 Comparison of energy consumption per passenger-km and tonne-km

For the sources described above we compared the energy consumption per passenger-km and tonne-km. Actual vehicle energy use is the most suitable parameter for this comparison, as this is not influenced by the emissions from electricity production (which vary across countries), which are a very important factor for the CO_2 emissions of electric trains. The assumptions made regarding the emissions associated with power generation are described in Section 2.6.2.

Table 41 and Table 42 report figures on energy use for 2010 from SULTAN, TREMOVE, EcoTransIT and STREAM, as well as the deviation (in %) from SULTAN. The orange-shaded values indicate differences of over 25%.

Table 41 **Energy consumption for passenger transport in MJ/pass-km and in %, the latter indicating the difference from SULTAN (+ SULTAN value lower; - SULTAN value higher)**

	SULTAN	TREMOVE		EcoTransIT		STREAM	
	MJ/pass-km	MJ/pass-km	%	MJ/pass-km	%	MJ/pass-km	%
Car	1.5	1.6	5%			1.6	4%
EUAviation	2.2	2.9	34%	1.9	-13%	1.8	-28%
Pas Rail	0.32	0.48	52%			0.5	47%

Table 42 **Energy consumption for freight transport in MJ/tonne-km and in % compared with SULTAN**

	SULTAN	TREMOVE		EcoTransIT		STREAM	
	MJ/tonne-km	MJ/tonne-km	%	MJ/tonne-km	%	MJ/tonne-km	%
MedTruck	3.1	2.2	-27%			4.3	41%
HeavyTruck	1.3	0.9	-30%	1.1	-17%	1.3	1%
FreightRail	0.15	0.23	50%	0.21	41%	02	35%

Below we discuss the differences between SULTAN and the other sources and describe the choices made in the present study.

Passenger cars
All the sources are in reasonable agreement on the emissions of passenger cars. There is therefore no reason to deviate from the values reported by SULTAN.

EU aviation
EcoTransIT and STREAM report a significantly lower emission factor for EU aviation than SULTAN (-13% and -28%, respectively). TREMOVE, on the other hand, reports a far higher value than SULTAN (+34%). The spread of these factors reflects the fact that there are several parameters of major influence on aircraft emission factors.

The first issue is the allocation of emissions to passengers and freight. As with plane occupancy rate, this only influences energy consumption per passenger-km and not total energy consumption. If the reported differences are due to differences in allocation method or assumed aircraft occupancy rates, emissions per km should be more or less the same. In the case of EcoTransIT and STREAM the differences are indeed smaller if we compare energy consumption per vehicle-km (+11% and -22%, respectively), while for EcoTransIT the value becomes even higher relative to SULTAN. TREMOVE does not report emissions per km, nor an occupancy rate. The remaining differences may be due to differences in assumptions regarding aircraft type and distances travelled.

It is difficult to say which source provides the most reliable value. As the SULTAN value lies somewhere between the figures reported in the other sources, however, this figure has been adopted in the present study.

Passenger rail

In SULTAN the energy consumption of trains is very low compared with the other sources, which are all in reasonably good agreement. The reason for this is that because of a calibration in SULTAN the energy consumption for trains was adjusted downwards. This worked fine in SULTAN, but the source is not suitable for our purpose. In this study the TREMOVE emission factors have therefore been adopted.

Heavy trucks

In the case of heavy trucks the SULTAN value is in line with the STREAM value, while TREMOVE and EcoTransIT report values that are far lower (-30% and -17%, respectively). Comparison of the energy consumption per vehicle-km reduces this deviation to +3% and +2%, respectively. This shows that the deviations originate from differences in load factor and it can thus be concluded that all sources agree on emissions per vehicle-km.

It is difficult to conclude which source is the most reliable with regard to load factors. The SULTAN figures are not entirely different from those reported in the other sources, however, and for practical reasons we have therefore adhered to the SULTAN scenario.

Freight rail

The energy consumption reported for freight rail transport is significantly lower in SULTAN than in the other sources, for the same reason discussed under passenger rail. Again, the TREMOVE emission figures have therefore been adopted.

Annex B Emission factors

B.1 Sources for determining emission factors per segment

Modality	Average emission factor	Trends towards 2050	Distribution over distance classes	Distribution over travel motives (passengers)	Distribution over cargo types (freight)
Cars	SULTAN	SULTAN	TREMOVE/CBS	TREMOVE/CBS	-
Aviation	SULTAN	SULTAN	TREMOVE	-	-
Passenger rail	TREMOVE	SULTAN	TREMOVE	-	-
Trucks	SULTAN	SULTAN	Eurostat	-	Eurostat
Freight rail	TREMOVE	SULTAN	TREMOVE	-	TREMOVE

B.2 Emission factors

Direct emissions (g CO_2 eq./pass-km or g CO_2 eq./tonne-km)

Passengers		2020			2030			2050		
		<100 km	100-500 km	>500 km	<100 km	100-500 km	>500 km	<100 km	100-500 km	>500 km
Train	Private	14	9	1	13	9	1	11	7	0.8
	Business	14	9	1	13	9	1	11	7	0.8
Car	Private	80	72		72	65		65	59	
	Business	135	143		122	129		110	116	
Aviation	Private	195		119	179		109	154		93
	Business	195		119	179		109	154		93

Freight	2020				2030				2050			
	<500 km		>500 km		<500 km		>500 km		<500 km		>500 km	
	Rail	Road	Rail	Road	Rail	Road	Rail	Road	Rail	Road	Rail	Road
Container	7.2	117	5.8	88	6.3	113	5.1	85	4.7	103	3.8	77
Bulk	6.7	75	5.4	69	5.9	73	4.7	67	4.4	66	3.5	61
Miscell. goods	7.2	126	5.7	94	6.3	122	5.0	91	4.7	111	3.7	83

Indirect emissions (g CO_2 eq./pass-km or g CO_2 eq./tonne-km)

Passengers		2020			2030			2050		
		<100 km	100-500 km	>500 km	<100 km	100-500 km	>500 km	<100 km	100-500 km	>500 km
Train	Private	33	22	24	23	15	17	5	4	3.9
	Business	33	22	24	23	15	17	5	4	3.9
Car	Private	9	8		8	7		7	6	
	Business	15	16		13	14		12	13	
Aviation	Private	36		119	33		20	28		17
	Business	36		119	33		20	28		17

Freight	2020				2030				2050			
	<500 km		>500 km		<500 km		>500 km		<500 km		>500 km	
	Rail	Road	Rail	Road	Rail	Road	Rail	Road	Rail	Road	Rail	Road
Container	5.7	14	4.6	11	4.2	14	3.3	10	1.1	13	0.9	9
Bulk	5.3	9	4.3	8	3.9	9	3.1	8	1.1	8	0.8	7
Miscell. goods	5.7	15	4.5	11	4.2	15	3.3	11	1.1	14	0.9	10

Annex C Sources for determining volumes per segment

Modality	Average volume	Trends towards 2050	Distribution over distance classes	Distribution over travel motives (passengers)	Distribution over cargo types (freight)
Cars	SULTAN	SULTAN	TREMOVE[1]	TREMOVE	-
Aviation	SULTAN	SULTAN	TREMOVE	-	-
Passenger rail	SULTAN	SULTAN	TREMOVE[1]	-	-
Trucks	DG TREN	DG TREN	TREMOVE	-	TREMOVE
Freight rail	DG TREN	DG TREN	TREMOVE	-	TREMOVE

1 The assignment of pass-km to the classes <100 km and >100 km was performed on the basis of expert judgement.

Annex D TREMOVE model description

TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector. It is an integrated simulation model developed for the strategic analysis of the costs and effects of a wide range of policy instruments and measures applicable to local, regional and European transport markets.

TREMOVE consists of three main modules: Transport Demand module, Vehicle Stock module and Fuel Consumption and Emissions module. Additionally, a Life-cycle Emissions module and a Welfare module are also part of the model.

As far as transport demand is concerned, the baseline is taken from an external model (from the TRANS-TOOLS model in the latest version, previously from the SCENES model). The TREMOVE demand module then enables assessment of changes in transport demand under various policy scenarios.

The demand module produces aggregate transport quantities by mode. The vehicle stock module disaggregates these into detailed vehicle-kilometre figures by vehicle type, vehicle technology and vehicle age. For cars, motorcycles, vans, light-duty trucks and buses the disaggregation by vehicle type is performed using a discrete-choice (multinomial) logit model calibrated on (mainly) figures from COWI, EUROSTAT and ACEA. The evolution of the train fleet in the baseline is based on exogenous inputs; in the latest version of TREMOVE it is consistent with the long-term trends in the EX-TREMIS database[32].

In the fuel consumption and emissions module fuel consumption and exhaust and evaporative emissions are calculated for all modes. Emission factors have been derived consistently from EU sources, and may therefore deviate from national estimates. For road vehicles, TREMOVE emission factors are based on (a preliminary version of) the COPERT IV emission calculation methodology, to which several additions have been made, including:

- Disaggregation of COPERT diesel car fuel consumption factor into three factors according to engine displacement, based on EU CO_2 monitoring data.
- Upward scaling of COPERT fuel consumption factors for 2002 cars, based on EU test-cycle monitoring data and information on the difference between test-cycle and real-world fuel consumption.
- Introduction of fuel efficiency improvement factors. For cars these are based on the voluntary agreements between the EU and the automotive industry.
- Update of moped and motorcycle emission factors based on recent information.
- Emission factors for CNG vehicles.

32 EX-TREMIS is a reference system on fleet and transport activity data, specific energy consumption, emission factors and total emissions for non-road transport modes (maritime, rail and aviation) in the 27 EU Member States. The database has been developed for the EC JRC-IPTS and is accessible from the website http://www.ex-tremis.eu/.

Fuel consumption and emission factors for non-road modes have been derived from the EX-TREMIS database (in previous versions of TREMOVE the source was TRENDS[33]). The life cycle assessment module of TREMOVE is restricted to the fuel cycle only. Thanks to this module, it is not only the operational emissions of vehicles that are calculated, but also the emissions due to production and distribution of the fuel (or electricity),. i.e. well-to-tank and tank-to-wheel emissions.

33 Georgakaki, A., Coffey, R. Sorenson, S. C. (2002): Transport and Environment Database System (TRENDS). Detailed Report 3: Railway Module. Final Report to the European Commission.

Annex E Measures to improve capacity

There are numerous strategies for improving the capacity of the European rail network and they may be assessed very differently according to the perspective of the analyst (infrastructure manager, operator). In any such assessment it is important to consider the full set of railway system components, and not merely the infrastructure. Rolling stock, for example, is often considered as a constraint and not as an optimisation variable. In this annex we briefly consider the main strategies available.

Increasing the number of tracks

Rail operators (freight or passenger) aim to operate their trains with as few constraints as possible. When capacity limits are reached, they generally argue for increasing the number of tracks. Thus, formerly double-track lines become full-length triple- or quadruple-track lines. Sometimes this leads to construction of a new double-track line, as has been the case for high-speed lines and base tunnels, for example.

While certainly costlier, expansion from double to quadruple tracks is the solution that offers the greatest operational flexibility. With two parallel tracks assigned to one direction, active overtaking (both trains moving) is possible along the entire length of the line without interfering with trains running in the opposite direction. This configuration also allows operation as two parallel independent lines, one assigned to fast trains and the other reserved for slow ones.

Full-length triple-track lines already alleviate many capacity concerns. However, expanding a line from double to triple tracks does not result in a 50% increase of capacity, as at least one track has to be used for both directions, reducing its capacity compared with a mono-directional track.

Increasing transport supply with infrastructure unchanged

Infrastructure managers often have serious difficulty obtaining funding for infrastructure expansion and find themselves obliged to consider developing their transport operations under the constraint of ‘unchanged infrastructure’.

On a saturated double-track line the only way to increase transport supply is to reduce service variability. This means reducing the number of train types or number of stops, or both, in order to achieve greater uniformity in rolling stock characteristics (e.g. braking and acceleration patterns) and timetables, respectively. This kind of policy move means either abandoning certain stops to accelerate slow trains, or artificial slowing of fast trains, by introducing extra stops or imposing speed limits. The idea here is to make train paths parallel, thus avoiding capacity-hungry overtaking operations.

Accelerating slow trains reduces the speed differential by avoiding a fast train catching up with a slow one just before an overtaking station or terminal station and/or by freeing up time slots in the timetable that can be devoted to extra train paths that can be added behind slow trains.

While it is clear that such actions will not in themselves be sufficient to resolve all capacity issues, it is important not to neglect them in an overall drive towards optimisation.

Controlling and signalling (ERTMS)

The ERTMS (European Rail Traffic Management System) comprises two main elements: ETCS (European Train Control System) and GSM-R (a radio control system for voice and data communication). ERTMS works by standardising both the information and the means of transmission used by trains to automatically send and receive data to and from signalling control systems. ERTMS has three levels. Level 1 essentially offers safety benefits rather than capacity, while Level 2 offers capacity benefits alongside safety benefits. At Level 3 the train reports its position, rather than relying on trackside equipment, allowing for potentially even greater capacity and lower costs due to less equipment. In principle, ERTMS Level 3 delivers greater capacity benefits than those achievable with Level 2. However, as the block size of a Level 2 system tends towards zero, the achievable capacity will tend towards that of an ERTMS Level 3 line. The advantage of Level 3 (running in a 'virtual' block mode) is that block size can be changed without altering the physical track infrastructure. Level 3 can give practical capacity benefits, particularly in certain high-density urban settings as well as in some regional settings as a replacement for absolute block signalling. In most other scenarios route capacity is constrained by other factors and conventional signalling has already been optimised to match these constraints.

Rescheduling the timetable

Rescheduling of timetables, in combination with train control, represents a promising low-cost strategy for increasing the capacity and stability of heavily used mixed-traffic rail networks. One way to increase the number of trains operated is to reduce the headway (time) between them. Headway is governed by two factors: safety and schedule reliability. The safety component ensures that trains are separated by enough distance to prevent collisions. The schedule reliability component is designed to provide sufficient reserve (or buffer) time to ensure trains remain on schedule (i.e. it reduces the impact of delays on system-wide operations). The lowest possible headway is determined in an absolute sense by considerations of safety, based on the distance required by a specific train to stop on a specific track segment. There are many strategies for reducing the minimum headway between trains, many of which are based on rapid communication of 'stop' or speed instructions to moving trains (e.g. moving block signals, ETCS/ERTMS). These require improvements to signalling systems and on-board equipment. Once the lowest technically feasible headway has been determined, schedule planners add reserve (buffer) time to the schedule to reduce the impact of delays and incidents on network operations, in other words improving schedule stability, but reducing capacity.

Increasing levels of train control and traffic management can provide improved safety and reliability in a railway network, thereby allowing headways to be reduced (and capacity to be increased).

Proper consideration to rolling stock

Although capacity expansion is primarily an infrastructure issue, the contribution of rolling stock should always be duly considered in this context. Indeed, in any comprehensive drive towards optimisation it is paramount to give appropriate consideration to rolling stock. This is for two main reasons:

- Maximum speed, tractive and braking performances and a range of other characteristics go a long way to determining the commercial speed of a train (and thus the capacity assessed as number of possible train paths).
- The length of the train-set and the type of coaches employed (single or double stack) are direct determinants of transport capacity.

By increasing train length or using double-stack coaches it is possible to increase passenger comfort (number of seated passengers) with no more infrastructure investments required than those needed to extend platforms at stations and adapt them to the increased height. In such cases, investments are shared between the infrastructure manager and train operators.

If these measures are insufficient or ill-adapted to basic needs (to provide a more balanced transport supply across the time spectrum, for example), actions in the first category mentioned above will need to be considered, i.e. acceleration of slow trains without abandoning intermediate stops. To reduce the impact of intermediate stops, frequently stopping trains should exhibit the best possible performances in terms of acceleration and braking. On saturated lines, slow trains are often slowed down not only because of frequent stops, but also because of their poor performance: in practice, rail operators tend to assign their oldest materiel to the least 'flashy' services.

Identifying condensation and compensation zones

The concepts of condensation and compensation zones derive from certain nodes and links in a railway network having excess capacity (compensation zones) while others have none (condensation zones). In condensation zones it is critical that trains will be operated extremely precisely or delays will occur that may propagate throughout the entire network. In compensation zones excess capacity provides trains with operational flexibility (i.e. speed control) that allows them to maximise the capacity and schedule stability in condensation zones. More specifically, trains can be operated in zones with excess capacity so that they arrive at exactly the right time and at exactly the right speed at the gateways to the capacity bottleneck zones. Note that arriving at both the correct speed and time is necessary to maximise capacity.

The division into condensation and compensation zones facilitates optimum operation of capacity bottlenecks and therefore guarantees that the current weak spots of a network are always the focus of planning. The integrated real-time rescheduling algorithms must be able to provide new production plans that specify a valid slot time for all trains entering the condensation zone and a specific platform departure time accurate to a tenth of a minute.

Differentiating measures for each railway corridor

Finally, there are several more general strategies for increasing rail capacity:

- Having a plan for each individual corridor that provides the best solution available for addressing capacity challenges in the short to medium term, with clearly identified options for addressing continued growth in demand in the long term.
- Pursuing ways of increasing capacity that are straightforward to implement, low-cost and uncontentious, in order to bring prompt increases in capacity. Where these solutions are inadequate, the search moves on to alternative approaches that have longer lead times or are more costly or more contentious.
- The right solution varies from corridor to corridor, because their starting positions and demand-growth prospects differ: in short, 'one-size-fits-all' solutions are inappropriate.