External Costs of Transport in Europe

Update Study for 2008

Report
Delft, November 2011

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Publication Data

Bibliographical data:
CE Delft, Infras, Fraunhofer ISI
External Costs of Transport in Europe
Update Study for 2008
Delft, CE Delft, November 2011

Transport / International / EC / Costs / Accidents / Air pollution / Climate Change / Noise / Congestion
FT: External cost

Publication code: 11.4215.50

CE-publications are available from www.cedelft.eu

Commissioned by: International Union of Railways UIC.
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Contents

Abstract

Previous UIC studies on external costs of transport (INFRAS/IWW 1995, 2000, 2004) are widely known and cited in the scientific and political arena and provide a comprehensive comparison of transport modes in Europe based on their economic impact on society. However, since 2004, various important developments took place such as the publication of the EC Greening Transport Package from 2008, the 2011 EU White Paper, the latest revision of the Eurovignette Directive and various new studies on the external cost of transport. Against this background UIC commissioned CE Delft, INFRAS and ISI to carry out this update study, to obtain a state-of-the-art overview of the total, average and marginal external costs of transport in the EU.

This update study shows that the average external costs for road transport are much higher than for rail. Per passenger-km the costs of cars or aviation are about four times those of rail transport. For freight transport we see a similar pattern. The predominant cost categories are accidents and emissions (climate change, air pollution and upstream).

When combining the average costs with transport volume data, the sum of all external costs were calculated. The total external costs of transport in the EU plus Norway and Switzerland in 2008 amount to more than € 500 billion, or 4% of the total GDP. About 77% of the costs are caused by passenger transport and 23% by freight. On top of these, the annual congestion cost of road transport delays amount to between € 146 and 243 billion (1 to 2% of the total GDP).

Road transport modes have by far the largest share in these costs (93%). This can be explained by the large share of road in the overall transport volume as well as their higher average external costs per passenger-km or tonne-km. Passenger cars have a share of about 61%, followed by trucks (13%), vans (9%), two-wheelers (6%) and buses (4%). From the non-road modes, aviation has the largest share in external costs with about 5%, although only intra-EU flights are included. Rail transport is responsible for less than 2% and inland shipping for only 0.3%. Sea shipping was not included in this study.

Apart from average costs, also marginal external costs have been calculated, distinguishing various network types, vehicle technologies and traffic situations. These results show that also the marginal external costs for road are much higher than for rail transport. It also becomes clear that the marginal costs in urban areas are much higher than in non-urban areas.
The external costs for road transport are lowest on motorways.

The results of this study can be used for various purposes. The total and average cost estimates provide a strong basis for comparing the environmental burden of various transport modes. They could also serve as a basis for transport pricing or be used in cost benefit analysis (CBA) or for general policy development.

Summary

Background of the update study

Previous UIC studies on external costs of transport (INFRAS/IWW 1995, 2000, 2004) are widely known and cited in the scientific and political area and provide a comprehensive comparison of transport modes in Europe based on their economic impact on society.

Since the last update study in 2004 using data for 2000, the relevance of the subject has increased. Internalisation of external costs is one of the main focus points of the EC Greening Transport Package from 2008 and also in the 2011 EU White Paper on Transport. The latest revision of the Eurovignette Directive now allows Member States to calculate tolls based on costs of air pollution and noise of road freight traffic. In addition, the topic of externalities was further developed by different European and national studies.

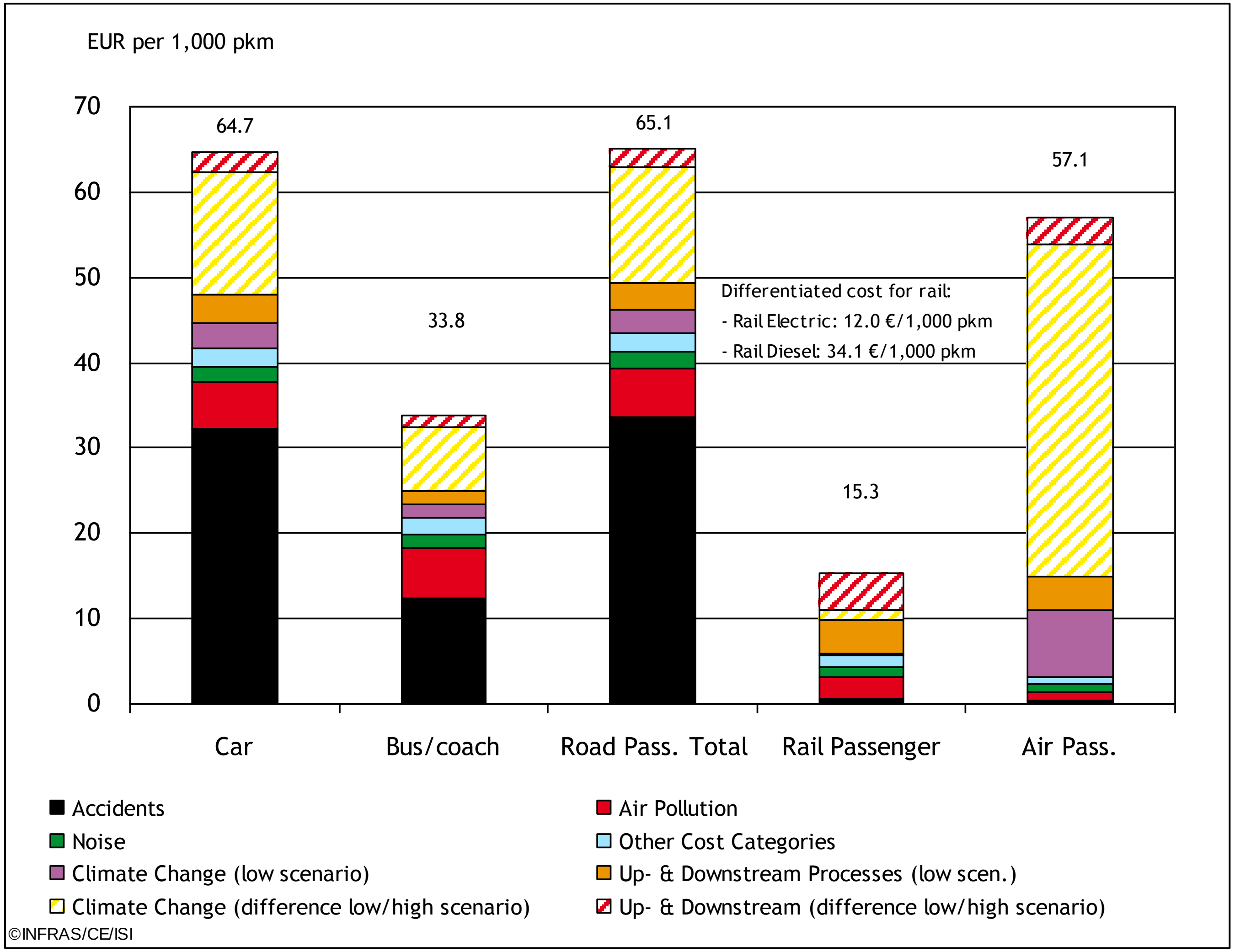
Against this background, UIC commissioned CE Delft, INFRAS and ISI to carry out this update study, to obtain a state-of-the-art overview of the total, average and marginal external costs of transport in the EU. With the EU enlargements of the last decade, the scope of the study was extended to the EU-27 with the exemption of Malta and Cyprus, but also including Norway and Switzerland.

Results for total and average external costs

Figure 1 and Figure 2 below shows that the average external costs for road transport are much higher than for rail. Per passenger-km the costs of cars or aviation are about four times those of rail transport. For freight transport we see a similar pattern. The predominant cost categories are accidents and emissions (climate change, air pollution and upstream). Note that congestion costs are not included in this graph[1].

[1] As in the previous external cost studies for UIC, the congestion-externality is presented separately and not added up in terms of total external costs of transport. Delay costs, which we use as the main congestion indicator, are mainly transport-sector internal and the social efficiency measure addresses different aspects of externalities. While from the transport efficiency perspective the separation of system-internal and system-external cost categories is irrelevant, it matters when comparing transport modes.

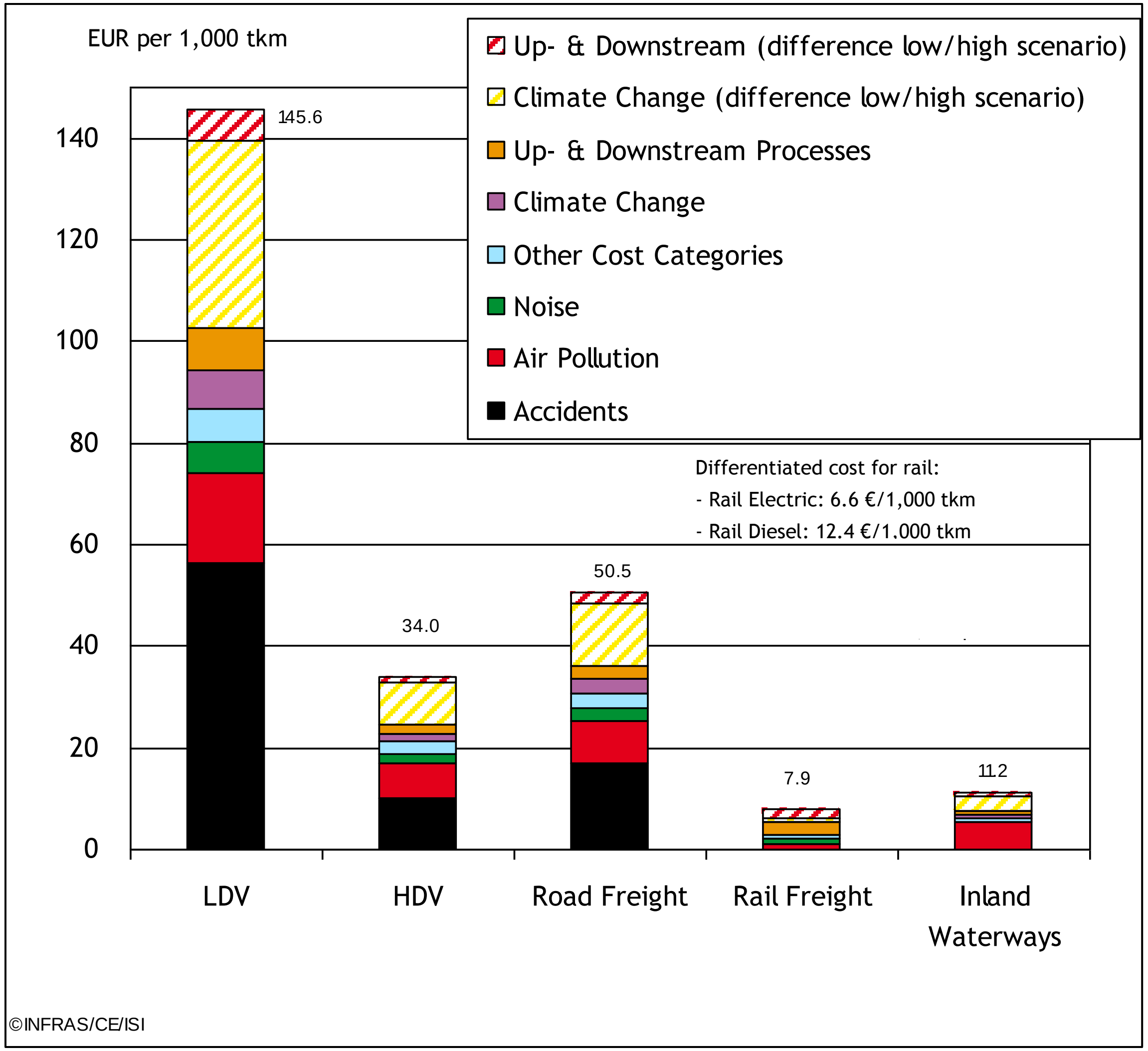
Figure 1 **Average external costs 2008 for EU-27*: passenger transport (excluding congestion)**



Other cost categories: Costs for nature & landscape, biodiversity losses (due to air pollution), soil and water pollution costs, additional costs in urban areas. Data do not include congestion costs.

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

Figure 2 Average external costs 2008 for EU-27*: freight transport (excluding congestion)



Other cost categories: Costs for nature and landscape, biodiversity losses (due to air pollution), soil and water pollution costs, additional costs in urban areas. Data do not include congestion costs.

Road Freight Total: The weighted average of all road freight transport modes.

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

Table 1 **Average external costs 2008 for EU-27* by cost category and transport mode (excluding congestion)**

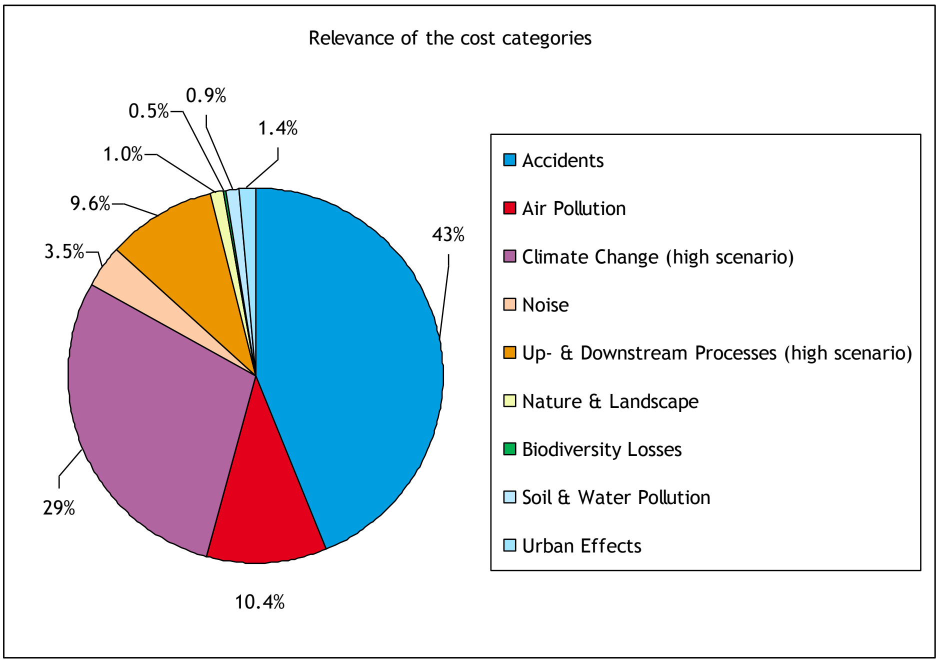
	Average costs per cost category												
	Passenger transport							Freight transport					
	Road				Rail	Aviation	Total	Road			Rail	Waterborne	Total
	Passenger cars	Buses & coaches	Motorcycles & mopeds	Total road passenger transport	Passenger transport	Passenger transport (cont.)		LDV	HDV	Total road freight transport	Freight transport	Freight transport	
Cost Category	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)
Accidents	32.3	12.3	156.6	33.6	0.6	0.5	29.0	56.2	10.2	17.0	0.2	0.0	13.4
Air pollution	5.5	6.0	11.8	5.7	2.6	0.9	5.2	17.9	6.7	8.4	1.1	5.4	7.1
Climate change high scenario	17.3	9.1	11.1	16.3	1.5	46.9	17.6	44.5	9.8	14.9	0.9	3.6	12.1
Climate change low scenario	*3.0*	*1.6*	*1.9*	*2.8*	*0.3*	*8.0*	*3.0*	*7.6*	*1.7*	*2.6*	*0.2*	*0.6*	*2.1*
Noise	1.7	1.6	14.4	2.0	1.2	1.0	1.9	6.3	1.8	2.5	1.0	0.0	2.1
Up- and downstream high scenario	5.7	2.8	3.6	5.4	8.1	7.1	5.7	14.3	3.0	4.7	4.2	1.3	4.4
Up- and downstream low scenario	*3.4*	*1.5*	*2.3*	*3.2*	*3.9*	*3.9*	*3.3*	*8.4*	*1.7*	*2.7*	*2.4*	*0.8*	*2.5*
Nature & landscape	0.6	0.3	0.5	0.6	0.2	0.6	0.6	0.9	0.7	0.7	0.0	0.4	0.6
Biodiversity losses	0.2	0.4	0.1	0.2	0.0	0.1	0.2	0.6	0.5	0.5	0.0	0.5	0.4
Soil & water pollution	0.3	0.9	0.3	0.4	0.5	0.0	0.4	1.8	0.8	1.0	0.4	0.0	0.8
Urban effects	1.0	0.4	0.8	0.9	0.6	0.0	0.8	3.1	0.5	0.9	0.1	0.0	0.7
Total (high scenario)	**64.7**	**33.8**	**199.2**	**65.1**	**15.3**	**57.1**	**61.3**	**145.6**	**34.0**	**50.5**	**7.9**	**11.2**	**41.7**
Total (low scencario)	*48.1*	*24.9*	*188.7*	*49.4*	*9.8*	*15.0*	*44.3*	*102.8*	*24.6*	*36.1*	*5.3*	*7.7*	*29.7*

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs.

When combining the average costs with transport volume data, the sum of all external costs was calculated. The total external costs of transport in the EU plus Norway and Switzerland in 2008 amount to more than € 500 billion per year, or 4% of the total GDP[2]. About 77% of the costs are caused by passenger transport and 23% by freight. On top of these, the annual congestion cost of road transport amount to between € 146 and 243 billion (delay costs), which is 1 to 2% of the GDP. Corresponding figures for the scheduled modes rail and air are not computed as here access management internalises capacity impacts on operating costs already in the planning phase.

Road transport modes have by far the largest share in these costs (93%). This can be explained by the large share of road in the overall transport volume as well as their higher average external costs per passenger-km or tonne-km. Passenger cars have a share of about 61%, followed by trucks (13%), vans (9%), two-wheelers (6%) and buses (4%). From the non-road modes, aviation has the largest share in external costs with about 5%, although only intra-EU flights are included. Rail transport is responsible for less than 2% and inland shipping for only 0.3%. Sea shipping was not included in this study.

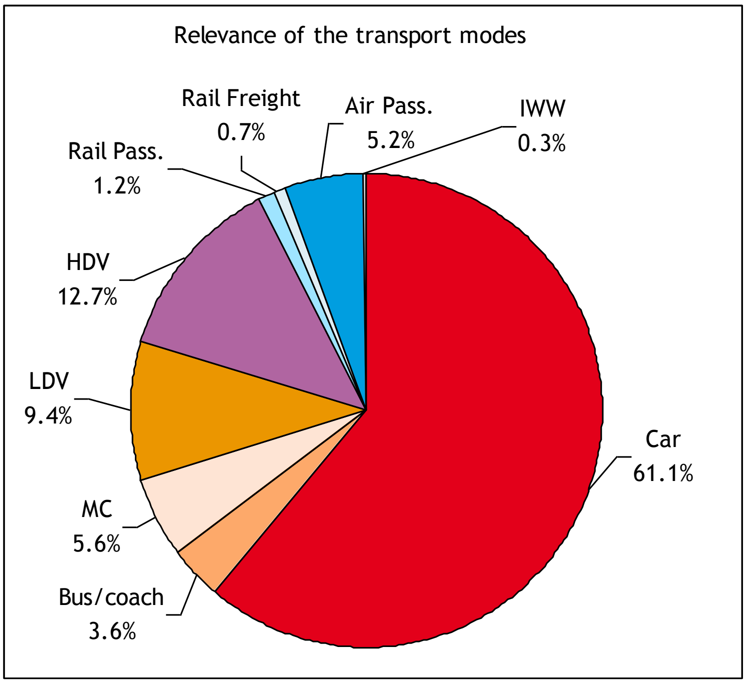
Figure 3 Share of the different cost categories on total external costs 2008 for EU-27* (excluding congestion)



* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs.

2 The GDP in EU27 in 2008 was about € 12.5 quadrillion (12.5 thousand trillion).

Figure 4 Share of the different transport modes on total external costs 2008 for EU-27* (excluding congestion)



* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs.

Table 2 **Total external costs 2008 for EU-27* by cost category and transport mode**

	Total costs per cost category								
	Road					Rail		Aviation	Waterborne (freight)
	Passenger cars	Buses & coaches	Motorcycles & mopeds	LDV	HDV	Passenger transport	Freight transport	Passenger transport (cont.)	Inland waterways
Cost category	**Mio €/a**	**Mio €/a**	**Mio €/a**	**Mio €/a**	**Mio €/a**	**Mio €/a**	**Mio €/a**	**Mio €/a**	**Mio €/a**
Accidents	157,105	6,839	22,584	18,677	19,604	238	71	223	0
Air pollution	26,636	3,347	1,696	5,933	12,995	1,092	483	426	782
Climate change high scen.	84,135	5,060	1,597	14,787	18,845	630	413	22,166	516
Climate change low scen.	*14,407*	*866*	*273*	*2,532*	*3,227*	*108*	*71*	*3,796*	*88*
Noise	8,201	865	2,076	2,094	3,537	477	476	457	0
Up- & downstream Proc. high scen.	27,679	1,568	523	4,765	5,802	3,354	1,947	3,356	194
Up- & downstream Proc. low scen.	*16,621*	*855*	*325*	*2,777*	*3,270*	*1,633*	*1,078*	*1,849*	*113*
Nature & landscape	3,008	149	75	284	1,293	75	21	296	64
Biodiversity losses	1,152	212	20	208	893	1	1	40	69
Soil & water pollution	1,582	485	40	601	1,629	220	164	0	0
Urban effects	4,814	232	116	1,035	965	229	59	0	0
Total (high scenario)	**314,310**	**18,757**	**28,727**	**48,384**	**65,564**	**6,318**	**3,636**	**26,964**	**1,625**
Road congestion (delay costs): min.	98,416	4,836	2,439	13,827	26,695	:	:	:	:
Road congestion (delay costs): max.	161,331	7,729	3,841	27,633	42,660	:	:	:	:

Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland; “:”: not applicable. Total excluding congestion costs.

Marginal external costs
Marginal external costs have also been calculated, distinguishing various network types, vehicle technologies and traffic situations. These results show that also the marginal external costs for road are much higher than for rail transport. It also becomes clear that the marginal costs in urban areas are much higher than in non-urban areas. The external costs for road transport are lowest on motorways.

The share of various cost categories in the total marginal costs depends strongly on the type of network. In urban areas, accident costs constitute about half of the marginal external costs, while in non-urban areas and particularly on motorways the costs of emissions are dominant, in particularly those of climate change.

Discussion of methodology and data quality
The external costs presented in this study have been based on the latest scientific literature on external cost estimation: the previous UIC external cost studies, a broad range of EU research projects (particularly NEEDS, UNITE, HEATCO and GRACE) and last but not least the meta-analysis and recommendations of the IMPACT Handbook on external costs.

The following subjects are recommended for further studying:
- Detailed assessment of climate cost estimates, e.g. by developing a cost curve for meeting the 2050 target from the 2011 White Paper.
- An in-depth study on the external costs of fuel and electricity production: oil spills, nuclear power production and also security of energy supply.
- A detailed calculation of the external costs related to transport infrastructure and vehicles (operation, maintenance and disposal).
- Update of the UNITE case studies on marginal external costs of noise and accidents.
- An EU-wide assessment of congestion costs (across all transport modes), nature and landscape and water pollution (shipping).

Policy application
The results of this study can be used for various purposes. The total and average cost estimates provide a strong basis for comparing the environmental burden of various transport modes. They could also be used for general policy development.

The results of the study can also be used as a basis for pricing strategies. Depending on the aim of the instrument, marginal or average cost estimates could be applied. For specific pricing instruments more detailed or specific estimates might be considered.

Another application could be within the area of cost benefit analysis (CBA). This could be for transport infrastructure projects but also for other types of projects for which a CBA is needed.

1 Introduction

1.1 Background

Internalisation of the external costs of transport is a way to give transport users the right incentives. When the taxes and charges are equal to the costs they impose to society, transport users will take all these costs into account in their decision making. When beneficial to them, transport users will change their behaviour, resulting in changing vehicle type, vehicle utilisation, transport mode or even their overall transport volume.

UIC studies on external costs of transport (INFRAS/IWW, 1995, 2000, 2004) are widely known and cited in the scientific and political area. For the first time in 1995 and with methodological improvements and new data in 2000 and 2004, a comprehensive comparison of transport modes in Europe was established based on their economic impact on society. They covered the most important externalities and presented quantitative figures for altogether seventeen Western European countries.

Since the last update study in 2004 using data for 2000, the topic of externalities was further developed by different European research projects (UNITE, GRACE, ASSET, to name a few) as well as in national research programs and external costs are already implemented as a leverage point for Heavy Goods Vehicle fees in different countries (e.g. Switzerland). To have a state-of-the-art overview of external costs of transport in Europe an update of the UIC studies is necessary, taking these scientific developments into account.

Additionally, in 2004 and 2007, several Eastern European countries joined the EU and their fast developing economies have considerable impacts on the transport systems. Therefore, an update of the UIC studies on external costs of transport can help to obtain an up-to-date and complete picture of transport impacts in the enlarged European Union.

Furthermore, one of the main focus points of the EC Greening Transport Package from 2008 includes a strategy in order to internalise the external costs of transport[3]. The overall objective of this strategy is to make transport prices better reflect the real costs to society. INFRAS, CE Delft and Fraunhofer ISI have carried out the IMPACT project, providing a state-of-the-art overview of external cost calculation methodologies and to suggest best practice approaches to assess marginal external costs for the major costs categories. Results are summarised within the Handbook on estimation of external costs in the transport sector (CE/INFRAS/ISI, 2008a). The project was supplemented by a study on road infrastructure costs and revenues in Europe (CE/ISI, 2008) as well as by an impact assessment of internalisation measures and development of policy strategies for external costs of transport (CE/INFRAS/ISI, 2008b).

Based on these findings the Commission launched in summer 2008 a proposal for the revision of the Eurovignette Directive 1999/62/EC in order to enable Member States to charge road freight traffic on the TEN-T network for their marginal external costs of air pollution, noise and congestion (on top of

[3] http://ec.europa.eu/transport/strategies/2008_greening_transport_en.htm.

infrastructure costs)[4]. In the Annex to the proposal, a methodology for calculating the external cost values was described, together with certain caps, both based on the findings of IMPACT. This resulted in an amendment of the Directive adopted in June 2011, saying that Member States are also enabled to charge HDV for the costs of air pollution and noise.

Also in the latest White Paper of Transport (EC 2011), presented by the European Commission in March 2011, internalisation of external costs is mentioned as one of the key policy lines.

Although the focus of the recent work of the EC was on marginal costs as basic input to transport pricing, total and average cost information is still relevant:
- Total and average costs provide a comprehensive overview on economic impacts of transport, especially for the New Member States which are midst in the transformation of their transport system.
- The level and structure of the total and average external costs of transport show the progress of each state towards sustainable mobility.
- Total and average external costs provide information on equity between modes and within a mode between different vehicle categories.
- Total and average costs are much easier to communicate than marginal costs.
- Pure marginal cost pricing may be difficult to implement, since marginal costs (esp. noise, accidents and congestion) vary considerably over time, place, etc.

Against this background there is a clear need for an update of the external cost estimates of transport in the EU.

1.2 Objective

The main objective of this study is to quantify the external costs generated by transport. More specifically the aim is to:
- Provide a complete and up-to-date overview of the external costs estimates for the main transport modes and for all EU countries.
- Use the most recent scientific knowledge, research results and data (base year 2008).
- Use differentiated and reliable country specific figures.
- Provide a handbook that can contribute to EU and national transport policy development.

1.3 Structure of the report

This report includes in *Chapter 2* the general methodological framework of the study. It gives an overview of the different external cost categories included in this update study. In addition, the most important data sources are explained. Finally the chapter provides a short overview of recent European and national research projects on external costs and discusses the implication of new findings for this update study.

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4 Proposal for a Directive of the European Parliament and of the Council amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures [COM(2008)436, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52008PC0436:EN:HTML:NOT

Chapter 3 describes in detail the methodology of the core cost categories and the relevant methodology adaptations to the previous INFRAS/IWW study, 2004. In addition the chapter contains a short description of the so-called other external cost categories. Data sources and valuation factors are presented and discussed.

Chapter 4 shows the core results of the present study. At first, the average and total costs of transport in Europe are shown in detail. The results are presented differentiated by transport mode, cost category and country.
The chapter also compares the average costs of the present study with the previous UIC study (INFRAS/IWW, 2004). In Paragraph 4.2 the results per cost category are shown including some interpretation. Paragraph 4.3 contains a short calculation of external costs on some selected North-South and East-West corridors in Europe for passenger and freight transport.

Chapter 5 contains an overview of marginal costs per cost category and transport mode. It shows marginal costs factors for different traffic situations, regions and fuel types.

The final *Chapter 6* includes an overall discussion of the results, methodology, data quality and robustness. In the end, the use of the results for policy issues (e.g. internalisation strategies) is discussed.

The *Annexes* contain general input data and comparison with other recent studies on the external costs of transport.

1.4 Involvement of experts

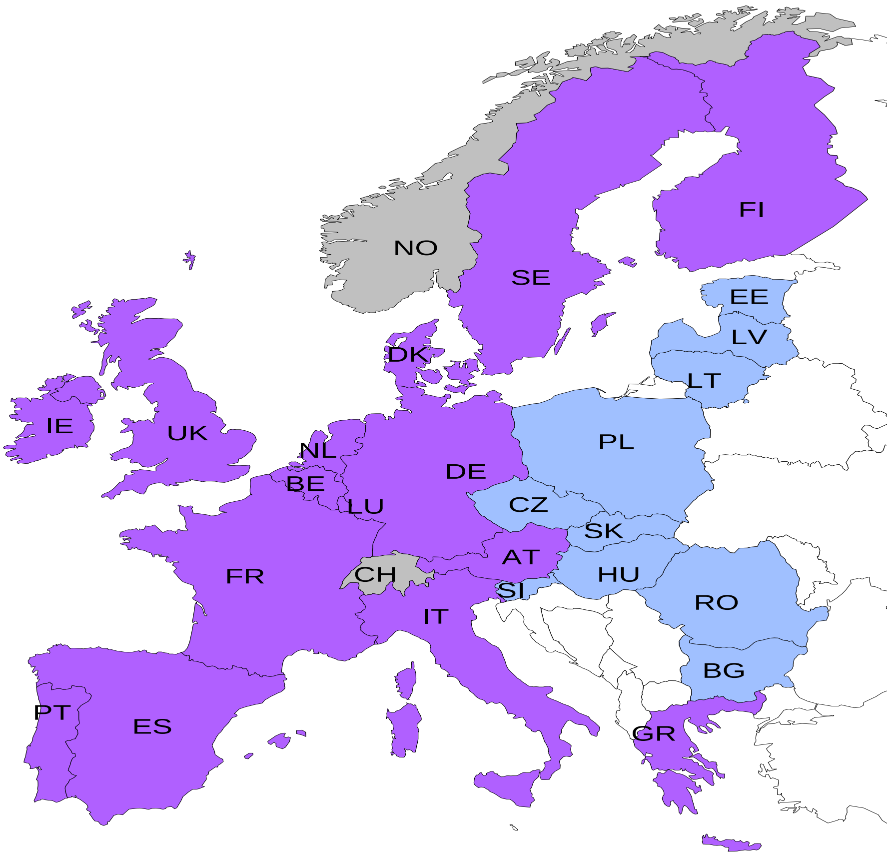
At the mid-term of the project in September 2010, there has been an expert workshop in Paris with all consortium partners, UIC advisory board members and two additional external experts: Prof. Werner Rothengatter from IWW Karlsruhe and Prof. Chris Nash from ITS Leeds. Both are well-known and respected experts in the field of transport economics with a long-term experience of external cost calculation. The aim of the expert workshop was the discussion of major methodological issues, critical valuation factors and important input data. The expertise of Prof. Rothengatter and Prof. Nash, together with the advisory group, helped to ensure that the study is based on up-to-date scientific knowledge and methodology.

2 General Methodological Framework and Recent Research Results

2.1 Geographical scope

This study covers altogether 27 European countries: The EU-27 countries except for Malta and Cyprus (they have no relevant railway infrastructure) but including Norway and Switzerland. The previous UIC study (INFRAS/IWW, 2004) covered 17 countries: EU-15 plus Norway and Switzerland).
The following map shows all countries covered within this study.

Figure 5 Geographical scope of the update study on external costs



Violet and grey coloured countries (EU-15 plus Norway and Switzerland) have already been covered in the last external cost study (INFRAS/IWW, 2004); the light blue countries (new member states) are included in the present study for the first time. Note that Malta and Cyprus are excluded, since they do not have any relevant railway infrastructure.

2.2 Transport modes

External costs of transport are calculated for the following four different modes of transport; the results are differentiated for passenger and freight transport:

1. Rail: passenger, freight (diesel and electric traction).
2. Road:
   - Road passenger: passenger cars, buses and coaches (one category), motorbikes/mopeds.
   - Road freight: light duty vehicles (LDV), heavy duty vehicles (HDV).
3. Air transport: passenger aviation.
4. Inland waterways: freight.

Maritime and short sea shipping and freight aviation have not been included.

2.3 Cost categories

In this update study total, average and marginal external costs are calculated for the following five core cost categories:

1. Accidents.
2. Air pollution.
3. Climate change.
4. Noise.
5. Congestion.

Table 3 provides an overview of the main cost elements and the valuation approach as well as of the main data sources for calculating the average and total costs. A detailed description of the methodology for each cost category is provided in Chapter 3.

Table 3 Methodology for average and total cost calculations of the core cost categories

Cost category	Cost elements and valuation approach	Data sources + input data
Accidents	Cost elements: Medical costs, production losses, loss of human life. Valuation: Willingness to pay approach for Value of statistical life VSL/Value of Life Years Lost VLYL. Cost allocation to different vehicle categories is based on a two-step approach: - Intermodal allocation (e.g. road/rail) is based on responsibility. - Within a transport mode (e.g. road) allocation according to damage potential approach (intrinsic risk). Degree of externality of accident costs: risk value is taken as 100% external.	National accident data available in the IRTAD database, CARE project and EUROSTAT (highly differentiated by transport mode, network type and vehicle category). Rail accident data based on UIC and EUROSTAT statistics, aviation accident data based on long-term development of aviation accidents in Europe.

Cost category	Cost elements and valuation approach	Data sources + input data
Air pollution	Health/medical costs (VLYL), crop losses, building damages, biodiversity losses (biodiversity losses due to air pollution are covered in a separate cost category, see Table 4). Valuation: Impact-Pathway-Approach. Dose-Response functions based on the EcoSense Model (ExternE, HEATCO). Willingness-to-pay values from NEEDS, HEATCO and CAFE CBA.	Air pollutant emissions based on TREMOVE emission factors and harmonised transport data (see Chapter 2.4). Damage cost factors per ton of air pollutant based on NEEDS, HEATCO and UBA.
Climate change	Cost elements: Avoidance costs to reduce risk of climate change, damage costs of increasing average temperature. Valuation: Unit cost per tonne of greenhouse gas (short term acc. to Kyoto targets, long-term acc. to IPCC aims).	CO_2 emissions per transport mode based on TREMOVE emission factors and harmonised transport data (see Chapter 2.4). New findings on avoidance and damage costs based on recent literature. Two different scenarios (low and high value).
Noise	Annoyance costs, health costs. Valuation: Cost factors for annoyance and health effects per person and dB(A).	Noise exposure data: Noise maps based on Directive 2002/49/EC, extrapolation of data for missing regions or countries. Valuation based on HEATCO.
Congestion and delay costs	Cost elements: Time and additional operating costs; for scheduled transport: delay costs. Valuation: Cost calculation acc. to different approaches (deadweight loss, revenues to compensate deadweight loss, delay costs).	Speed-flow curves, level of traffic and capacity per network segment. Measurements of time losses peak-off peak. Studies and statistics on road congestion in specific countries. Traffic model analysis based on TRANS-TOOLS model, local statistics and studies.

In addition to the core cost categories, five other important cost categories are updated: costs of up- and downstream processes, costs for nature and landscape, additional costs in urban areas, biodiversity losses (due to air pollution), soil and water pollution. These other external costs categories are summarised in Table 4.

Table 4 Methodology for average and total cost calculations of the other external costs

Cost category	Cost elements and valuation approach	Data sources + input data
Up- and downstream processes	Cost elements: Climate change and air pollution costs of energy consumption and GHG emissions of up- and downstream processes. The focus is hereby on fuel and electricity production. Emissions from vehicle and infrastructure production, maintenance and disposal are not taken into account.	LCA data per transport mode (TREMOVE well-to-tank emissions, Ecoinvent database). Electricity mix data for European railways based on UIC data.
Costs for nature and landscape	Cost elements: Repair cost and restoration measures (e.g. unsealing, renaturation, green bridges). Valuation: definition of reference state, calculation of repair/restoration costs per network-km.	Network length based on data analysis. Valuation: based on new findings of NEEDS project (for restoration) as well as updated cost factors from the last UIC study (INFRAS/IWW, 2004) for unsealing.
Additional costs in urban areas	Cost elements: Time losses of non-motorised traffic in urban areas.	Urban population and estimated time losses due to the road and rail network in urban areas.
Biodiversity losses	Cost elements: Damage or restoration costs of air pollutant related biodiversity losses (new evidence based on NEEDS project).	Air pollutant emissions (based on TREMOVE) and damage cost factors of NEEDS project.
Soil and water pollution	Cost elements: Restoration and repair costs for soil and water pollutant. Focus on transport related heavy metal and hydrocarbon emissions.	Emission factors based on Ecoinvent 2.1. Restoration cost factors based on INFRAS/IWW, 2004 and Swiss studies.

2.4 Data basis and country allocation

Main data basis

Transport data are mainly taken from official EUROSTAT statistics (EUROSTAT), the EU Transport Pocket book and the TREMOVE database which gives a complete picture for all countries and transport modes:

- For road transport performance (pkm, tkm) the basic values (total data per transport mode and country) are mainly taken from EUROSTAT. Only where no comprehensive data were available, TREMOVE data have been used (e.g. for motorcycles). For vkm data, EUROSTAT could only be used for heavy goods vehicles. For cars, national data have been used for seventeen countries. For the other countries as well as for buses and motorcycles TREMOVE values are used (see Annex A, p. 126 for details about transport data).
- For rail transport UIC rail statistics is used. Certain gaps of the UIC statistics are compensated with EUROSTAT data.
- Air transport data are based on EUROSTAT information with cross-checks to some national statistics.
- Transport data for inland waterways are taken from the EU Statistical Pocketbook.

Emission factors for all modes are taken from TREMOVE because this is the only comprehensive up-to-date database on emission factors for all countries and transport modes included (based on the Copert emission model which is part of the EMEP-Corinair guidebook). Total emissions of greenhouse gases and air pollutants are then calculated using adjusted mileage data as described above and TREMOVE emission factors.

In detail, the complete data basis on traffic volumes and emissions for all modes is described and discussed in the relevant Annex A.

Emission and transport data are differentiated by region type (metropolitan, other urban, non-urban) and fuel type (gasoline, diesel, electric). Therefore, different share of various regions, fuel types, etc. are taken into account in the calculations. The results, however, are not expressed in this degree of differentiation. Otherwise, the amount of data would become too large.
In the marginal cost chapter, the cost factors are shown differentiated by fuel type and region.

Harmonisation of transport data
The detailed analysis of the data used in the 2004 update study (INFRAS/IWW, 2004) using mostly TRENDS data for 2000 and the comparison with EUROSTAT data revealed that overall transport volume especially for road freight transport has been overestimated in TRENDS. Also overall TREMOVE data (total sums of vehicle and passenger-/ton-kilometres) showed considerable deviation to official EUROSTAT data.

These differences can be explained partly due to different system boundaries. Whereas TREMOVE has a territory perspective for transport performance data, hence TREMOVE shows mileage data of national and foreign vehicles within the boundaries of the respective country, EUROSTAT reports transport performance data of the national vehicle fleet within the respective country and abroad. Thus only total values for Europe have to be more or less consistent assuming that the 'import' and 'export' of transport performance outside the study area (e.g. Russia, former Yugoslavian states) are balanced. The second important reason for deviation between TREMOVE and other data sources is the fact, that TREMOVE results are calibrated model data from a bottom-up model.

Therefore, TREMOVE data were only used when no EUROSTAT or national statistical data were available. In any case, TREMOVE data were adjusted using EUROSTAT and national statistical data in a way that total European figures match for both data sources.

Allocation of cost to countries
In general, costs can be allocated to different countries based on two approaches:
1. Causer (nationality) perspective: all transport related externalities caused by users of a specific country are considered.
2. Sufferer (territory) perspective: all transport related externalities being caused in a specific country are considered.

The basic cost allocation perspective is the territory perspective. However, cost calculation methodologies for some cost categories (e.g. air pollution, biodiversity losses due to air pollutant emissions and climate change) also cover costs which are caused by long-distance transport of pollutants and by global effects (climate change). Other cost categories like noise and accidents can be clearly limited to a national territory.
The present study – like most external cost studies – is implicitly based on the first approach, the causer (nationality) perspective, since transport data (vkm) from EUROSTAT are also having the same perspective.

2.5 Overview of recent research projects

2.5.1 European research

Several European research projects have been carried out since the last update study in 2004 (INFRAS/IWW, 2004). In the following sections the most important project findings will be briefly discussed especially with respect to the estimation of external costs in this study:

HEATCO (2004-2006)

HEATCO (Developing Harmonised European Approaches for Transport Costing and Project Assessment, 6th Framework Programme): This projects focuses Cost-Benefit Analysis for Transport Infrastructure and proposes harmonised guidelines in order to value changes in travel time, accident risks and environmental costs (air pollution damages, noise, global warming).
For 25 countries standardised fallback values are produced in case that no specific national studies are available. The most important outputs are especially valuation factors for different air pollutants in Euro per tonne of pollutant for altogether 26 countries (EU-25 + Switzerland), cost factors for noise exposure and accident casualties. Especially in the field of transport related air pollution HEATCO provides updated cost factors based on the ExternE project series.

GRACE (2005-2008)

GRACE (Generalisation of Research on Accounts and Cost Estimation, 6th Framework Programme): The GRACE project aims to support policy makers in developing sustainable transport systems by facilitating the implementation of such pricing and taxation schemes that reflect the costs of infrastructure use. The GRACE project focuses on marginal cost case studies in order to fill the existing gaps (in terms of more differentiated values for specific transport means, traffic situations and so on). Transport Accounts (which contain total and derived average cost data like the INFRAS/IWW – studies on behalf of UIC) are mainly seen as monitoring instruments and not as a basis for determination of charge levels or charge structures. The monitoring function should give information on:

- **Level and structure of social costs and revenues** of infrastructure providers and transport operators.
- **Progress towards sustainable transport** by giving information on total environmental and accident costs disaggregated into the most relevant components (air pollution, noise, climate change, etc.). Accounts enable the monitoring of policy measures for sustainability in transport such as regulations, eco tax reforms, emission trading and marginal social cost pricing (MSCP).
- **Financial viability**: definition of required level of subsidies for not self-financing modes.
- **Equity** between modes and within a mode between vehicle categories.
- **Impacts of pricing policies and second-best pricing schemes**: GRACE states that transport accounts based on total and average costs can contribute to pricing policy (marginal cost pricing, subsidies, etc.).

The GRACE project with its strong focus on marginal costs gives new evidence for external cost calculation, which also provides new inputs for total and average cost calculation.

CAFE CBA (2005-2006)

CAFE CBA, the Cost-Benefit Analysis of Air Quality Related Issues, part of the Clean Air for Europe (CAFE) Programme is a peer-reviewed EU research project. The project applied the impact-pathway approach (developed in ExternE) for calculating air pollution costs. Values were expressed as damages per tonne emission of $PM_{2.5}$, NH_3, SO_2, NO_x and VOCs from each EU-25 Member State (excluding Cyprus) and surrounding seas. CAFE CBA can be used in order to value external air pollution costs (four different sensitivity scenarios included).

ASSET (2007-2009)
ASSET (ASsessing SEnsitiveness to Transport) is a new EC funded project which aims to develop the scientific and methodological capabilities to implement European policies aiming at balancing the protection of environmentally Sensitive Areas (SA) with the provision of an efficient transport system. Case studies in different sensitive areas are conduced in order to assess marginal costs (mountainous areas, urban/metropolitan areas, natural/protected areas, and coastal areas).

IMPACT (2006-2008)
The IMPACT project commissioned by EU DG TREN (CE/INFRAS/ISI, 2008a/b) has produced a Handbook on estimation of external costs in the transport sector (D1). In addition the study provided an overview of road infrastructure cost data (D2) and an assessment of policy instruments for internalising the various external costs, an assessment of the impacts of various pricing scenarios and a policy analysis and recommendation on internalisation strategies (D3). The results of IMPACT have been used as the basis for the 2008 Commission proposal for amending the Eurovignette Directive.

The IMPACT Handbook was based on a broad and in-depth meta-analysis of existing literature, synthesising and evaluating best practice. From this point of view this Handbook is the today's reference for marginal cost estimation methodologies. The Handbook is focussing on marginal social cost pricing and presents an overview of recently published studies and research projects in the field of external costs of transport. As a major result, central best unit values were presented which could be directly adjusted by each member state with simple adjustment procedures. In this study, the results of the IMPACT Handbook will be adjusted and updated for different cost categories; especially for marginal cost results.

NEEDS (2004-2009)
The ultimate objective of NEEDS (New Energy Externalities Development for Sustainability) is to evaluate the full costs and benefits (i.e. direct + external) of energy policies and of future energy systems, both at the level of individual countries and for the enlarged EU as a whole. Results from NEEDS included a full state-of-the-art set of external cost estimates of air pollutant emissions. In addition to the impacts valued by previous studies such as CAFÉ CBA or HEATCO, NEEDS also presented estimates for the external costs of biodiversity losses due to air pollutant emissions as well as for the valuation of greenhouse gas emissions.

2.5.2 National research projects
In addition to the various external costs at the European level, also a broad range of national studies exists. The authors of this report have carried out broad national overview studies for Switzerland (Ecoplan/INFRAS, 2008) and the Netherlands (CE, 2004). Also for other countries like Belgium, the United Kingdom, Austria, France and Germany studies on the external costs of transport exist. Some of these studies cover also all transport modes and all the main cost categories, while other focus on specific modes or cost categories. For more information on national studies we refer to the IMPACT Handbook (CE/INFRAS/ISI, 2008a) which contains an overview of the main studies.

2.6 Overview of recent external transport cost studies with involvement of the authors (CE Delft, INFRAS, ISI)

In the last years, several external cost studies have been published by the authors of the present studies, e.g. the previous UIC study (INFRAS/IWW, 2004), the EU Handbook on external cost of transport (CE/INFRAS/ISI, 2008a), two German studies for the 'Allianz pro Schiene' (INFRAS/ISI/IER, 2007), *Are trucks taking their toll* (CE, 2009), a study for the German aviation sector (*Initiative Luftverkehr für Deutschland*, ILFD) (INFRAS/ISI, 2010) and a study for the French, Belgium and Dutch inland waterways authorities within the context of TEN-T project 30 on the Seine-Scheldt corridor CE/INFRAS/Alenium, 2010).

The studies differ in several aspects, such as focus, methodology, input data, system boundaries, cost factors used, etc. The main aspects and differences of the studies are the following:

- **UIC studies (INFRAS/IWW, 2004; CE/INFRAS/ISI, 2011):** The main focus of the present and previous UIC studies is the total and average external cost of transport. The studies present data for all EU countries as well as Norway and Switzerland and cover all transport modes. The study also includes information on marginal costs.
  Concerning climate change costs, the UIC studies always include a high and low scenario with two different CO_2 prices. In the previous UIC study (INFRAS/IWW, 2004) air transport has included completely (world perspective), whereas in the present UIC study a European perspective has been chosen, in order to allow a better comparability of different transport modes (i.e. comparison of continental transport for road, rail and air).
- **IMPACT (CE/INFRAS/ISI, 2008a):** The EU Handbook on external costs focuses on methods and marginal cost factors as a basis for transport pricing in Europe. It does not show total costs or average costs per country.
- **Allianz pro Schiene (INFRAS/ISI/IER, 2007):** The study shows total and average external cost of transport in Germany. It has updated the results of the previous UIC study (INFRAS/IWW, 2004) for Germany, taking into account the most recent methodological development. The study includes all transport modes. For climate change costs, there has been used one central cost factor based on UBA recommendations (UBA, 2006b). Additionally, sensitivity calculations with a low and high cost factor have been carried out.
  For air transport, the study adopted an inland perspective and only included domestic flights. This allows a comparison of transport modes within Germany (national perspective).
- **ILFD (INFRAS/ISI, 2010):** The main focus of the ILFD study was not the external costs but the total cost of transport in Germany, including infrastructure costs. Another focus was on the funding and financing systems of transport in Germany. External costs of transport have been calculated, too, but less in-depth than in the other studies where this was the main focus.
  The methodology is almost the same as in the Allianz pro Schiene study (INFRAS/ISI/IER, 2010). One important difference concerns the climate change costs, where the IMPACT CO_2 cost factor has been used, which is substantially lower than the UBA value (see above)[5]. For air transport the ILFD study takes a world perspective (like INFRAS/IWW, 2004) and

[5] Additionally, the RFI factor (RFI: radiative forcing index) differs between the two studies from Allianz pro Schiene (RFI 2.5) and the ILFD study (RFI 1.0).

therefore includes all planes. In the present UIC study a European perspective has been chosen, since this allows a better comparability of different transport modes on a continental level.

- **Seine-Scheldt Corridor Study (CE/INFRAS, 2010):** This study was carried out within the context of TEN-T project 30 which is about the upgrade of the Seine-Scheldt connection on the corridor Paris-Brussels-Rotterdam-Amsterdam. The valuations in this study were all based on the marginal external cost estimates from IMPACT (CE/INFRAS/ISI, 2008).
- **Are trucks taking their toll? (CE, 2009):** This study provided an overview of mainly total cost estimates of road freight traffic in Europe, which was mainly based on INFRAS/IWW, 2004 and IMPACT (CE/INFRAS/ISI, 2008).

A detailed overview of the first five studies (present and previous UIC, IMPACT, Allianz pro Schiene, ILFD) is given in Table 68 in the Annex, with a main focus on the comparison with the present UIC study.

3 Methodology per Cost Category

3.1 Accidents

3.1.1 General approach and overview of cost estimation

External accident costs constitute a relatively large part of total external costs, in particular for road transport. The methodological approach for the calculation of accident costs is mainly based on the INFRAS/IWW (2004) update study but uses an improved database and updated valuation factors.

Accident costs in general are the result of traffic accidents. These social costs include costs for material damages, administrative costs, medical costs, production losses and immaterial costs (lifetime shortening, suffering, pain, sorrow, etc.). Material costs can be calculated using market prices as they often (but not always) can be insured against. In contrast for immaterial costs no such market prices do exist and other sources are needed to estimate these costs (e.g. risk values through stated-preference studies). The sum of material and immaterial costs builds the total social accident costs.

From these the share of *external* accident costs has to be separated. This is done by identifying the costs covered through transfers from the insurance systems and by accounting for risk costs that are well anticipated and therefore already internalised by individuals own cost calculations (assumptions on risk anticipation of individuals).

Table 5 summarises the components of accident costs and shows which part of them will be considered when calculating external accident costs.

Table 5 External accident cost components

Effect	Fatalities	Injuries
Risk value	Loss of utility of the victim, suffering of friends and relatives	Pain and suffering of victims, friends and relatives
Human capital losses	Net production losses due to reduced working time, replacement costs	
Medical care	External costs for medical care before the victim deceased	External costs for medical care until the person completely recovers from his/her injury
Administrative costs	Costs for police, for the administration of justice and insurance, which are not carried by the transport users	
Damage to property	Not included because material damages are paid by the traffic participants through insurance premiums	

The calculation of the external accident costs in this study concentrates on the value of human life, production losses and some further cost elements (e.g. medical and administrative costs) that are not covered by insurances. This top-down approach is also recommended by the IMPACT Handbook (CE/INFRAS/ISI, 2008a) if the focus is on all types of accident externalities, which is the case in this study.

The number of fatalities and injuries in official statistics only represent reported accidents; these data are corrected for unreported accidents.[6]

The allocation of the external accident costs on the different transport modes and vehicle categories is done by differentiated accident data (fatalities, severely and slightly injured persons). Three allocation approaches can be effectuated for accidents with multiple parties involved, depending on data availability:

– **Monitoring perspective**: allocation according to involvement, casualties of an accident are allocated to the transport category they were using when the accident did take place. This is normally what accident statistics report.
– **Responsibility perspective (guilt)**: external costs are attributed to the party 'causing' the accident. However, transport statistics often do not contain information on the responsible part of an accident. Thus, as a proxy, results of detailed accident data for specific countries have to be used to allocate victims of accidents to the responsible vehicle category. For some countries (e.g. Germany) there is a differentiated annual statistic available which also contains information on the causer of the accident and the casualties of the not guilty part of an accident.
– **Damage potential perspective (intrinsic risk)**: allocation according to the damage potential (sometimes also referred to as intrinsic risk approach) of a certain vehicle category. This means that all victims in a certain vehicle involved in a multiple party accident are attributed to the other vehicle involved. This approach is rather new in external cost calculation and discussed in CE (2004). A first argument for this approach is the fact, that the guilty or responsible party of an accident can not be deduced from standard accident statistics. In addition, CE (2004) argues that 'responsibility' for an accident, in a causative and moral sense, lies not only with the party 'in error' but may also lie with a party or parties that, legally speaking, committed no error at all. It is, after all, a fact of life that certain activities undertaken by society bring with them an additional intrinsic risk, even if those performing these activities do not 'error' at all. Thus, transport and mobility are obviously accompanied by a certain intrinsic risk (damage potential). Even though drivers may comply with traffic and other regulations, they still make society a more dangerous place. In a residential area with children playing on the streets this is self-evident, but the same also holds on a motorway with respect to the mutual danger to which drivers continually expose one another. More specifically, the heavier and faster a vehicle, the greater the danger to which it will expose other road users (i.e. the bigger its damage potential). However, also for this allocation method, conflict tables, which report how casualties are divided across vehicle categories in multiple-vehicle accidents.

For the present study a *two-step approach* is applied:
1. For accidents where several transport modes are involved (relevant for road and rail at level crossings), the allocation is based on the *responsibility* approach. This can be done since it is known that for almost 100% of the intermodal accidents at level crossings road transport is responsible.[7]

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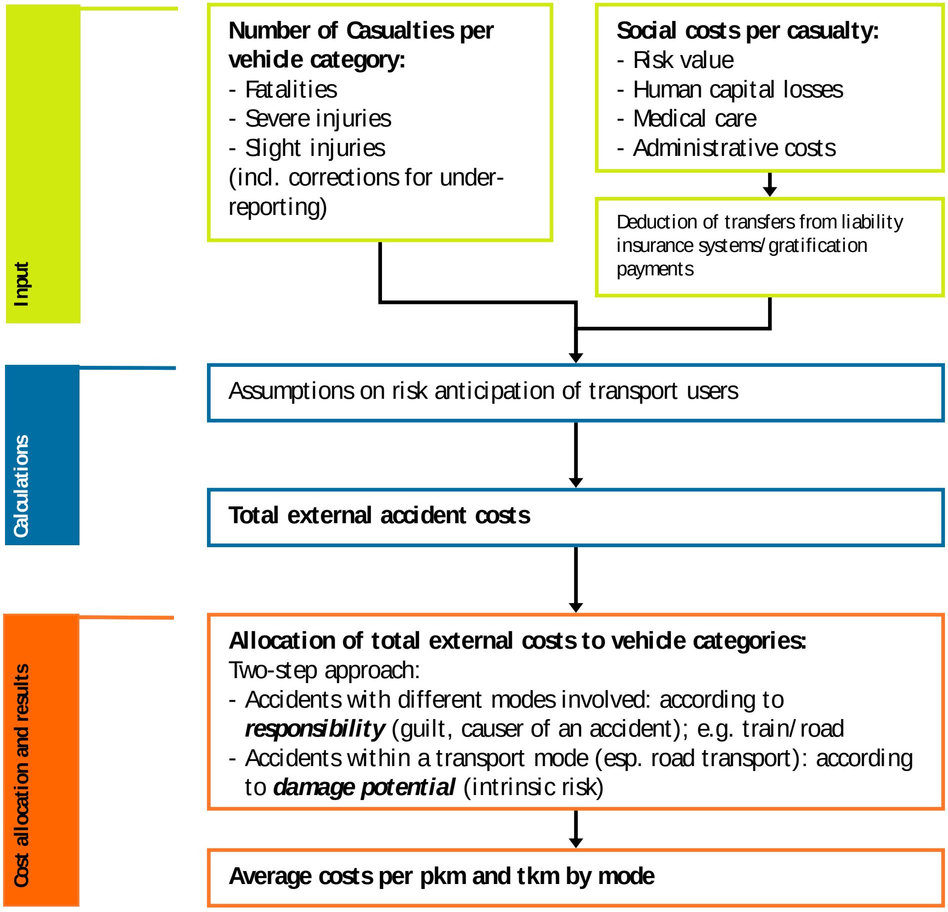
[6] See INFRAS/CE/ISI, 2008 on page 40 for a complete list of recommended European average correction factors.

[7] An alternative would have been to apply the damage potential approach here as well, as it is done for different vehicles within one transport mode. Note that the impact of such an alternative approach on the accident costs for road and rail would be very small.

2. For the allocation of the external costs of multiple party accidents within a transport mode (mainly relevant for road transport) the allocation is done according to the *damage potential* approach. Allocation according to responsibility is difficult to apply due to lack of data (data are only available for Germany). Additionally, the attribution of guilt (responsibility) within the road transport mode is often somewhat arbitrary and also dependent on national regulations. Therefore, cost allocation for accidents with different road transport types involved is based on the *damage potential* approach (intrinsic risk). Data situation for this approach is much better: the CARE database includes extensive road accident data and has therefore been applied (see also Paragraph 3.1.3).

Figure 6 recapitulates the general approach for calculating and allocating external accident costs.

Figure 6 General approach for calculating external accident costs



3.1.2 Cost elements and valuation factors

In this study we focus on human losses (which cause suffering, pain or loss of joy of living to casualties itself and their families and friends), production losses and some further cost elements as external parts of overall accident costs. These cost elements will be shortly described in this chapter.

Risk value

Costs for human losses can be expressed by the valuation of safety in general. This is done using the standardised concept Value of a Statistical Life (VSL). In this concept individuals are asked how much they are willing to pay for a certain reduction of the accident risk (e.g. reducing the risk of a fatal crash from 5 in 100,000 to 3 in 100,000). Such willingness-to-pay studies (stated-preferences) report monetarised values for statistical lives.

In the literature there is a huge range of possible risk values beginning by $ 150,000 up to $ 36 million (2005 values)[8]. Regarding the current discussion in the literature no consensus on a single value is reached. Hence, it seems reasonable to calculate with a VSL of € 1.5 million (1998 values for EU-15) as suggested in the UNITE project and as done in the update study (INFRAS/IWW, 2004). This VSL is adjusted to 2008 values using GDP/cap. development and to the countries according to GDP/cap. PPP. The calculations have been carried out on the basis of country specific values. The European average value of statistical life (VSL) for 2008 used in this study is € 1.67 million for EU-27 (incl. NO and CH).

Risk values for injuries are computed as proposed by the IMPACT Handbook (CE/INFRAS/ISI, 2008a), i.e. 13% of VSL for severe injuries and 1% of VSL for slight injuries.

Human Capital Costs
This cost element accounts for production losses caused by accidents when casualties are killed or not able to work in the direct aftermath of accidents (or at all in case of paralysis or fatalities). These production losses are calculated according to the UNITE methodology as net production loss, i.e. the difference between gross production loss and the future consumption.

Other external Costs
The remaining external costs come from different costs elements and include medical and administrative costs that are not covered by insurances. This cost element is calculated by analysing statistical data for some specific countries. These values have been adjusted for all other countries to receive a best guess.

3.1.3 Data situation

Road accidents
The main source for road accident data is the European Road Accident Database CARE. It delivers casualties of accidents for all EU member countries for the year 2008 and allows the allocation of accidents according to the damage potential approach. Data for Switzerland and Norway were extracted from national statistics and from the PIN report (ETSC, 2010). With this data basis the damage potential approach can be applied.

Rail accidents
Rail accidents are taken from the UIC railway statistics. Since annual rail accidents vary considerably, the number of casualties is calculated by taking average values of the years 2002-2008. These values are crosschecked with publications of EUROSTAT on rail accidents.

Concerning injuries no differentiated data for slight and sever injuries for rail transport is available. It is assumed that all rail injuries are severe injuries. Fatalities from suicides or injuries from suicide attempts are not included. Since the UIC accident data do not differentiate passenger and freight trains, the allocation to passenger and freight transport has been done on the basis of train-km.

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8 See Andersson and Treich 2010 for a list of empirical estimates of VSL in road traffic.

Air transport accidents

Accident data from air transport are calculated by taking average values of the years 2002-2008 from EUROSTAT. Due to lack of data no injuries are included. The same reason applies for absence of the differentiation of passenger and freight transport.

Waterborne transport accidents

There is not data available on accidents for waterborne transport. However, we consider casualties from waterborne transport negligible.

3.1.4 Marginal cost methodology

The estimation of marginal accident costs is based on the IMPACT study (CE/INFRAS/ISI, 2008a). The results presented are based on a UNITE case study for Switzerland.[9] This is the most detailed study available on marginal accident costs which differentiates not only different vehicle categories but also three different road categories.

The results represent accident rates in Switzerland for 1998 and are expressed in $€_{1998}$. In order to derive marginal accident costs for other European countries we applied the following calculation steps:

- In a first step, accident risk rates are calculated for all countries for which detailed accident data was available in the CARE database. It is important to note that accident rates were not available or all countries (CARE database showed gaps especially for some Eastern European countries as well as for some other smaller countries (e.g. Luxembourg)). For countries with lacking accident data information, values have been estimated using average values for comparable countries.
- Secondly, cost factors are adjusted according to GDP per capita PPS (EUROSTAT) for 1998. The result of this first step are marginal accident costs for all European countries in $€_{1998}$ (€ct/vkm).
- In order to estimate marginal accident costs for 2008 the development of accidents for the different vehicle categories has to be considered as well as the economic development resulting in higher valuation factors per casualty. Accident rates again are provided for around 75% of the relevant countries by the CARE database.
- Marginal accident costs are then calculated adjusting the 1998 marginal cost values with the development of accident rates and real GDP per capita development 1998-2008.

We calculate marginal external costs for three road types (motorways, outside urban areas, urban areas) as well as for all roads for passenger cars and heavy duty vehicles (HDV). As for rail and air transport, average costs can be used as they do approximately represent the marginal costs.

3.2 Air pollution

3.2.1 General approach and overview of cost estimation

Air pollution caused by transport activities leads to different types of external costs. The most important external costs are health costs due to cardiovascular and respiratory diseases caused by air pollutants. Other external costs of air pollution include building and material damages, crop losses and impacts on biodiversity and ecosystems.

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[9] Sommer H., Marti M. and Suter S. (Ecoplan), Deliverable 9: Accident Cost Case Studies, Case Study 8a: Marginal external accident costs in Switzerland (UNIfication of accounts and marginal costs for Transport Efficiency) Deliverable 9. Funded by 5th Framework RTD Programme. ITS, University of Leeds, Leeds.

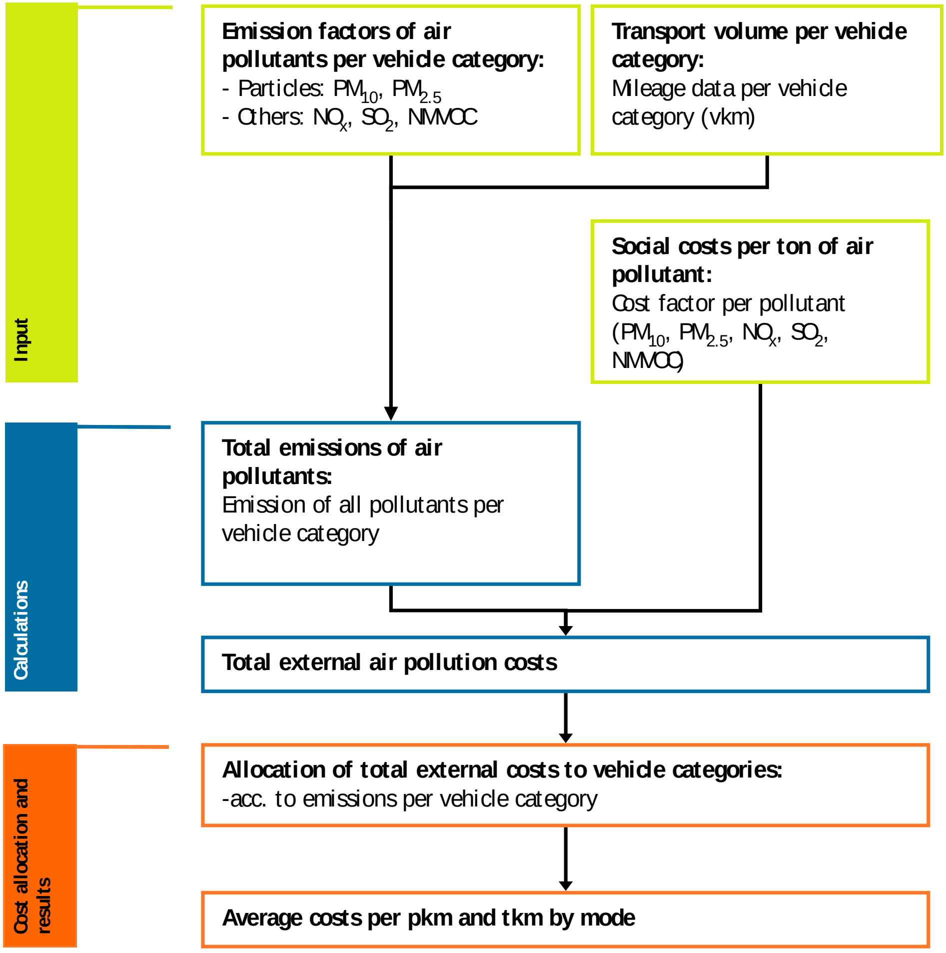
The most important transport related air pollutants are particulate matter (PM_{10}, $PM_{2.5}$), nitrogen oxide (NO_x), sulphur dioxide (SO_2), volatile organic compounds (VOC) and Ozone (O_3) as an indirect pollutant. Greenhouse gases are not included in the air pollution costs since they do not have any direct toxic effects. They are covered within the climate change cost category.

External effects of air pollution and their monetary valuation have been studied broadly in scientific research. Therefore the basis for calculating air pollution costs is solid and the methodologies widely accepted.
To calculate the external costs caused by air pollution, there are two different approaches:

– **Bottom-up approach:** Calculation of damage costs based on an impact-pathway approach, which requires the following methodological steps: emissions – transmission – concentration (dose) – impact/damage (humans, ecosystems, buildings) – monetisation – costs. The bottom-up approach has been applied in a variety of European studies such as NEEDS (2006, 2007, 2008); HEATCO (2006a, b); CAFE CBA (2005a, b); ExternE (2005); UNITE (2003a, b). This detailed approach is regarded as the most elaborated and therefore best practice methodology, above all for calculating site-specific external costs. The IMPACT study (CE/INFRAS/ISI, 2008a) also lists unit costs values (in € per ton of pollutant) for all relevant air pollutants, based on HEATCO and CAFE CBA. The most recent study applying this approach for air pollution cost was the European research project NEEDS.
– **Top-down approach:** Estimation of health effects due to the exposure of air pollutants and valuation with specific costs per additional case of mortality or morbidity. The health effects are valuated with cost factors for the different health effects. An important precondition for the application of this approach is the availability of detailed country specific exposure data for the relevant air pollutants (at least for $PM_{2.5}$ or PM_{10}). Cost allocation to different modes and vehicle categories requires additional information on the contribution of each mode and vehicle category to the overall ambient concentration of the respective pollutant. This approach was applied in the previous studies (INFRAS/IWW, 2004; INFRAS/IWW, 2000) and was based on the tri-national study for Austria, Switzerland and France (WHO 1999a-d). Results from these three countries have been extrapolated to the other European countries considering national emission and population density data.

In the present study the bottom-up approach is applied, thus the calculation methodology is modified compared to the last study (INFRAS/IWW, 2004). Figure 7 shows the methodology applied for calculating the external air pollution costs.

Figure 7 Methodology air pollution costs



3.2.2 Cost elements and valuation factors

As mentioned above, external air pollution costs consist of several cost elements:

- **Health effects:** The aspiration of air transport emissions increases the risk of respiratory and cardiovascular diseases. The main source of disease is particles (PM_{10}, $PM_{2.5}$).
- **Building & material damages:** Air pollutants can cause damages to buildings and materials in two ways: a) soiling of building surfaces by particles and dust; b) degradation of facades and materials through corrosive processes due to acidifying pollutants (NO_x, SO_2).
- **Crop losses:** Ozone as a secondary air pollutant (formed due to the emission of VOC and NO_x) and acidifying substances (NO_x, SO_2) cause crop damages. This means an enhanced concentration of these substances leads to a decrease in the amount of crop.
- **Impacts on ecosystems and biodiversity:** Ecosystem damages are caused by air pollutants leading to acidification (NO_x, SO_2) and eutrophication (NO_x, NH_3). Acidification and eutrophication have an impact on biodiversity which is mainly negative. These effects are not yet included in most external cost studies. The project NEEDS is one first studies that gives reliable cost factors for ecosystem and biodiversity damage due to air pollution.

The health effects are by far the most relevant element causing the highest external costs.

Input data

For calculating the air pollution costs within this study, only emission data and unit cost factors are used. For the present study, we applied NEEDS as well as HEATCO values (see details below).

In the recent European research project NEEDS, the external cost of air pollution were looked at again in detail. With the help of a survey, the willingness-to-pay data for monetary valuation of air pollution costs have been determined. Based on this, the German IER recalculated air pollution cost factors for Germany (UBA/IER, unpublished). Except for PM emissions from transport, NEEDS values are used since they include a broader range of damage effects (also effects outside the national territory) and are based on the latest scientific insights.

NEEDS does also provide values for PM emissions, but these are not appropriate for the specific type of PM emissions from transport[10]. Therefore, the transport specific cost values from IMPACT have been used. These cost factors for PM in the IMPACT study are based on results of the European research project HEATCO (2006a) as well as the method convention of the German environmental office (Umweltbundesamt, UBA, 2006b).

The cost factors per ton of pollutant (shadow prices) from both NEEDS and HEATCO are based on input data which include monetary values for health effects. Air pollution leads to increased mortality and morbidity (risk of getting ill), which can be monetised based on willingness-to-pay data. Table 6 shows the monetary values for health effects used in the HEATCO project, which is one of the sources of cost factors of this study (mainly for PM). Values for 2008 are calculated from 2002 data using the GDP per capita development.

The value of a life year recommended in NEEDS is 40,000 $€_{2006}$ for EU-25 (NEEDS, 2007), which is somewhat lower than in HEATCO. On the other hand, the costs of a case of chronic bronchitis are estimated to 200,000 $€_{2006}$ in NEEDS, which is a little higher than in HEATCO.

Table 6 Health valuation data: monetary values for economic valuation (EU average, EU-27)

Impact	Cost factor (€ per unit)		Unit
	2002	2008	
Acute mortality (years of life lost, YOLL)	60,500	67,200	Per year
Chronic mortality (years of life lost, YOLL)	40,300	44,800	Per year
Chronic bronchitis	153,000	169,900	Per case
Respiratory/cardiac hospital admission	1,900	2,100	Per admission
Restricted activity days	76	84	Per day
Minor restricted activity days	31	34	Per day
Use of respiratory medication (e.g. bronchodilator)	1.0	1.1	Per day

Source: Heatco, 2006a (Deliverable D5, Annex D). Values adjusted to $€_{2008}$ using GDP/cap development.

10 NEEDS values for PM are mainly derived from air pollution due to energy production, where the emitted particles are generally larger and having less severe health effects. They also occur on higher level above ground than in transport.

Cost factors

Table 7 shows the cost factors (shadow prices) used in this study. The data correspond to the values recommended in the IMPACT study (Handbook on estimation of external costs in the transport sector, IMPACT 2008) for PM emissions ($PM_{2.5}$ and PM_{10}) and the more recent European research project NEEDS (NEEDS 2008) for the other pollutants (NO_x, NMVOC, SO_2). The values are adjusted to 2008 ($€_{2008}$) using GDP per capita development of the respective country.

The IMPACT cost factors as well as the cost factors from NEEDS cover health costs, building and material damages as well as crop losses. Biodiversity losses due to air pollution are not included in the data in Table 7. They are calculated separately, also based on NEEDS (see Table 8).

Table 7 Air pollution cost factors in EUR/ton of pollutant (€$_{2008}$ values)

Pollutant	$PM_{2.5}$ (exhaust)			PM_{10} (non-exhaust)			NO_x	NMVOC	SO_2
Region type	Metropolitan	Urban	Non- urban	Metropolitan	Urban	Non- urban			
Source	HEATCO	*UBA/ HEATCO	HEATCO	*UBA/ HEATCO	*UBA/ HEATCO	*UBA/ HEATCO	NEEDS	NEEDS	NEEDS
Country									
Austria	481.500	155.600	80.600	192.600	62.300	32.200	13,600	1,600	10,000
Belgium	495.100	159.800	106.900	198.000	63.900	42.800	8,700	2,600	10,900
Bulgaria	73.900	23.800	19.000	29.600	9.500	7.600	7,100	400	6,200
Czech Republic	381.300	122.900	94.600	152.500	49.200	37.900	10,600	1,100	9,500
Denmark	448.400	144.600	52.700	179.400	57.800	21.100	5,300	1,200	5,700
Estonia	265.100	86.200	44.700	106.000	34.500	17.900	2,800	600	4,500
Finland	407.900	131.400	34.000	163.200	52.600	13.600	2,600	600	3,500
France	453.800	146.100	90.800	181.500	58.400	36.300	10,500	1,400	9,900
Germany	430.500	138.800	83.900	172.200	55.500	33.600	12,700	1,400	10,900
Greece	338.400	109.100	47.600	135.400	43.600	19.100	2,700	600	5,800
Hungary	312.700	100.600	80.200	125.100	40.200	32.100	12,400	1,000	9,100
Ireland	535.100	172.700	55.900	214.000	69.100	22.400	4,400	1,100	5,400
Italy	426.700	137.900	77.700	170.700	55.100	31.100	9,500	1,100	8,700
Latvia	233.800	75.200	43.400	93.500	30.100	17.400	4,000	700	5,000
Lithuania	253.900	82.500	50.800	101.600	33.000	20.300	5,600	800	5,700
Luxembourg	922.400	296.900	131.400	369.000	118.800	52.600	12,700	2,400	10,300
Netherlands	495.300	159.900	96.800	198.100	63.900	38.700	8,800	2,100	12,800
Norway	393.700	126.600	38.300	157.500	50.600	15.300	3,100	800	3,400
Poland	234.500	75.300	70.400	93.800	30.100	28.100	7,800	1,000	8,400
Portugal	299.600	96.500	44.400	119.800	38.600	17.800	1,500	800	3,800
Romania	63.700	20.500	16.300	25.500	8.200	6.500	9,700	800	7,400
Slovakia	332.100	106.300	89.700	132.800	42.500	35.900	11,000	900	8,800
Slovenia	350.300	112.600	72.600	140.100	45.000	29.000	11,500	1,400	8,900
Spain	384.800	123.900	52.900	153.900	49.500	21.200	3,600	800	5,200
Sweden	424.400	136.500	41.300	169.800	54.600	16.500	4,100	800	4,200
Switzerland	475.200	152.900	78.500	190.100	61.200	31.400	19,300	1,300	13,000
UK	453.200	145.900	70.700	181.300	58.400	28.300	5,200	1,400	7,300

Values adjusted to €$_{2008}$ using GDP/cap development for each country.

* Values calculated on the basis of HEATCO values, taking into account results of the project UBA, 2006b.

Biodiversity losses

The cost factors in Table 7 do not include biodiversity losses due to air pollution; these costs are presented separately in this section. Transport activities can lead to biodiversity losses in two ways:

1. Airborne emissions lead to the eutrophication and acidification of natural ecosystems, which can have negative effects on biodiversity.
2. The construction of transport infrastructure leads to land use change and habitat fragmentation. This again reduces species diversity, i.e. leads to biodiversity losses.

Since the first path is caused by air pollutants, it is covered within the present chapter (but the results are shown separately). The second effect, however, is covered in the nature and landscape chapter (Paragraph 3.6.2).

Within NEEDS, the external cost of biodiversity losses due to transport activities have been analysed and quantified (NEEDS, 2006). In this study, the negative impact of air pollutants on biodiversity was quantified using dose-response-relationships that lead to so-called 'Potentially Disappeared Fraction' (PDF) of species. The PDF can be interpreted as the fraction of species that has a high probability of no occurrence in a region due to unfavourable conditions caused by acidification and eutrophication.
In NEEDS, the PDF of species is then valuated in monetary terms by a restoration cost approach. This is done by valuing the restoration cost for the reconversion of acidified and eutrophic land to a natural state with high biodiversity. At the end, the NEEDS project reports cost factors for biodiversity losses due to airborne emissions in Euro per ton of air pollutant (SO_x, NO_x, NH_3) for all EU-27 countries as well as Norway and Switzerland.

These cost factors are taken in the present study to calculate biodiversity losses due to airborne emissions of transport. The cost factors only need to be transformed from 2004 to 2008 (with GDP per capita of each country) and then multiplied with the total emissions of the corresponding pollutants. Since NH_3 (ammonia) is not relevant for transport, the calculation can be focussed on nitrogen oxide (NO_x) and sulphur dioxide (SO_2). Table 8 shows the cost factors for biodiversity losses due to air pollution.

The cost of biodiversity losses is additional to the air pollutant costs described above (health costs, building & material damages, crop losses). The total external cost of air pollution is the sum of both cost aspects.

Table 8 **External cost factors for biodiversity losses due to airborne emissions**

Country	Sulphur Oxide (SO_2) € (2004) per ton	Nitrogen Oxide (NO_x) € (2004) per ton
Austria	290	1,510
Belgium	180	960
Bulgaria	0	60
Czech Republic	100	540
Denmark	70	400
Estonia	40	500
Finland	400	1,360
France	50	480
Germany	260	1,410
Greece	0	20
Hungary	90	400
Ireland	30	140
Italy	50	530
Latvia	0	230
Lithuania	30	210
Luxembourg	300	1,550
Netherlands	210	1,150
Norway	320	950
Poland	100	530
Portugal	0	60
Romania	10	100
Slovakia	170	790
Slovenia	290	1,420
Spain	0	60
Sweden	360	1,100
Switzerland	460	2,790
UK	160	480
EU-25	*150*	*750*

Data source: NEEDS, 2006 (p. 40). Values for 2004. Adjustment to 2008 is done using GDP/cap development for each country.

3.2.3 Data situation

Emission data

Data of total emissions of air pollutants are calculated based on emission factors and transport volume (mileage) data. The emission factors of air pollutants due to exhaust emissions are taken from the TREMOVE database with base year 2008 (TREMOVE, 2010). TREMOVE emission data are available per vehicle category and region type (metropolitan, other urban, non-urban). To obtain total emission data, the TREMOVE emission factors are multiplied by transport mileage data of 2008. These transport mileage data are based on EUROSTAT and TREMOVE databases and are listed in the Annex. Total emissions per transport type are also shown in the Annex.

Non-exhaust emission factors for particulate matter (PM) in road and rail transport cannot be taken from TREMOVE: non-exhaust emission factors from rail transport are not given in TREMOVE and the emission factors for road transport are not reliable when comparing it to other data sources. Therefore, emission factors for non-exhaust PM emission are taken from the EMEP database (EMEP, 2009, EMEP: European Monitoring and Evaluation Programme).

Cost factors

The cost factors for external costs per pollutant (and region type) are based on the values recommended by NEEDS and IMPACT (see Paragraph 3.2.2 above).

Cost allocation on vehicle categories

The cost allocation on the different transport modes and vehicle categories is directly done according to the total emissions per vehicle category.

3.2.4 Marginal cost methodology

Since dose-response functions for the calculation of air pollution costs are linear functions and exposure calculations are in our top-down model also linear functions, marginal air pollution costs are approximately equal to average air pollution costs.

Therefore, there are no separate bottom-up calculations of marginal air pollution costs in this study. In the marginal cost chapter (Chapter 5), differentiated marginal (average) costs per transport mode and region type are shown.

3.3 Climate Change

In 2007 about 19.5% of total greenhouse gas (GHG) emissions in Europe were caused by transport (European Commission, 2010b). These emissions contribute to global warming resulting in various effects like sea level rise, agricultural impacts (due to changes in temperatures and rainfall), health impacts (increase in heat stress, reduction in cold stress, expansion of areas amenable to parasitic and vector borne disease burdens (e.g. malaria, etc.), ecosystems and biodiversity impacts, increase in extreme weather effects, etc.

The main greenhouse gases with respect to transport are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). To a smaller extent emissions of refrigerants (hydrofluorocarbons) from Mobile Air Conditioners also contribute to global warming. However, in this study the latter emissions are not taken into account. In the case of aviation also other aircraft emissions (water vapour, sulphate, soot aerosols and nitrous oxides) at high altitude have an impact on global warming.

3.3.1 General approach and overview of cost estimation

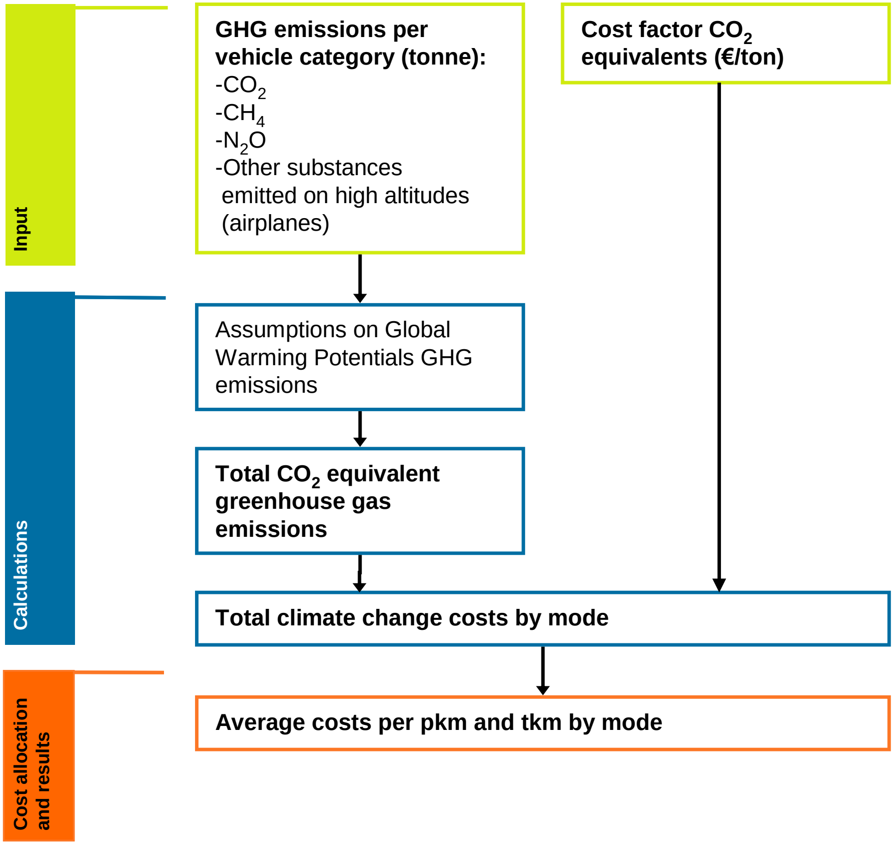
The general approach of estimating the average climate change costs for various transport modes consist of four steps (see also Figure 8):

- *Assess total GHG emissions by type of vehicle per country*. The estimation of total GHG emissions for the various modes is explained in the Annex.
- *Calculate total CO_2 equivalent GHG emissions using Global Warming Potentials*. The climate change impact of CH_4 and N_2O could be weighted with the climate change impact of CO_2 by using so called Global Warming Potentials (GWP). The GWP for CH_4 and N_2O are 25 and 298 respectively, indicating that their climate impact is 25 and 298 times larger than the impact of the same amount of CO_2 emissions (IPPC, 2007).
- *Multiplication of the total tonnes of CO_2 equivalent greenhouse gas emission by an external cost factor expressed in €/tonne to estimate total external costs related to global warming per country*. Due to the global effect to the damage caused by global warming, there is no difference how and where in Europe the emissions of greenhouse gases take place. For this reason we will apply the same cost factor in all countries. However, the cost factor is time-dependent in the sense that emissions in future years

will have greater impacts than emissions today. Hence, we have to calculate the impacts of emissions in different years separately.
In Paragraph 3.3.2 we will extensively discuss the cost factor to be applied in the estimations of average climate change costs per transport mode.

- *Calculate the average climate change costs (per tkm/pkm) by dividing the total costs per vehicle type per country by the number of tkm/pkm per country.*

Figure 8 Methodology climate change costs



Estimation approach climate change costs.

3.3.2 Cost elements and valuation factors

Methodological approaches for valuation of climate change impacts

In general, two methodological approaches for the valuation of climate change impacts could be distinguished: assessment of damage costs and assessment of avoidance costs. Both approaches are discussed below.

Damage costs

The damage cost approach estimates (by use of detailed models) the physical impacts of climate change and combines these with estimations of the economic impacts resulting from these physical impacts (see e.g. Watkiss, 2005a and 2005b). The costs of sea level rise could e.g. be expressed as the capital cost of protection and the economic value of land and structures lost in the absence of protection. Another example is the impact of climate change on agriculture, which could be expressed as costs (less crops) or benefits (more crops) for producers and consumers.

There is a broad and established literature on the valuation of non-market impacts, such as effects on human health and ecosystems. However, economic valuation of these effects of climate change is often controversial. This is mainly the consequence of the lack of knowledge about the physical impacts caused by global warming. Some of these effects are quite certain and proven by detailed modelling, while other possible effects, like extended flooding, hurricanes with higher energy density or more dramatic non-linear effects such as a slowing down or even stop of the gulf stream, are often not taken into account due to lack of information on the relationship between global warming and these effects. Indirect effects such as socially contingent damages (e.g. regional conflicts) are even more difficult to assess.

Available damage cost estimations of greenhouse gas emission will vary due to special theoretical valuation problems related to equity, irreversibility and uncertainty. Concerning equity both intergenerational and intra-generational equity must be considered. Besides the assessment of physical impacts and the question of which impacts are included in the assessment, key issues determining variances between studies are:

- Discount rate used; the impact of variances in discount rates applied is rather large. For example, Watkiss et al. (2005) show that the damage costs increase by a factor 5 if a pure rate of time preference of 1% is applied instead of a rate of 0%.
- Approach to weighting impacts in different regions (equity weighting); Equity weighting corresponds to the intuition that ‘a Euro to a poor person is not the same as a Euro to a rich person’. More formally, the marginal utility of consumption is declining in consumption: a rich person will obtain less utility from an extra Euro available for consumption compared to a poor person. For ethical reasons it could be justified to take these differences between regions in marginal utility of consumption into account, so called ‘equity weighting’. There are two approaches available for equity weighting (Friedrich, 2008):
    - Using world average weights, i.e. adjust regional monetary values by a world average income. For damages of climate change in Europe this would imply that the cost value becomes lower, while the cost values for damages outside Europe will increase. Since the main part of the damages of climate change are expected outside Europe, this kind of equity weighting will result in higher damage costs than in case of no equity weighting.
    - Using regional/EU weights, i.e. the damages are valued by the monetary values from the region in which the GHG emissions causing the damages are emitted. This would imply that European values should be applied to all damages caused by GHG emissions emitted in Europe. From a ethical point of view this could be justified by the fact that Europe is paying for the risks/damages they are causing.
    - As shown by Watkiss et al. (2005) using equity weighting could increase damage costs by a factor of up to 10.

Avoidance costs

The avoidance cost approach is based on a cost-effectiveness analysis that determine the least costs option to achieve a required level of greenhouse gas emission reduction, e.g. related to a policy target. The costs of reaching the specified target are estimated by using a cost curve approach or other modelling methodologies. The target can be specified at different geographical levels, e.g. national, EU or worldwide level. Additionally, targets could be defined for the transport sector only or for all sectors together.

From a welfare economic point of view the avoidance cost approach is not a first-best-solution (Watkiss, 2005b). However, the approach can be considered as theoretically correct under the assumption that the selected reduction target represents people's preferences appropriately. In that case the marginal avoidance cost related to the target could be seen as a willingness-to-pay value. This implies that the avoidance cost approach will preferably only be applied when clear reduction targets are laid down in existing and binding policies or regulations. If (objective) targets are not (yet) confirmed by binding policies, no indication of social desirability of the target is available.

The avoidance costs will probably increase over time since reduction targets for CO_2 are probably tightened in a stepwise approach over the years.

Damage vs. avoidance costs

From an economic point of view the damage cost approach is generally to be preferred to the avoidance cost approach by valuating the external costs of transport. The former approach measures directly the damages related to the external effects and hence provides a first-best estimation of the monetary value of these impacts (CE, 2010a). However, with regard to climate change there are two reasons why the avoidance cost approach could be preferred:

- Reduction targets are already set; if some specific reduction targets with respect to GHG emission reduction are in place, the avoidance cost based approach is preferred to a damage cost based approach (CE, 2010a). Even if the costs of reduction measures are above the damage costs, the measures have to be implemented until the targets are reached. Hence, the avoidance cost approach provides a more practical and transparent valuation of the climate change costs in this case. For the short and medium term reduction targets for GHG emissions are set by the Kyoto-convention (2012) and the European Commission (2020). With regard to the latter the EU has agreed upon a reduction of 20% with the option of increasing this to 30% if a post-Kyoto agreement comes into force (European Commission, 2010a). For the longer term (2050) the European Union has the objective of capping the temperature increase by 2˚C (CE, 2010). This target has been incorporated in the Copenhagen Agreement of 18 December 2009 and was supported by 55 countries representing almost 80% of global emissions[11]. According to IPPC (2007) the greenhouse gas emission concentrations must be kept between 445 and 495 ppm CO_2 equivalent in order to have a probability of 50% of avoiding more than 2˚C global warming. This would mean that global GHG emissions should decline by 50 to 80% in 2050 compared to 2005 levels (EEA, 2009). Based on this, the EU reduction target for 2050 of 80% has been set. In addition, the EU White Paper and the Roadmap 2050 for decarbonisation contain a specific target for transport of 60% reduction in 2050 compared to the 1990 level.
- The precautionary principle; many effects of climate change can be modelled quite well and hence could be assessed in a good way by applying a damage costs approach. However, there are also some risks that on the long run could create very high damages, although the probability is considered either low or unknown (e.g. methane outbursts, loss or reversal of the gulf stream). Since most people are risk-averse these possible impacts of climate change should be taken into account (the precautionary

[11] Notice that there is not a fixed commitment for this objective (in contrast to the 20% reduction aim in 2020) but a non-binding declaration of interest. This means that it could become valid under the condition that the fulfilment of the aim is economically and socially feasible. It is possible that the objective will be adjusted when these issues have been discussed and hence the related CO_2 avoidance costs will change.

principle). Currently, there are no methodologies available to include risk aversion into the assessment (Friedrich, 2008). The only way to include the risk aversion (or the precautionary principle) into the assessment is by applying a avoidance based approach, assuming that the political decision on the reduction target do take these unknown, but important impacts into account.

For the reasons mentioned above we prefer the avoidance cost approach to estimate the CO_2 costs. However, in case damage costs are higher than avoidance costs we will use the damage costs estimates as an upper bound, since this may indicate that the targets set by the government are not socially optimal.

Transport specific or economy wide avoidance cost estimates?

To avoid negative impacts on competiveness of certain sectors, different targets and hence avoidance cost levels in different sectors may be acceptable or even to be preferred. Stringent European climate change policies (and hence a high CO_2 price) may harm the competitiveness of companies that compete with industries outside the EU. This may have negative impacts on the EU economy and employment, and even on the effectiveness of the CO_2 policy (because of carbon leakage). From this point of view it may be preferred to assign a lower GHG reduction target to these sectors.

The main part of the EU transport sector does not compete with transport sectors outside the EU and hence a tighter reduction target for the transport sector could be applied. This would imply that a specific estimate of the transport CO_2 avoidance cost should be made. It is often claimed that such a transport specific CO_2 avoidance costs will be higher than an economy wide estimate due to the relatively expensive reduction measures to be taken in the transport sector. This is reflected by the fact that various EU policies in the transport sector already promote the application of technologies with abatement costs that are significantly higher than the current CO_2 price (ca. 25 €/ton). Examples are:

- The EU Biofuels Directive, aiming at a share of 5.75% biofuels in the energy use in 2010 and the proposal to oblige fuel producers to reduce well-to-wheel greenhouse gas emissions from fuels with 1% p.a. between 2011 and 2030. The first generation biofuels, that will be used to meet the target of the Directive, have CO_2 avoidance costs of several hundred Euro per tonne CO_2. For the 2nd generation biofuels avoidance costs will be lower but still around 50 to 100 €/tonne CO_2.
- The proposed EU policy to reduce CO_2 emissions from new passenger cars to 130 g/km in 2012. CO_2 abatement costs of various technical measures available to improve fuel efficiency of passenger cars involve abatement were estimated at in the order of 50 to 150 €/tonne CO_2 (see e.g. TNO, 2006). However, as shown by CE (2009), this depends strongly on the oil price. With (current) oil prices of around € 100 per barrel, the 130 g/km regulation would be highly cost-effective (cost of around minus € 150 per ton of CO_2).

The existence of specific reduction targets for the transport sector, as mentioned in the 2011 White Paper and the Roadmap 2050 would be strong arguments for using transport specific reduction cost estimates. The 60% GHG reduction target could ideally be taken as a starting point. However, for this target there are no cost estimates available. Moreover, it is generally considered more appropriate to base the GHG reduction cost on the cost for the entire economy, e.g. the 80-95% reduction target for 2050. For this, various estimates are available. When in the coming years the 60% target turns out to be a fixed and independent target that drives the GHG policy in transport, it would be good to base CO_2 cost for transport on reduction costs for this target.

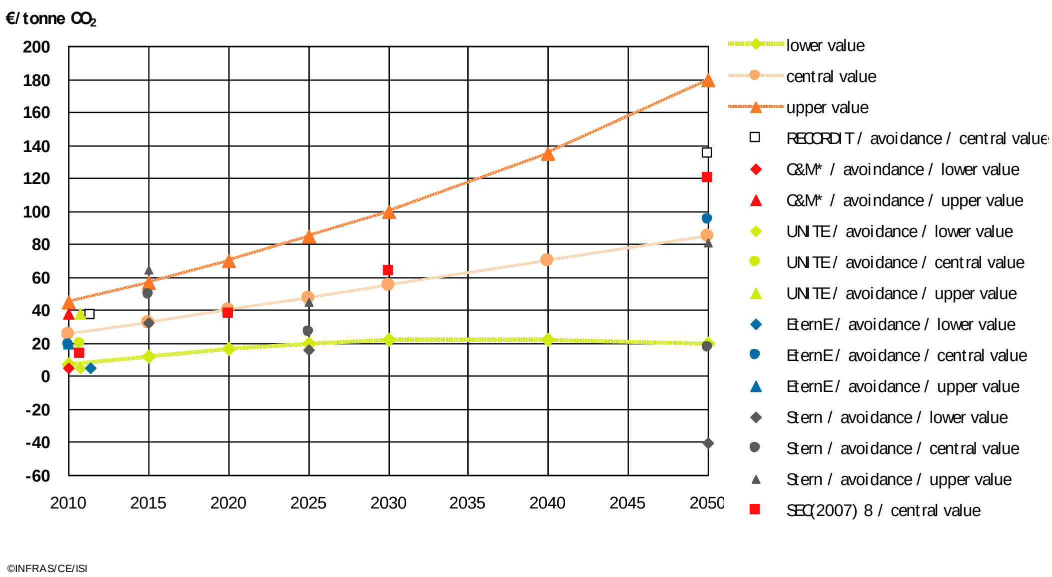
Therefore, although there are good reasons to estimate transport specific CO_2 avoidance costs, we will use economy wide figures in this report. There are hardly any studies assessing the CO_2 avoidance costs for the transport sector. To our knowledge, Ecofys and AEA (2001) is the only study providing CO_2 avoidance cost estimates in the transport sector for Europe. However, in this relatively old study a baseline which (incorrectly) includes successful implementation of the Voluntary Agreement between car industry and European Commission to reduce the CO_2 emissions of new cars to 140 g/km in 2008/9 is applied, as a consequence of which the avoidance cost estimates are too high.

An additional complication in the estimation of transport specific CO_2 avoidance costs is that many mitigation options in the transport sector have non-financial welfare costs, which are often difficult to valuate.

Existing literature on climate change costs

Avoidance costs
A broad overview of avoidance cost estimates is presented in the IMPACT study (CE/INFRAS/ISI, 2008a). The main results of the literature review performed in this study are presented in Figure 9. The values along the shaded lines correspond to the values recommended by CE/INFRAS/ISI, 2008a.

Figure 9 External climate change costs (avoidance costs)



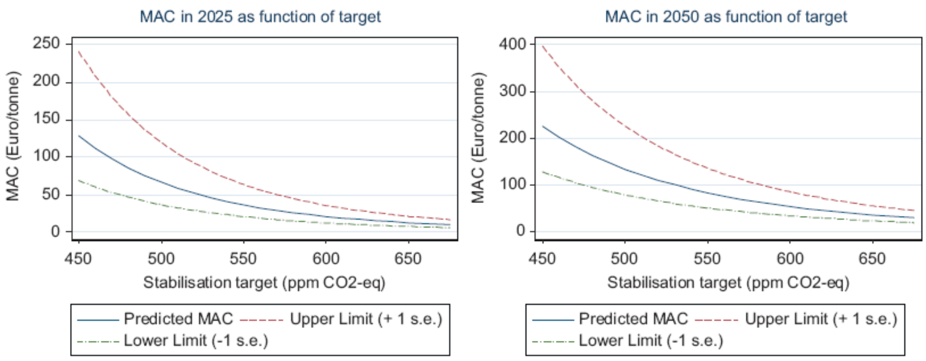
Overview of the CO_2 avoidance costs (in €/tonne CO_2) as presented by CE/INFRAS/ISI, 2008a.

The variance in the cost values presented in Figure 9 is quite large, especially for the long-term. The Stern Review even presents negative avoidance costs for 2050, which are the result of large economies of scale and learning effects (Stern, 2006). However, these low avoidance costs are criticised by various other studies (e.g. Tol and Yohe, 2006; Weyant, 2008) and judged to be too optimistic.

For Stern (2006) and ExternE (2005) it should be noticed that the (emission based) targets which have been taken into account are lower than the current estimations of the targets needed to reach the 2˚C objective. The ExternE (2005) estimate for CO_2 avoidance costs is based on a target of 4.5 Wm^{-2}, which according to Kuik et al. (2009) corresponds to a temperature increase of about 3.6˚C. Stern (2006) considers a target of 500–550 ppm CO_2 eq., which according to Kuik et al. (2009) corresponds to about 2.5˚C. The lower targets used by these studies could have a significant reducing effect on the avoidance costs estimated. For example, Stern (2006) states that the cost of stabilising emissions at 500–550 ppm CO_2 eq. would be around a third of doing so at 450-500 ppm CO_2 eq.

A recent study into the costs of greenhouse gas mitigation policies that aim at the long-term stabilisation of these gases in the atmosphere was carried out by Kuik et al. (2009). Based on a meta-analysis of 62 studies they estimated the avoidance costs as functions of target implemented (ranging from 450 to 650 ppm CO_2 eq.) for both 2025 and 2050 (see Figure 10). Both the value of and the uncertainty in the avoidance costs figures increase when the reduction targets are tightened. With regard to a long-term target of 450 ppm CO_2 eq. (corresponding to a temperature increase of about 2˚C) the avoidance cost in 2025 is estimated to be equal to € 129, with a bandwidth of € 69-241. For 2050 the central estimate is € 225, with a bandwidth of € 128-396 per tonne CO_2 eq.

Figure 10 Avoidance cost estimates as a function of target level (left 2025, right 2050)



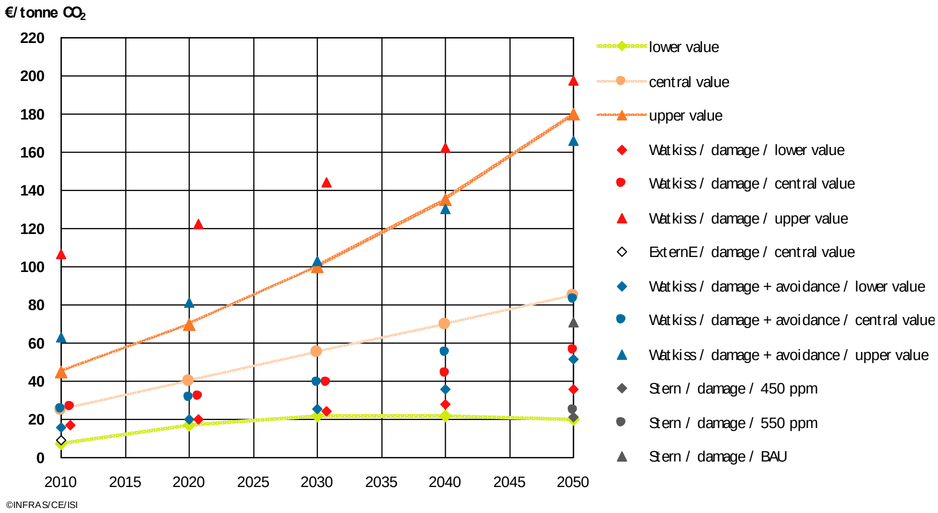
For the medium term, JRC (2007) assessed with the help of the energy model POLES and the general equilibrium model GEM-E3 the CO_2 avoidance costs. The targets taken into account by this study were -30% by 2020 and -50% by 2030 compared to 1990 levels. These targets are stated to be consistent with a pathway that will allow meeting the 2˚C target. For 2020 and 2030 they found avoidance cost estimates of € 37 and 64 per tonne CO_2 eq. Notice that these estimations are in the same range as the figures recommended by CE/INFRAS/ISI, 2008a.

Recent estimations of CE (2010b) shows that the avoidance costs of -30% CO_2 reduction in the EU in 2020 will be equal to ca. € 20-65 per tonne CO_2 eq. (the exact avoidance costs depends on the amount of CDM permitted). In this last study the effects of the economic crisis are taken into account.

Damage costs

CE/INFRAS/ISI (2008a) provides a broad overview of damage cost estimates from the literature. The results of their assessment are presented in Figure 11. The damage cost estimates by the various studies differ widely, which is among other factors caused by differences in assumptions on discount rate and equity weighting.

Figure 11 External climate change costs (avoidance costs)



Overview of the CO_2 damage costs (in €/tonne CO_2) as presented by CE/INFRAS/ISI (2008a).

Also Anthoff (2007) shows the large impact of equity weighting on the estimated damage costs. Based on calculations with the FUND model he finds values which differ with a factor 10 (1% pure discount rate). Some results from his study are presented in Table 9. The ranges found in the study by Anthoff correspond to the ranges found by CE/INFRAS/ISI (2008a).

Table 9 CO_2 damage cost estimates according to Anthoff (2007) (in €/tonne CO_2)

Year of application	No equity weighting	World average equity weighting	EU equity weighting
2005	7	20	97
2015	11	25	122
2025	14	29	148
2035	15	27	137
2045	17	28	143
2055	27	40	196

Conclusions on climate cost value

In the case of climate change, the uncertainty in both avoidance cost and damage cost estimates is extremely large. The avoidance costs are highly sensitive for oil price and discount rates, while the damage costs are very sensitive for the type of equity weighting and also discount rates. In addition the costs of risks for some potentially very high damage cannot be quantified well. This is one of the main reasons why the cost estimates used in this study are based on avoidance costs.

With the very high uncertainties in climate costs, it would be misleading to give a single cost estimate. Therefore we present a lower value and an upper value. It is generally assumed that climate cost increase over time. However, as the scope of this study is just providing cost estimates for the year 2008, no estimates are given for future years.

The lower cost estimate is based on the avoidance cost estimates for meeting the EU GHG reduction target for 2020. These are estimated to be at least € 25 per ton of CO_2.

The higher climate cost estimate is based on the cost for meeting the long-term target for keeping CO_2 eq. level in the atmosphere below 450 ppm in order to keep global temperature rise below 2 Centigrade. Extrapolating the cost values for 2025 from Kuik (2009) back to 2008, results in values of € 42 (low), € 78 (medium) and € 146 (high) per ton of CO_2 (applying a discount rate of 3%). Based on this, we use € 146 per ton of CO_2 as high value for 2008.

When in the coming years the specific GHG reduction target for transport (60% compared to the 1990 level) turns out to be a fixed and independent target that drives the GHG policy in transport and when also reliable cost estimates for meeting this target are available, it is recommended to base the CO_2 cost for transport on the reduction costs for this target.

Valuation of the climate change impacts of aircraft emissions

As mentioned before, the emission of some non-CO_2 substances at high altitudes by airplanes also have an impact on global warming. These impacts are partly heating effects, partly cooling effects, such as atmospheric chemical reactions on the basis of NO_x which increase ozone concentrations in the atmosphere (heating) and which convert methane (cooling), soot emissions from aircraft engines (heating), sulphur aerosols (cooling), and formation of condensation trails (cooling in daytime and heating at night) and possibly cirrus clouds.

To compare the climate impact of non-CO_2 emissions and CO_2 emissions for aviation a slightly different approach should be followed than for the other modes. Often, the radiative forcing index (RFI) is used to compare these impacts for aviation. This index gives the ratio between the total radiative forcing from aviation at some given time to the radiative forcing from aviation emissions of carbon dioxide at the same time (Forster et al., 2006).

According to scientific studies (IPPC, 1999; Sausen, 2005) the RFI is equal to ca. 2–4, indicating that the total climate impact of aviation at a certain point of time is 2 to 4 times bigger than the impact of the CO_2 emissions. However, the RFI is not a good indicator to weight the various GHG emissions with respect to their impact on the social costs of climate change. The reason is that this index does not take the variances in lifetime of the climate change impact of the various emissions into account. For example, if equal masses of two different substances were emitted on the same day and one had a lifetime of a few days and the other over 100 years, the substance with the 100 year lifetime would obviously have the bigger impact on climate. The lifetime of GHG emissions of aviation differ widely, from just a few hours (contrails) to ten years (aircraft induced methane reduction and its associated indirect effect on ozone) and even up to 300 years (CO_2). So, if we would multiply a current amount of CO_2 emissions by a factor 2 tot 4 to find the total climate change impact of aviation, we would overestimate the long-term climate impact of aviation.

A better index to weight the climate impact of GHG emissions of aviation would be the Global Warming Potential (GWP). This index considers the time-integrated radiative forcing from a pulse emission for a specific period (e.g. 100 years) and hence provides a good basis to compare the climate change impact of future GHG emissions. A robust version of such an index is not available yet. However, there are some first estimations of so called Emission Weighting Factors (EWF) which can be considered as approximate GWPs of aviation (Forster et al., 2007a). These estimates do not include the impacts of aircraft induced cloudiness.

More recently Lee et al have made similar estimates and come to values of 1.3 to 1.4 (Lee et al, 2009). Moreover, Lee et al also present estimates that include the GWP of aviation including preliminary estimates for the effects of aircraft induced cloudiness. The estimates they present are 1.9-2.0. As noticed by Lee et al. themselves the uncertainties in this index are, although unknown, probably large. However, due to a lack of alternative indices, we will use in this study the factor of 2 to estimate the non-CO_2 climate impacts of high altitude emissions from aviation.

3.3.3 Data situation

The calculation of greenhouse gas emissions for the different modes is explained in the Annex.

3.3.4 Marginal cost methodology

For climate costs, we assume marginal costs to equal the average costs.
The data uncertainties applying to the average climate costs, do also apply to the marginal climate cost estimates.

3.4 Noise

Noise can be defined as the unwanted sound or sounds of duration, intensity or other quality that causes physical or psychological harm to humans. In general, two types of negative impacts of transport noise could be distinguished:

- **Costs of annoyance**
  Transport noise imposes undesired social disturbances, which result in social and economic costs like any restrictions on enjoyment of desired leisure activities, discomfort or inconvenience, etc.
- **Health damages**
  First, noise levels above 85 dB(A) can cause hearing damage. Lower noise levels (above 60 dB(A)) may increase the risk on cardiovascular diseases (heart and blood circulation) and may also result in nervous stress reactions such as increase of blood pressure and hormonal changes. Finally, transport noise can also result in a decrease of subjective sleep quality. These negative impacts of noise on human health result in various types of costs, like medical costs, costs of productivity loss and the costs of increased mortality.

An additional impact of transport noise is the restricted land use possibilities in areas around airports and some (rail)roads. In many countries governments establish ‘cordon sanitairs’ around large noise sources like airports. In these cordon sanitairs land use is restricted, e.g. it is not allowed to build new houses. These restrictions in land use change result in welfare losses and hence should be taken into account by estimating the external costs of aviation noise. However, due to a lack of available data on this issue, we will not estimate these costs in this study.

Noise cost due to maritime shipping and inland waterway transport are assumed to be negligible, because emission factors are comparably low and most of the transport activities occur outside densely populated areas. For that reason, noise costs of shipping are not taken into account.

3.4.1 General approach and overview of cost estimation

To estimate the average noise costs for the various modes we will use a bottom-up approach, which consists of three steps (see also Figure 12):

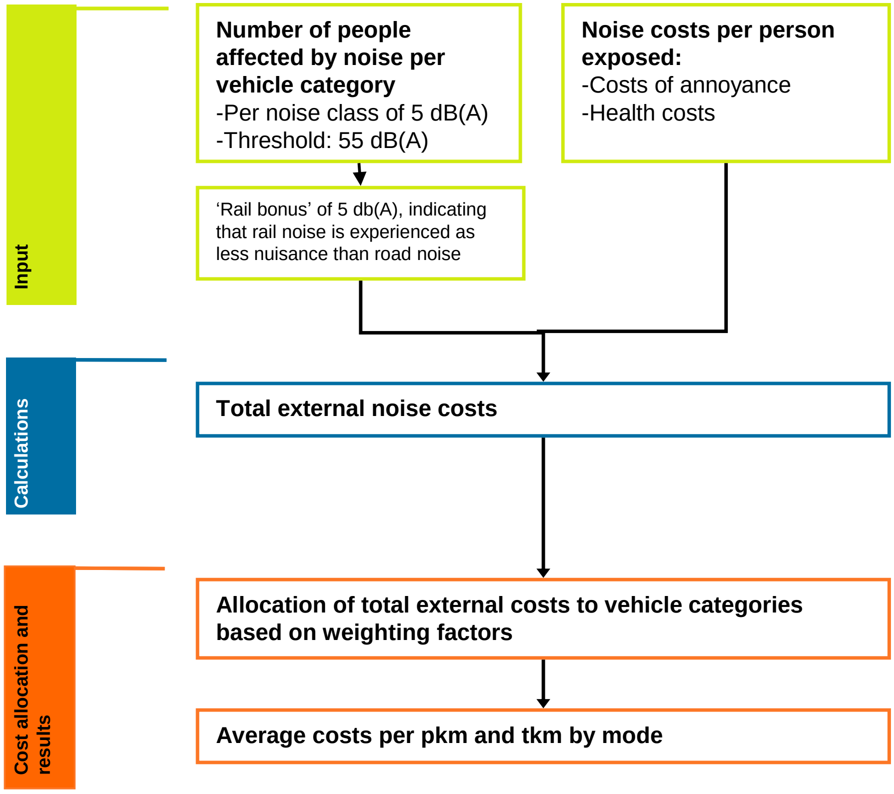
- Estimation of the number of people affected by noise per vehicle type. Based on data from the noise maps Member States are required to deliver (by Directive 2002/49/EC) to the European Commission the number of people affected by road traffic, rail traffic or aviation noise is estimated (see also Paragraph 3.4.3). According to the noise map data, the following noise classes are distinguished for calculation of the total noise costs: 55-59 dB(A), 60-64 dB(A), 65-69 dB(A), 70-74 dB(A) and more than 75 dB(A). For noise levels below 55 dB(A) it is assumed no adverse effects on annoyance and health occur.
- Estimation of total noise costs by multiplying the number of people affected by the noise costs per person exposed; the adverse effects of traffic noise for the affected people could be valuated by cost factors presented by CE/INFRAS/ISI (2008a). In Paragraph 3.4.2 we will discuss these cost factors.
- Calculation of the average noise costs by allocating the total noise costs to the various transport modes by using specific weighting factors.
  To estimate the average noise costs we will allocate the total noise costs to different transport modes. This allocation will be based on total vehicle kilometres per mode. In addition, some weighting factor must be applied to take differences in noise characteristics between modes into account. CE/INFRAS/ISI (2008a) recommends to use the weighting factors presented in Table 10.

Table 10 Noise weighting factors for different vehicle classes

	Urban (50 km/h)	Other roads (80 km/h or higher)
Road		
Passenger car petrol	1.0	1.0
Passenger car diesel	1.2	1.0
Passenger car LPG	1.0	1.0
Moped	9.8	3.0
Motorcycle	13.2	4.2
Bus	9.8	3.3
Van	1.5	1.2
HDV solo < 12 ton GVW	9.8	3.0
HDV solo > 12 ton GVW	13.2	4.2
HDV with trailer	16.6	5.5
Rail		
Passenger train	1	
Freight train	4	

Source: IMPACT (CE/INFRAS/ISI, 2008a) and CE (2004).

Figure 12	Methodology noise costs



3.4.2 Cost elements and valuation factors

CE/INFRAS/ISI (2008a) provides an extensive overview of studies on the noise cost per person affected. Based on this overview it is recommended to use the national values provided by HEATCO (2006). As an example the values for Germany are presented in Table 11. These cost factors do take into account both, the costs of annoyance and the health costs due to traffic noise. The costs of annoyance are based on stated-preference research by Navrud (2002), which could be considered as state-of-the-art in this field. To estimate the health costs a distinction was made between medical costs and costs of premature deaths. To valuate the latter a Value of a life year lost of € 40,300 ($€_{2000}$) was used, in line with the valuation of accident costs (see Table 6). The medical costs include the costs of the hospital and absentee costs.

The annoyance cost values for rail noise are set at noise levels 5 dB above the levels for road noise. The reason is that there is evidence that rail noise causes less annoyance than road noise at the same noise levels (in literature also referred to as 'rail bonus')[12]. Health costs values (starting from 70 dB(A)) are assumed to be the same for road and rail traffic.

12 In the scientific literature there is some discussion on the 5 dB(A) correction for rail noise relative to road traffic noise. Several studies carried out after this issue shows contradictory results. Based on a review of this literature Jerson and Öhrström (2007) conclude that there is significant evidence for applying this correction.

Table 11 Noise costs for Germany per person exposed per year (2008) €$_{2008}$

Lden (dB(A))	Road	Rail	Aviation
≥ 55	50	0	78
≥ 56	60	10	94
≥ 57	71	20	110
≥ 58	81	30	125
≥ 59	91	40	141
≥ 60	101	50	157
≥ 61	111	60	172
≥ 62	121	71	188
≥ 63	131	81	204
≥ 64	141	91	219
≥ 65	151	101	235
≥ 66	161	111	251
≥ 67	171	121	266
≥ 68	181	131	282
≥ 69	192	141	298
≥ 70	202	151	313
≥ 71	265	213	381
≥ 72	281	230	403
≥ 73	297	246	425
≥ 74	314	263	447
≥ 75	330	279	469
≥ 76	347	296	491
≥ 77	363	312	513
≥ 78	379	329	535
≥ 79	396	345	557
≥ 80	412	362	579
≥ 81	429	378	601

3.4.3 Data situation

Data on the number of people affected by road, rail and air noise have been based on data that have been compiled by the ETC/LUSI according to the IP2008-2010/EEA and a specific agreement between EC and EEA (EEA, 2010). These data summarise the reported noise data of the EU member countries according to Directive 2002/49/EC[13].
According to the directive data are reported for:

- Agglomeration ≥ 250,000 inhabitants.
- Major civil airport ≥ 50,000 movements per year.
- Major roads ≥ 6 million vehicles per year.
- Major railways ≥ 60,000 trains per year.

To get the complete number of people per country exposed to noise, data on noise in agglomerations have been extrapolated to all people living in areas with a population density over 500/km^2, both for road and rail. For the extrapolated part it is assumed that traffic density is half of the intensity in the reported areas and the average exposure level is therefore 3 dB lower as compared to the reported areas. Furthermore a correction has been made to

[13] See http://eea.eionet.europa.eu/Public/irc/eionet-circle/etcte/library?l=/2009_subvention/113noise/data&vm=detailed&sb=Title and http://circa.europa.eu/Public/irc/env/d_2002_49/library?l=/strategic_december&vm=detailed&sb=Title

correct for reported major roads and rail tracks which are in areas with a density > 500/km^2.

The resulting data on exposed people and more details on the method are given in the annex.

3.4.4 Marginal cost methodology

Marginal noise costs are highly dependent on local factors. Three general key cost drivers for marginal noise costs can be distinguished:

- **Population density** close to the emission source: this cost driver gives an indication of the population exposed to the noise. Generally spoken, the closer to an emission source, the more nuisance will occur, and the higher the marginal costs will be. A rough indication of the population density close to the emission source could be made by distinguishing area types (urban, suburban, rural). In general the population density will be highest in urban areas and lowest in rural areas.
- **Existing noise levels** (depending on traffic volume, traffic mix and speed): along an already busy road the noise costs of an additional vehicle are small compared to a comparable situation along a rural road. The higher the existing background noise level, the lower the marginal costs of an additional vehicle. As a proxy for the existing noise levels we will use area type (urban, suburban, rural) and traffic situation (thin or dense traffic).
- **Time of the day**: noise disturbances at night will lead to higher marginal costs than at other times of the day. To take this cost driver into account we will distinguish between marginal noise costs for night and day.

For road and rail transport we will estimate marginal noise costs differentiated to area type, traffic situation, time of the day and mode based on the recommended values presented by CE/INFRAS/ISI (2008a).

The marginal noise costs of air traffic depend heavily on local factors (e.g. population density around airports), flight path, aircraft type and technology, and time of the day. Therefore, it is not possible to present an accurate (range of) values that could be applied for all situations. Specific case studies are needed to provide these cost estimates. To provide some rough indications of the marginal noise costs of air traffic we will use the same approach as in INFRAS/IWW (2004), i.e. we assume that the marginal noise costs of air traffic range between 30 and 60% of the average costs. The marginal noise costs estimated by this approach will be checked with the figures found by some case studies on marginal noise costs of aviation on European airports.

3.5 Congestion

3.5.1 The nature of congestion and concepts for quantification

The nature, extent and appropriate quantification of delays and congestion is subject to controversial debates among economists and traffic engineers. Transport users experience congestion through increases in travel times, travel time unreliability and operating costs. These delays have multiple causes, including accidents, construction sites and weather (Fraunhofer-ISI et al., 2007) , and their level of acceptability may change by travel purpose, time and even city size (OECD, 2007).

Congestion in economic terms is described as the mutual impacts of users arising when competing for scarce capacity. Congestion arises in transport networks, such as road networks, where infrastructure users compete individually for limited infrastructure-capacity. It increases with traffic load, but is to some extent present at all levels of demand. Even before full capacity limits are reached, users may experience mutual disturbance, resulting in lower speeds. The relation between speed and traffic load is specific to every road section, junction or larger network parts. Speed or travel time per kilometre can be measured and expressed by speed-flow (or time-flow) functions. They vary significantly with network characteristics, but also by traffic flow compositions, weather, driver behaviour, road works or accidents. By introducing values of time, which again depend on a number of factors such as travel purpose, time of day, etc., the travel time-load function can be translated into a corresponding cost-load function.

3.5.2 Economic theory and measures of congestion

Costs related to congestion mainly consist of the cost of additional travel time plus some 10% for vehicle operations and have internal and external components. The cost of delays experienced by each individual traffic participant is internal and is part of his or her user costs. The cost of delays imposed on other road users is external. For approaching the external part of congestion costs, some basic reflections may help.

Economic welfare theory suggests, that whether costs or benefits are 'internal' or 'external' is defined only with regard to the proper functioning of a certain market. External cost is one of several reasons for market failure. The proper functioning of the market depends on the conditions under which market participants take their individual decisions. Markets can work properly (i.e. welfare maximising) only if all costs entailed by every single decision of individual market participants are taken into account with this respective decision. Costs are 'external' if it they are not taken into account by the individual market participant who is causing this cost by his or her decision. Therefore costs can still be partly external even if they are borne by market participants as a group as long as these costs (or part of these costs) have to be borne independently of the individual decisions of the members of this group.

The cost of congestion experienced by an additional road user, i.e. the marginal internal congestion cost, as well as the marginal external congestion cost imposed on other road users are determined by the shape of the cost-flow function. The steeper the upward-slope of the function measured by its first derivative is, the larger is the marginal external cost of congestion relative to its internal cost experienced by additional road users themselves.

Congestion differs from other external effects of transport as the market participants affected by it are largely identical to those causing it. For the principal definition of external effects from the individual user perspective, i.e. the concept of marginal costs and optimal internalisation prices, this distinction is not relevant, and even for the definition of total costs it does not deny the existence of externalities. Given the different groups of market participants experiencing congestion and other externalities, however, it was decided that in this study the congestion-externality would be presented separately and not be added up in terms of total external costs of transport.

The degree of market failure caused by the external cost of congestion or by any other externality can be characterised by several indicators. The most common indicator used for all other types of externalities in this study is the total amount of external cost. The total amount of external congestion cost can be determined by summing up the marginal external cost-contributions of the individual road users. In mathematical terms this means integrating over the marginal external cost function from zero to the actual traffic load.

The indicator which is linked closest to the degree of market failure is the social welfare which is lost due to the market failure related to external cost. This so called 'deadweight loss' is identical to the additional social welfare all users competing for a scarce road capacity could gain, in case everyone considers her/his impact on other road users when taking travel decisions. The deadweight loss is defined as the sum of differences between demand-depending user- plus external congestion cost and the users' maximum willingness to pay for the respective demand level. These differences have to be integrated (summed up) for traffic loads ranging from optimum (where the difference is zero) to actual traffic load.

A simple and intuitive approach to indicate the probable degree of market failure due to external congestion cost is the computation of delay costs against a given reference speed. Respecting the findings of a 'users' expectation approach' towards congestion (OECD 2007) we consider delays against a reference speed of 60% of free flow speed (Fraunhofer-ISI, 2007).

A fourth indicator for the degree of market failure could be the total sum of revenue from those congestion charges which would be necessary to reduce the traffic load to the optimum level. This is the optimum traffic load up to which – as mentioned above – still no deadweight loss will occur.

Among the measures discussed, the deadweight loss constitutes the most cautious approach while delay costs constitute the upper range of possible values. The ranges, however, are strongly subject to road characteristics and demand elasticity. This is illustrated by the example shown in Table 12. It lists the ratio of the various types of congestion cost indicators, for two types of cost function (linear or quadratic) and two different values of the demand elasticity.

Table 12 Illustrative relative levels of congestion cost measures relative to delay costs

Cost function	Linear		Quadratic	
Demand elasticity	-0.3	-0.8	-0.3	-0.8
Delays against 60% free flow speed	100%	100%	100%	100%
Integral of marginal external costs	58%	58%	77%	77%
Deadweight loss	10%	16%	23%	31%
Congestion charging revenues	179%	134%	196%	153%

For reasons of transparency of the computations we present delay costs due to the scarcity of road infrastructure as the leading indicator, but report on the deadweight loss as the lower estimate where appropriate. This approach, framing the integral of marginal costs, is more in line with the other cost categories, but differs from the more cautious approaches of the proceding studies (INFRAS/IWW, 2000 and 2004). The terminology 'external congestion costs' for the delay measure is not totally correct as it does not exclude internal cost components and does not comply with the economic definition of congestion. However, as delay causes other than excessive demand or insufficient capacity are excluded we remain with the term congestion including 'capacity driven delays' in this study.

Market failure due to congestion and partly congestion driven delays are only valid for modes with multiple and independent users or operators, who make travel decisions case by case depending on the prevailing situation. These conditions are fully met by road transport. Although the liberalisation of rail markets and the competition of airlines for scarce runway capacity at major airports create mutual impacts between multiple operators, rail and air services consist of central capacity allocation units. We assume that rail network operators and air traffic control follow the objective of efficient capacity allocation and thus exclude these modes from the computation of congestion costs.

In contrast, delays due to capacity shortages also appear in rail and air transport (compare INFRAS/IWW, 2004). In particular in the European aviation sector EUROCONTROL has available a systematic and rather comprehensive database on flight delays and delay causes (EUROCONTROL, 2007). Similar analysis tools for road and rail transport would be desirable to get an idea of the most important causes of delays across all modes.

3.5.3 Cost elements and valuation factors

A compilation of European traffic congestion records and studies by the COMPETE project (Fraunhofer-ISI et al., 2007) reveals, that the data situation on road capacity utilisation and congestion in Europe is scattered and inhomogeneous. A few regular accounts and several one-off studies exist, but they do hardly allow to draw a comprehensive picture across the EU. As the availability of national congestion and delay studies has slightly improved, we follow a two-fold approach for quantifying inter-urban congestion levels in this study. First, we keep the model based approach as done for the previous studies (INFRAS/IWW, 2000 and 2004). According to this approach, the deadweight loss and delays are computed from European road networks with capacity and traffic load information. Second, we contrast these results with a meta-study of national approaches in order to make best use of all available information.

In contrast to the previous studies, we exclude potential revenues from congestion charges as they are not very reliable to estimate economic losses and highly depend on the type of charging system installed. We present two output measures:

- Deadweight loss (= social losses due to lacking social efficiency in taking trip decisions). And
- Delay costs as a simple and more robust indicator for the scarcity of capacity and for the extent of market failure due to congestion.

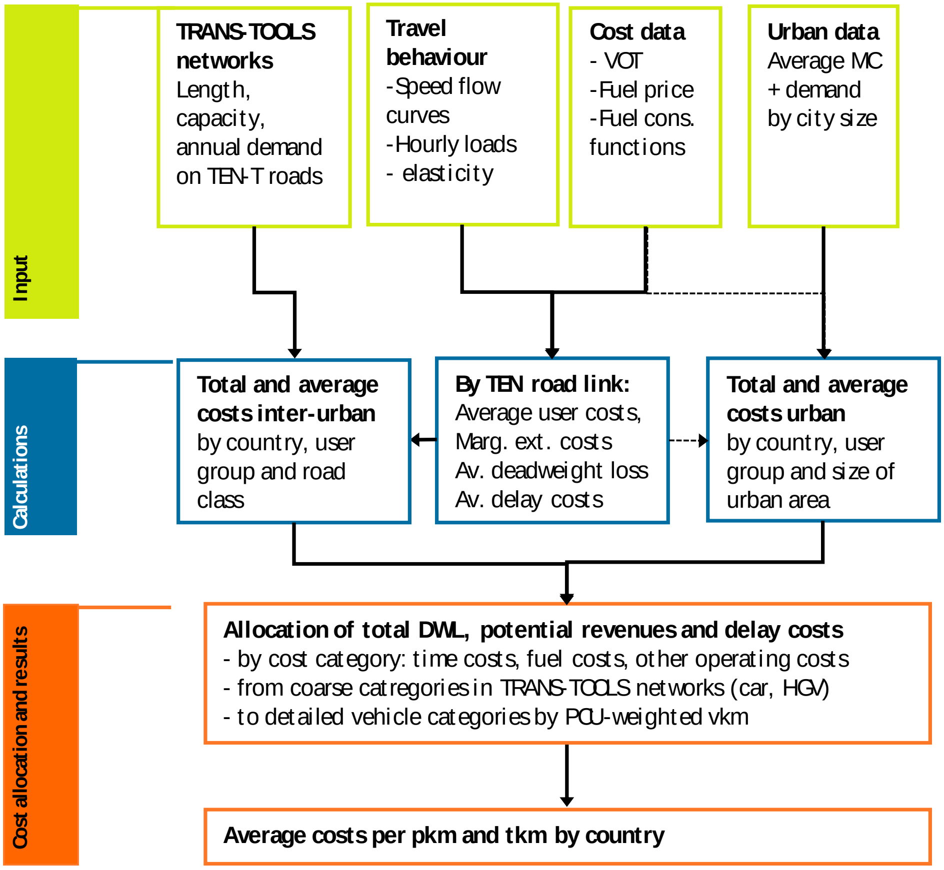
For each of these we consider the economic costs of time losses plus an addition due to additional fuel and vehicle operating costs under congested conditions.

To get reliable and consistent figures for the impacts of congestion, the TRANS-TOOLS model application is accompanied by two alternative estimates:

- A meta-analysis of existing studies and statistics on road delays and congestion to better acknowledge national travel conditions and specificities.
- A meta-analysis of urban congestion studies. This is required as the TRANS-TOOLS model, as other European simulation tools, does not cover urban networks.

The physical assessment of delays and infrastructure scarcity effects then are assessed in economic terms by considering users time values. Figure 13 shows the structure of the congestion cost estimation procedure.

Figure 13 Estimation procedure for congestion costs. Input data, computation steps and output indicators for inter-urban congestion estimation



Value of travel time

The monetary values attached by travellers to changes in travel time or by forwarders to variations in delivery times are among the most relevant cost categories for the economic assessment of alternative routes. In passenger transport the valuation of travel time depends on several factors, such as travel purpose, means of transport, distance or comfort. CE/INFRAS/ISI (2008a) and HEATCO (2006a) on-trip values per passenger-hour range from € 24 per hour for business trips down to € 7 per hour for short leisure trips. Values for long-distance trips are roughly 10% above those for short distances and travel time values for bus trips are 10 to 25% lower than respective values when using passenger cars. These findings are synthesised from national European investment guidelines, which are again based on national revealed or stated-preference surveys.

In freight transport, values of travel time are usually extracted from revealed preference studies. These may be designed as uni-modal experiments observing route shift effects, or as multi-modal studies interpreting modal split behaviour of forwarders. For deriving the economic value attached to in-time delivery of goods while excluding vehicle operating costs, modal split based studies are preferred. The EU cost estimation handbook (CE/INFRAS/ISI, 2008a) reports a value of € 2.98 per tonne of goods in road haulage. It is not totally clear from the original source (HEATCO, 2006a) to what extent lorry operating costs are excluded here, but the value itself looks like as this is the case.

The value of travel time used here reflects public benefit from time savings rather than forecasting or private WTP values (Fowkes, 2011). In principle the value of travel time should consider the reliability of passenger and freight services (De Jong, 2004 and Fraunhofer-ISI et al., 2007). But this detailed consideration of local transport system conditions is not feasible from the European perspective taken in this study. Respecting vehicle occupancy rates we receive an average value per passenger car hour of € 20.55 in 2008 prices across the EU. This value is transferred by country applying PPP-adjusted GDP per capita values.

Vehicle operating and fuel costs

Vehicle depreciation denotes the loss of the vehicle's value due to aging and use. As associating aging-related depreciation with detouring is very speculative, the concept of distance-related depreciation appears more applicable. Depreciation costs are decision-relevant only for commercial traffic such as haulage or bus services. But in economic terms also the non-perceived loss of resources in private car traffic are considered according to the methodology of the German transport investment plan (BMVBS, 2003). The distance-related vehicle depreciation costs are then estimated by dividing purchase- or replacement costs by the vehicles average life expectancy and annual kilometres driven. Interest on the capital on vehicle purchase could be interesting for commercial fleet operators, but are neglected here.

Vehicle operations other than fuelling mainly comprise of driver costs. This cost block is only relevant for commercial services and is depending on the time of operation rather than on kilometres driven. The indicative wage rates are approximated from information by the German road haulage association (BGL, 2010). While the impacts on air pollution and global warming are captured by the relevant sections, here we consider the monetary implications to the respective transport users or operators.

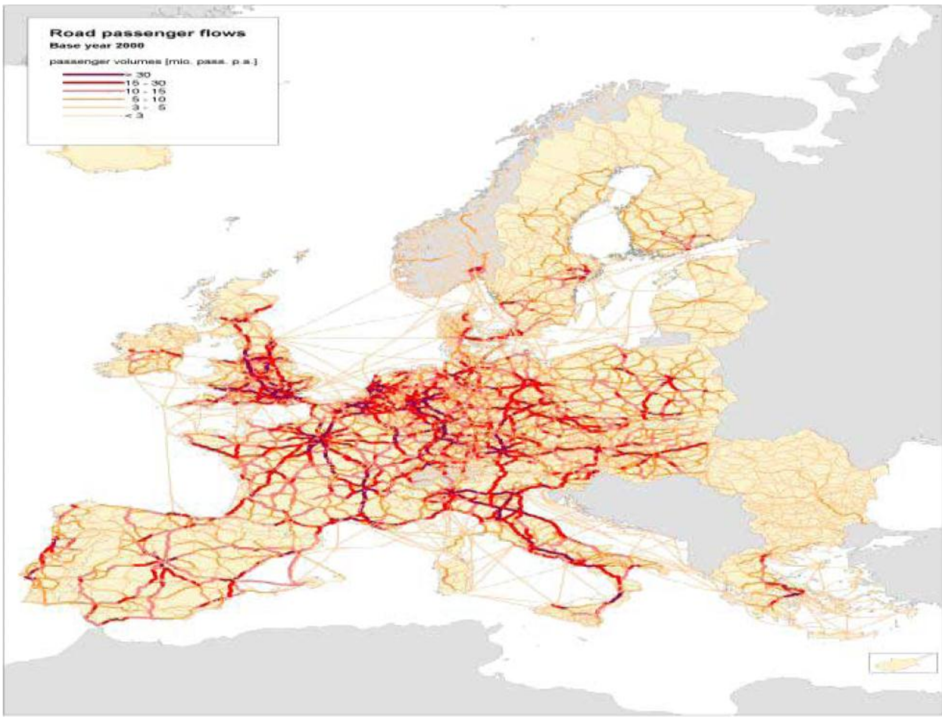
3.5.4 Data situation

The computation of time and fuel cost components due to road traffic congestion in Europe requires several data inputs. These are described and qualified in turn.

Transport network data

In order to comply with recent EC studies we use the European inter-urban road network of the TRANS-TOOLS model, version 2. The model constitutes a synthesis of several European transport models and was developed under the 6th framework program of the EC since 2004. Currently version 2 of the model is available and further improvements are under development. The model delivers road lengths by typology and average annual traffic loads. The TRANS-TOOLS networks, however, do only provide information on flows between NUTS-3-regions. Intra-zonal traffic, in particular urban traffic, is not contained in the databases. Figure 14 shows the TRANS-TOOLS road network with passenger car loads.

Figure 14 TRANS-TOOLS road traffic network. Passenger car volumes p.a. for base year 2000



Source: TRANS-TOOLS, 2008.

National congestion statistics

Since the previous study on external costs a number of national statistics and studies on the quality of road transport has been conducted. The most comparable indicator of these sources and the TRANS-TOOLS network database analysis are total time losses by country on the primary road network. These and other indicators are reported as follows:

- **United Kingdom** (DfT, 2010): The Department of Transport (DfT) issues annual reports on the development of travel times on England's strategic road network. Related to free flow speeds the 2009/2010 dataset 125 million delay hours, which corresponds to 0.073 minutes per vehicle-km. As for other parts of the UK only the Scottish Executive reports on congestion within the 2009 household survey (Scottish Executive, 2010) we extrapolated the average delay costs for England to the UK by a factor +20%. Due to its regularity, detailed methodological discussions and the application for setting transport policy targets the study series, which is carried out for urban areas in alternate years, is considered of high quality and thus is used as reference source for this study.
- **The Netherlands** (Rijkswaterstaat (2011)): Rijkswaterstaat publishes congestion, delays and related impacts for 106 routes on the primary road network. The assessment of traffic observations lead to annual time losses in the Netherlands in peak hours of 62 million hours. Input data is taken from traffic jam observations, i.e. ignores the existence of small delays. Referring to respective sensitivity computations in ARE (2007) for Switzerland show, that the under-estimation of total vehicle delay hours may be around 40%. Some further correction should be considered for off-peak periods. Accordingly, the real number of congestion hours in the Netherlands may be above 100 million annually. In addition, CE Delft reports potential pricing revenues from a congestion charge of € 1.9 billion for primary and secondary roads, generating a social surplus of € 680 million (CE, 2002).

- **Germany** (IVV, 2004): Germany does not conduct systematic congestion monitoring. But a forecast of travel quality on the motorway network in 2015 (IVV, 2004) gives a detailed overview of bottlenecks and travel conditions. The study reports 31 to 42% of critically congested links and 950 million delay minutes in 1997 on motorways calculated against a reference speed of 75 kph. The computations appear rather detailed in technical terms by including road surface conditions, speed restrictions and time-variant demand patterns. But the authors constitute a downward bias as accident and weather related traffic jams and parts of small delays have not been accounted for. As in the meantime massive investments for congestion relief have been realised and passenger transport as the main source of congestion shows tendencies of stagnation, we do not put a specific adjustment factor on the study results.
- **France** (Koning, 2010): an estimate of congestion costs, the Paris Ring Road and the French primary road network leads to a deadweight loss of € 3.2 million and travel time losses of 27.4 million hours against free flow speeds. Input data to estimate geographically and temporally differentiated demand-delay functions is taken from road side detector loops operated by URF (Union Routière de France). It requires intensive adjustment and bears a considerable under-reporting is expected as the loops do not cover all road sections and the assessment is restricted to working days. We Thus apply a correction factor of 2.0 to make the results comparable. By comparing 2000 to 2007 data the work reports on the success of regional and local programs at Ile-de-France to shift traffic and to reduce environmental pollution by narrowing road space and modernising public transport.
- **Switzerland** (ARE, 2007): reports 52 million delay hours in 2005 on the inter-urban road network, based on traffic message analyses and estimates of small delays. These involve roughly € 870 million social costs, of which 85% are due to travel time losses. Without small delays only 25 million lost vehicle hours are reported, leading to an adjustment factor for other country results (compare Netherlands) of 1.4. The study compares delay hours and costs in 1995 (20 million), 2000 (28 million) and 2005, leading to a clear upwards trend.
- **Belgium** (TML, 2008) finally has carried out a study on travel quality on the Belgium motorway network. For working days the assessment of detector loop data leads to annual travel time losses of 6.1 million hours. This pilot is probably subject to the same downward bias as Koning (2010) for France, plus the effect that modelling approach captures small delays. We thus apply a correction factor of 2.5 to include all road sections, all times and also small delays.

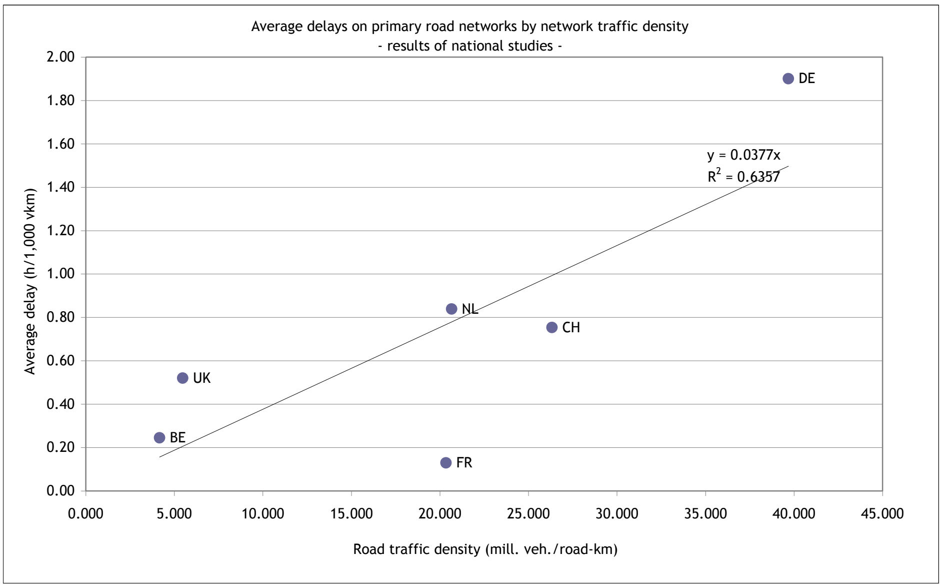
The methodologies of the approaches are different and not always documented in full detail. But the plot of the average delay per vehicle kilometre on the traffic density of the relevant road network provides a more or less clear trend. With a national perspective, higher network loads generally imply higher average vehicle delays as indicated by Figure 15. The graph reveals the high congestion level in the UK and Germany, but conveys some astonishing results. According to the respective national studies, Switzerland should be much more congested than the Netherlands, which is probably due to the much higher traffic performance in Holland. Belgium, and in particular France, appear to suffer least from road delays.

The network delimitation of the studies make a direct comparison difficult, and in most cases the original sources did not provide all necessary data to compute the correct traffic density and average delays. This may be the reason why the result for France appears so extraordinarily low. But with reference on OECD and EU sources, Koning (2010) points on the huge differences in congestion estimates, ranging from 0.1 and 2% of GDP.

The trend line is used to extrapolate the average delay levels in all other countries related to their individual traffic density on roads. Using the relative levels of the several congestion measures computed from the TRANS-TOOLS model, the deadweight loss is finally estimated as a fixed share of delay costs. The final output values are then expressed as range between maximum and minimum values as follows:

- **Maximum values** for inter-urban congestion costs are taken from the TRANS-TOOLS database adjusted by the over-estimation of delayed traffic on the long road sections. By comparing the different model applications in this and proceeding studies we reduce total delay costs by 30%.
- **Minimum values**: We start from the regression on national statistics with a general adjustment factor for small delays and under-reporting due to missing link data and off peak times. Despite the single adjustments in selected studies above, we add 40% according to the Swiss sensitivity tests (ARE, 2007).

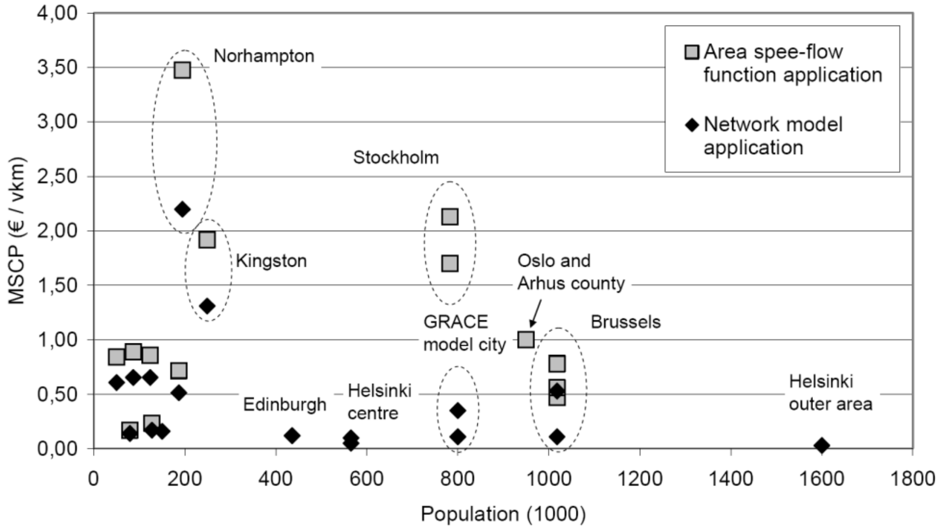
Figure 15 Average delays against road network occupation



Urban transport data

Unit congestion costs by type of urban area have been compiled by the IMPACT Handbook (CE/INFRAS/ISI, 2008). Figure 16 gives an overview of different estimates of marginal external congestion costs for different urban areas and road classes. Respective population data by urban areas in the EU are provided by EUROSTAT and traffic volumes are compiled by national statistics (Annex). With this data total charge revenues and, with the help of general relations from TRANS-TOOLS assessment, the deadweight loss and delay costs can be estimated.

Figure 16 Urban congestion cost estimates from different studies (€$_{2000}$ per VKM)



Source: IMPACT, Deliverable 1 (CE/INFRAS/ISI, 2008a).

Speed-flow functions

Speed-flow functions are available by road type and type of area (urban and inter-urban) for several countries. In line with the IMPACT study, we use the German functions developed by FGSV (1997) for computing time losses and the deadweight loss from the TRANS-TOOLS inter-urban road database. For urban areas generalised speed-flow functions are derived from model applications from literature. A summary of current findings is compiled in IMPACT D1.

Price elasticity of demand

Besides the value of time, the possible user reactions on introducing internalisation charges determine the level of the optimal external congestion costs and the thus the deadweight loss. In compliance with common practice we use a value of - 0.3 in passenger transport and - 0.5 in road haulage. These reflect short-term elasticities; in the long-term price elasticity values are commonly higher.

3.5.5 Marginal cost methodology

Marginal costs are commonly used for setting pricing signals. Thus we consider the correct charge level for internalisation of congestion costs, i.e. the marginal external congestion costs at the optimal demand level. These costs are computed using speed flow functions, values of travel time and fuel consumption rates by road class and traffic level. A starting point is given by the recommended values for congested situations given by the IMPACT Handbook (CE/INFRAS/ISI, 2008a).

Given the strong non-linearity of speed-flow-relationships marginal costs functions rather than single point estimates are presented for external congestion costs. Their slope and uncertainty ranges are discussed for different road types and traffic situations.

3.6 Other external costs

3.6.1 Up- and downstream processes

General approach and overview of cost estimation

Transport activities do not only directly cause negative effects but also indirectly. The most important indirect effect of transport includes the well-to-tank emissions, i.e. the emissions due to production and distribution of fuel and electricity. According to a life cycle view, the negative effects of these up- and downstream processes should be included, too. There are three main categories of up- and downstream processes related to transport activities:

1. **Energy production and distribution (well-to-tank):** Fuel and electricity production causes emissions of pollutants due to extraction of raw materials, transport of the fuels and transmission of electricity. These so-called 'well-to-tank' emissions lead to external effects, mainly air pollution costs (health effects, etc.) and climate change costs.
2. **Vehicle production, maintenance and disposal:** The manufacturing, maintenance and disposal of transport vehicles is energy and material intensive and therefore leads to external costs, above all climate change and air pollution costs.
3. **Infrastructure production, maintenance and disposal:** As for vehicles, the manufacturing, maintenance and disposal of transport infrastructure leads to negative external effects. The most important effect relates to the land use of transport infrastructure and the following costs of nature and landscape.

Cost elements and valuation factors

Although the above-mentioned negative external costs refer to other effects already considered within other chapters of this report (esp. air pollution and climate change), it is useful to treat the up- and downstream effects separately, in order to increase transparency. The following cost elements will be considered in the present study:

1. Energy production and distribution:

- Air pollution costs due to well-to-tank emissions of air pollutants (PM_{10}, $PM_{2.5}$, NO_x , SO_2, NMVOC).
- Climate change costs due to well-to-tank emissions of greenhouse gases (CO_2, N_2O, CH_4).
- Different risks due to energy production and distribution: e.g. nuclear power risks of electricity production for (rail) transport, or the risk of oil spills due to the extraction of raw oil for transport fuel production.

-> The production and distribution of all energy sources are associated with risks that can lead to considerable external costs. Some of the very famous and high risks are the risk of nuclear power accidents (e.g. maximum credible accident, MCA) and the risk of oil spills due to deep sea drilling of oil. Both of them have recently proved to be latent risks with a very high disaster potential (Deepwater Horizon disaster in the Gulf of Mexico in 2010; disaster in the nuclear power plant of Fukushima in March 2011). Both incidents showed that there are considerable external costs associated with those technologies. However, there are no recent and valid cost factors available for both of the risks[14]. A new in-depth study based on the new experience would have to be carried out.

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[14] In the previous UIC study (INFRAS, IWW, 2004), a shadow price for nuclear risk of € 0.035 per kWh has been used. However, this value is based on very old studies in the 80's/90's and therefore no longer appropriate. New studies based on recent incidents need to be conducted to derive shadow prices that are more up-to-date.

-> *Hence, due to the lack of such data/information, the external costs of risk due to energy production and distribution are not included in this study.*

2. Vehicles and infrastructure (production, maintenance & disposal):
The up- and downstream effects of transport vehicles and infrastructure also lead to the emission of air pollutants and greenhouse gases and therefore to external costs.
-> However, the costs of those effects (infrastructure and vehicle production, maintenance and use) are not included in the calculation due to a) high uncertainty, b) the lack of data and c) the different dimension of these costs.
Differently to the cost of energy production and use, the effects of vehicle and infrastructure production and maintenance are not directly related to the use of vehicle. Therefore, the inclusion of these effects would broaden the scope. Concerning data availability, LCA inventory data for infrastructure related emissions of GHG and air pollutants are only available for Switzerland and Germany. Swiss Infrastructure impacts are presumably not representative for the rest of Europe since the share of bridges and tunnels is considerably higher. For Germany only very limited data is available for High Speed Infrastructure. -> *Therefore, these costs are not included in this study.*

The relevance of vehicles and infrastructure production, maintenance and disposal for the total ecologic footprint of transport services has been subject of different studies. Only very few studies, however, have calculated the external cost of vehicle and transport infrastructure. According to a Swiss study (Ecoplan/INFRAS, 2008), the external costs of vehicle and infrastructure for road transport account for 50% of the total up- and downstream costs (the other 50% are due to energy production and distribution). For rail transport, however, the vehicle and infrastructure costs are responsible for more than 80% of the up- and downstream costs. This is mainly due to the fact that the external cost of rail electricity production are very low in Switzerland, thanks to the high share of water based electricity. In other European countries, the share of infrastructure on total up- and downstream cost of rail will therefore be considerably lower than in Switzerland.

A recent UIC study investigated the carbon footprint of high speed railway infrastructure (UIC, 2009). It showed that rail transport infrastructure contributes to about 14% (Germany) to 23% (Switzerland) of the total rail energy demand (the rest is used in operation). Looking at the total CO_2 emissions, the results are completely different, due to the different energy production mix. In Switzerland, 94% of the total CO_2 emissions of rail transport are due to infrastructure, whereas in Germany the share of infrastructure is only 25% due to the high proportion of precombustion emissions for electricity production.

For road transport the energy demand of infrastructure accounts for about 13% (Switzerland) to 35% (USA). Another recent US study analysing the importance of infrastructure and vehicle operation and maintenance (Chester, Horvath 2009) showed results that were in the same range.

Due to the reasons described above, the calculation of external costs of up- and downstream processes in this study only includes the costs due to the emission of air pollutants and greenhouse gases due to energy production and distribution (so-called precombustion processes or well-to-tank emissions).

The calculation of external costs of up- and downstream processes is done the same way for all effects: emission data (air pollutants, greenhouse gases) are multiplied with cost factors (shadow prices) per pollutant for air pollution costs and climate change costs. Hence, the methodology is the same as described in the air pollution (Paragraph 3.1.1) and the climate change chapter (Paragraph 3.3). Accordingly, the cost factors for up- and downstream emission of air pollutants are the same as described in Table 7. Equally, the cost factors for climate change costs due to up- and downstream emissions are also the same as in the corresponding chapter.

There is one case where other cost factors need to be applied: For the emission of particulate matter (PM) the cost factors used in the air pollution chapter (Paragraph 3.1.1) are not appropriate since they are specifically for transport emissions. Since up- and downstream emissions have different sources (e.g. emission from oil drilling and refinery or electricity generation), general cost factors for PM emissions need to be applied. Therefore, the more general NEEDS values are applied for the up- and downstream emission of PM (NEEDS, 2007).

Data situation

The following sources are taken for emission data:

- Pre-combustion emission of air pollutants and greenhouse gases (well-to-tank emissions): data from TREMOVE database for well-to-tank emissions with base year 2008 (TREMOVE, 2010). TREMOVE also formed the basis for direct emission data for calculating air pollution and climate change costs.
- The electricity mix of railways is based on official UIC data, published in the EcoPassenger report from IFEU (IFEU, 2010). Data are shown in Annex A.

As described above, the monetary values (cost factors) are based on the values used for air pollution and climate change costs.

3.6.2 Costs for nature and landscape

General approach and overview of cost estimation

Transport infrastructure has negative effects for nature and landscape. It leads to sealed areas and as a consequence to the loss of natural ecosystems. The sealing of ecosystems results in the loss of natural habitats on the one hand, and in habitat fragmentation on the other hand. All this leads to a biodiversity loss.

Please note that this cost category only includes biodiversity losses due to habitat loss and fragmentation (change in land use), whereas biodiversity losses due to air pollution are calculated separately and covered in the air pollution chapter (Paragraph 3.2).

As there is no methodology for calculating the damage costs, a repair cost approach is chosen in this study. It is the same approach as chosen in the last UIC study (INFRAS/IWW, 2004). As in the last study, only the transport infrastructure built after 1950 is looked as responsible for damage to nature and landscape.

Cost elements and valuation factors

There are two cost elements calculated within this study:

- Unsealing costs: To repair and compensate the damages of transport infrastructure to nature and landscape, the area of transport infrastructure has to be unsealed.

– Restoration costs of target biotopes/ecosystems: After the unsealing process the initial ecosystems are not repaired properly. The area has to be restored in a way that the initial ecosystem (biotope) is re-installed.

The cost factor for unsealing costs is based on the last UIC study (INFRAS/IWW, 2004) and updated to 2008 by using the price development between 2004 and 2008 (consumer price index). The base value for Germany is € 27.2 per m^2. The German cost factor is transferred to other countries by using the GDP per capita (PPP adjusted). The unsealing costs are only accounted for the sealed area of transport infrastructure.

The cost factor for restoration costs is based on the recent European research project NEEDS (NEEDS, 2006), where the average restoration costs of different ecosystems are given for all European countries in € per m^2 for 2004. From this study, the country average value has been taken. For EU-25, the average restoration costs are € 1.52 per m^2. The restoration costs are accounted for the sealed area of transport infrastructure and the so-called additional impaired area along transport infrastructure. For the additional impaired area, the same data are used than in the last UIC study (INFRAS/IWW, 2004)[15].
The allocation of the costs per transport mode to the vehicle categories (e.g. for road transport) is based on the transport mileage per vehicle category (vehicle-km, train-km). For road transport, the mileage data are weighted with the passenger car unit (PCU)[16], taking into account the different infrastructure use of the vehicles.

Data situation

For the estimation of the costs of nature and landscape data on the area (length, width) of the road, rail and air transport infrastructure is needed. The respective data sources and input data are presented in the Annex.
The sealed area of road, rail and inland waterways infrastructure is calculated on the basis of the infrastructure length and assumptions about the average width of the different infrastructure types[17]. The sealed area of airports is calculated on the basis of the number of airports (differentiated by their capacity) and the average sealed area by airports of different sizes. The share of infrastructure built after 1950 is based on the same assumptions as in INFRAS/IWW, 2004[18].

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15 Additional impaired area: 5-15 m along roads (motorways: 15 m; highways: 8 m; secondary and other roads: 5 m), 5 m along railway lines, 40 meters along channels; 25-50 m along airports.

16 PCU: passenger cars: 1.0; buses/coaches: 2.5; motorcycles: 0.5, LDV: 1.5; HDV: 2.5.

17 The following average infrastructure width/area have been used:
Road: motorways: 23 m; national roads/highways: 7 m; regional/secondary roads: 5.7 m; other roads: 4.4 m.
Rail: single tracks: 7 m; double or more tracks: 13 m.
Air: international airports: 3.0 km^2; regional airports: 0.8 km^2.
Inland waterways: 10 m for channels.

18 Road: Motorways: 100% are assumed to be built before 1950; for all other roads: 30%.
Rail: 10% of the total rail network is assumed to have negative effects to nature and landscape.

3.6.3 Additional costs in urban areas

General approach and overview of Cost estimation

In urban areas motorised traffic has different effects on non-motorised traffic participants (pedestrians, cyclists, etc.). In several previous studies (INFRAS/IWW, 2004; INFRAS, 2006; Ecoplan/INFRAS, 2008) the following two effects have been quantified:

1. **Time losses for pedestrians due to separation effects:** Road and rail transport infrastructure in urban areas lead to separation effects for non-motorised traffic. When crossing road and rail infrastructure, pedestrians have to wait (at traffic lights, crossings or railway crossing gates) and therefore lose time. These time losses can be regarded as external costs.
2. **Scarcity problems** (expressed as the loss of space availability for bicycles): Above all at large roads, there is limited space available for bicycles. To give bicycles the space they need, separate bike lanes or even bike paths would have to be built. As long as these scarcity effects are not solved, it can be seen as external costs due to motorised road transport.

Another possible effect (urban visual intrusion due to transport volume and infrastructure) is very difficult to measure and no reliable estimates are available.

Since the quantification of scarcity problems has a very small relevance, is rather difficult and highly uncertain, we *focus on time losses due to separation effects of pedestrians*. The omission of the scarcity effects has only a minor effect on the results, since recent studies showed that the external costs due to scarcity problems are only of little importance (less than 2% of total cost in urban areas, according to the latest Swiss study, Ecoplan/INFRAS, 2008).

Cost elements and valuation factors

The estimates for calculating separation effects in urban areas are based on a detailed calculation for Swiss cities (Ecoplan/INFRAS, 2008), where the time loss has been quantified for road and rail infrastructure. The data are based on a pilot survey for Zurich, where the levels and crossings are measured in detail. From this survey, the number of road and rail crossings per person and day is known (differentiated by road and rail type: breadth, number of lanes/tracks). Additionally, the average time loss per crossing is known, too.

At the end, the average cost per person (urban population) in a city can be calculated. This value can then be transferred to other cities by multiplying the cost factor with the number of urban population. However, only big cities with more than 50,000 inhabitants are included, since the time losses are hardly relevant in smaller cities.

The methodology applied is the same for road and rail transport. For the present study, the resulting values for Switzerland have been cross-checked with an older European study (EUROMOS: European Road Mobility Studies), where data for some other European cities (Munich, Southampton, Madrid) were available. The cost factors of that older study are similar. The latest values from Switzerland are slightly lower, which is a result of the lower time cost value used. Recent research revealed that time cost factors are lower than expected in the nineties (König et al., 2004)[19].

[19] In the Swiss study (INFRAS/Ecoplan, 2008) a time value of 7 EUR(2005) per hour was used for pedestrians. This value represents a lower value of time, e.g. for leisure activities, based on König et al., 2004.

Table 13 shows the cost factors resulting from the above-mentioned Swiss study (Ecoplan/INFRAS, 2008). For other countries, the 2005 data from Switzerland are transferred by using the GDP per capita PPS (power purchase standard). Afterwards, the values are transferred to 2008 according to the GDP per capita development of the individual countries. The data correspond to the values recommended in IMPACT (CE/INFRAS/ISI, 2008a).

Table 13 Cost factor: Separation costs per inhabitant (in urban areas), values for Switzerland

	CHF2005 CHF/(person*year)	€2005 EUR/(person*year)	€2008 EUR/(person*year)
Road	62.8	40.6	**43.8**
Rail	16.7	10.8	**11.6**

Source: Ecoplan/Infras, 2008.

Data situation

The origin of the cost data is described above. The other input needed is the number of inhabitants in cities. These data can either be gained directly from population data of all cities in the corresponding countries (> 50,000 inhabitants) or by taking the share of urban population from national or European statistics. Until now, the data have not been gathered yet. However, one of the two types of data should be available.

3.6.4 Soil and water pollution

General approach and overview of Cost estimation

Transport may have adverse impacts on the soil and water quality near transport infrastructure. The most important negative effects come from the emission of heavy metals and polycyclic aromatic hydrocarbons (PAH), which may result in costs like plant damage, decreased soil fertility, pollution of drinking water (which poses a threat to human health), wildlife habitat damages, etc. The relationship between infrastructure use and soil and water pollution is quite complicated and hence damage costs are difficult to estimate. Therefore we will use a second best approach to estimate the effects of soil and water pollution, based on the repair cost approach. This approach requires two steps:

1. Estimating the total land volume harmed by the water and soil pollution. We assume that the area harmed by these kinds of pollutions is equal to the area needed for the transport infrastructure and 5 m on both sides of the infrastructure. The way the area needed for transport infrastructure is estimated is explained in Paragraph 3.6.2 (nature and landscape). By assuming that the depth of pollution is 20 cm, the total soil volume harmed can be calculated.
2. Estimation of the costs of soil and water pollution by multiplying the total land area harmed by an external cost factor expressed in €/m^3. In the next section this cost factor will be further discussed.

The costs of water and soil pollution will only be estimated for road and rail transport. For aviation these costs are negligible, while for shipping not enough data is available.

Cost elements and valuation factors

As mentioned before, the repair cost approach has been applied to estimate the costs of soil and water pollution. The single pollutants are considered jointly be applying a decontamination cost value per m^3. CE/INFRAS/ISI (2008a) recommend to use the decontamination cost value from INFRAS (2006) for Switzerland (€ 60 per m^3, price level 2008)[20]. To transfer this value to other countries an adaptation is needed based on differences between countries in GDP/capita PPP. Notice that the uncertainty in the 'national' repair cost rates is quite large due to the fact that national and local specifications are not taken into account.

Data situation

For the estimation of the water and soil pollution costs data on the total emissions of heavy metals and polycyclic aromatic hydrocarbons (PAH) are needed. The total emissions are calculated on the basis of emission factors per vehicle category multiplied by the corresponding mileage data. The emission factors are taken from the Ecoinvent database (Ecoinvent, 2010).

3.6.5 Cost of energy dependency (or security of energy supply)

The unequal distribution of mineral oil in the different world regions leads to another category of external costs of transport which arise through the high dependency on oil producing countries (mostly organised within the OPEC cartel). A number of studies have assessed the economic costs of oil dependency (i.e. in percent of GDP) but only few studies assess the external costs of oil dependency with a direct link to transport costs.

The two major costs mentioned are economic losses as a result of oil prices above a competitive market level (due to market power of the oil suppliers) and costs of oil supply disruptions.

The IMPACT Handbook (CE/INFRAS/ISI, 2008a) contains a brief assessment of studies on this issue. It concluded that most of the studies on the costs of energy dependence are US studies on the costs of US oil imports and can thus only be used as indicative values for European countries. The estimates from these studies as presented in IMPACT range from 0.2 to 14 US Dollar per barrel (or 0.2 to 11 €cents per litre of mineral oil).

The subject of oil dependency receives increasing attention. Therefore, an in-depth study on the issue of related external costs is recommended as subject for further study.

[20] We assume that this decontamination cost value also includes the costs related to water pollution.

4 Results: Total and Average Costs

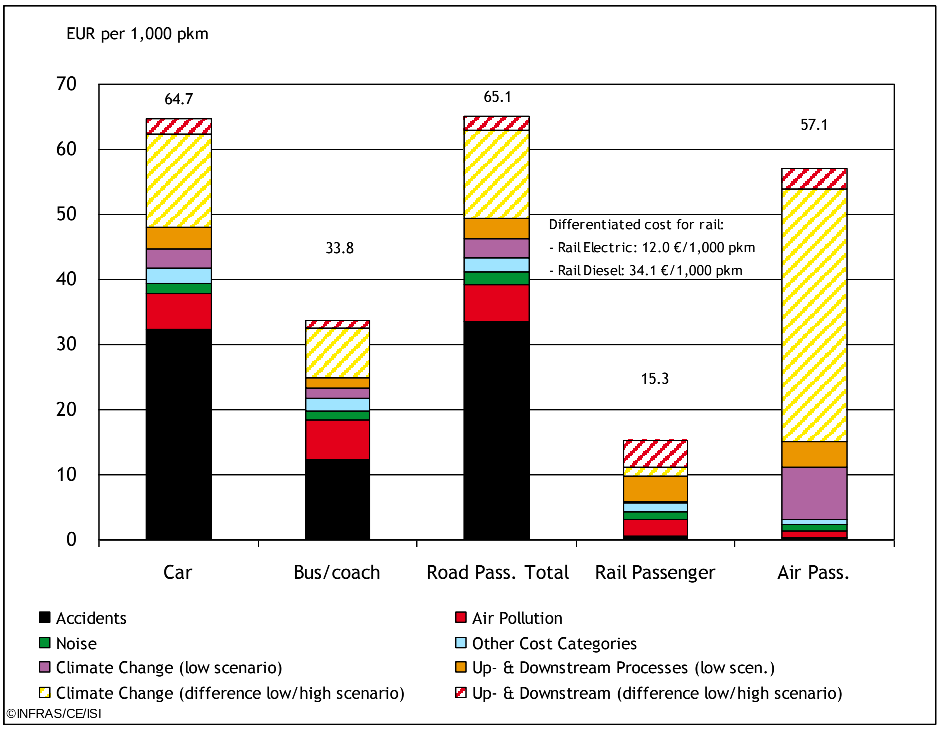
4.1 Overview: Total and average costs 2008

This chapter contains the overall results on average and total external costs. First, the average external costs per passenger-km and freight-km are presented. The average cost data allow an intermodal comparison. Afterwards, the total costs of transport are shown. All figures (sums) in this chapter reflect the high scenario for climate change (i.e. cost factor of € 146 per tonne of CO_2). All cost data are given in $€_{2008}$.

4.1.1 Average external costs

The average external costs of transport are expressed in Euro per 1,000 passenger-km and tonne-km. Looking at passenger transport (see Figure 17), passenger cars cause external costs of € 65 per 1,000 pkm (corresponding to 6.5 €cent per pkm). The average costs of passenger rail transport amount to € 15.3 per 1,000 pkm, which is 4.2 times lower than the costs for the road sector. The average costs of air transport are around € 57 per 1,000 pkm, which is 3.7 times higher than the rail costs. The air transport data only include continental flights within the EU, to ensure the comparability of the different transport means. For road transport, the predominant cost categories are accidents and emissions (climate change, air pollution and upstream). For air transport, climate change costs are the main category.

Figure 17 Average external costs 2008 for EU-27*: passenger transport (excluding congestion)



Other cost categories: Costs for nature & landscape, biodiversity losses (due to air pollution), soil and water pollution costs, additional costs in urban areas. Data do not include congestion costs.

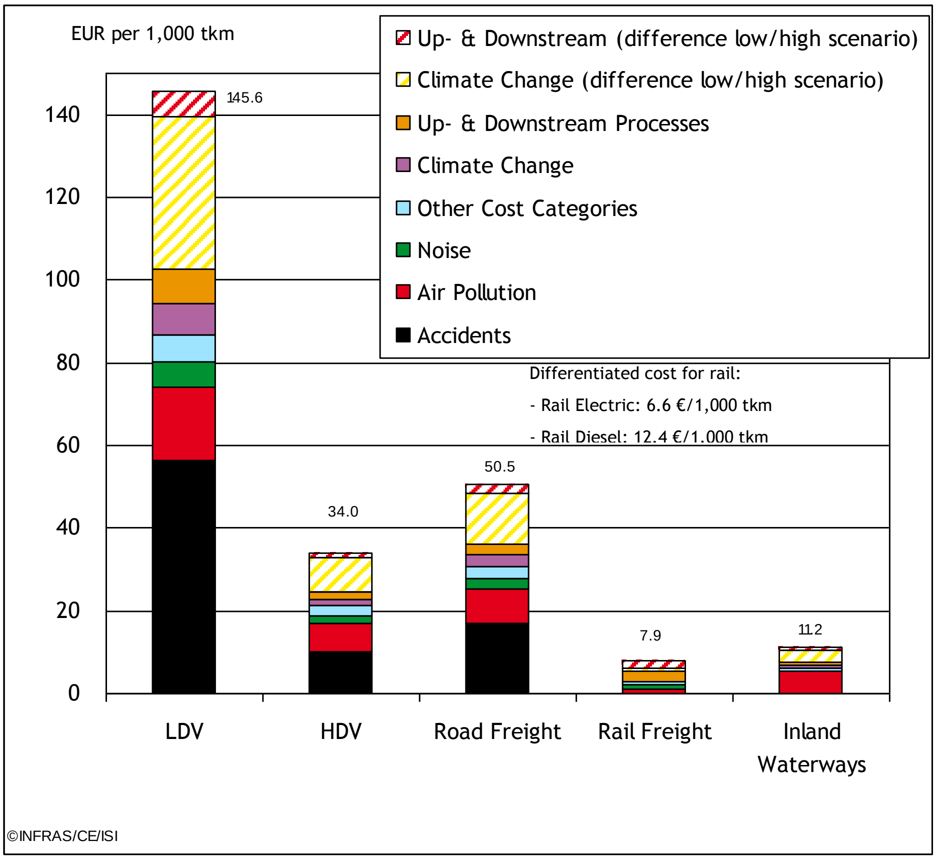
* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Road Pass. Total is the weighted average of all road passenger modes (car 87&, bus 10%, MC 3% of total pkm).

Average costs for rail transport differ a lot between electric trains and diesel trains. Due to significantly higher climate change and air pollution costs, the average costs of diesel trains are € 34 per 1,000 pkm, whereas the costs of electric trains only amount to € 12 per 1,000 pkm. A second reason for this difference (apart from the higher emission factors) is the fact that passenger diesel trains have lower load factors (number of passengers per vehicle) than electric trains.

For freight transport (see Figure 18 and Figure 19), the average costs are also lowest for rail transport (€ 7.9 per 1,000 tkm). The costs for inland waterways are slightly higher (€ 11.2 per 1,000 tkm) which is 1.4 times more than for rail. The average costs for road transport are € 50 per 1,000 tonne-km, which is 6.4 times higher than for rail. The average costs for HDV (heavy duty vehicles) amount to € 34.0, for LDV (light duty vehicles) to € 146 per 1,000 tkm. Therefore, the average costs of HDV are 4.3 times higher than for rail freight transport. For air freight transport, no external costs have been calculated due to lack of data.

Also for rail freight transport, average costs of diesel trains (12.4 €/1,000 tkm) are much higher than for electric trains (6.6 €/1,000 tkm), due to higher emissions of greenhouse gases and air pollutants.

Figure 18 Average external costs 2008 for EU-27*: freight transport (all freight modes; excluding congestion)

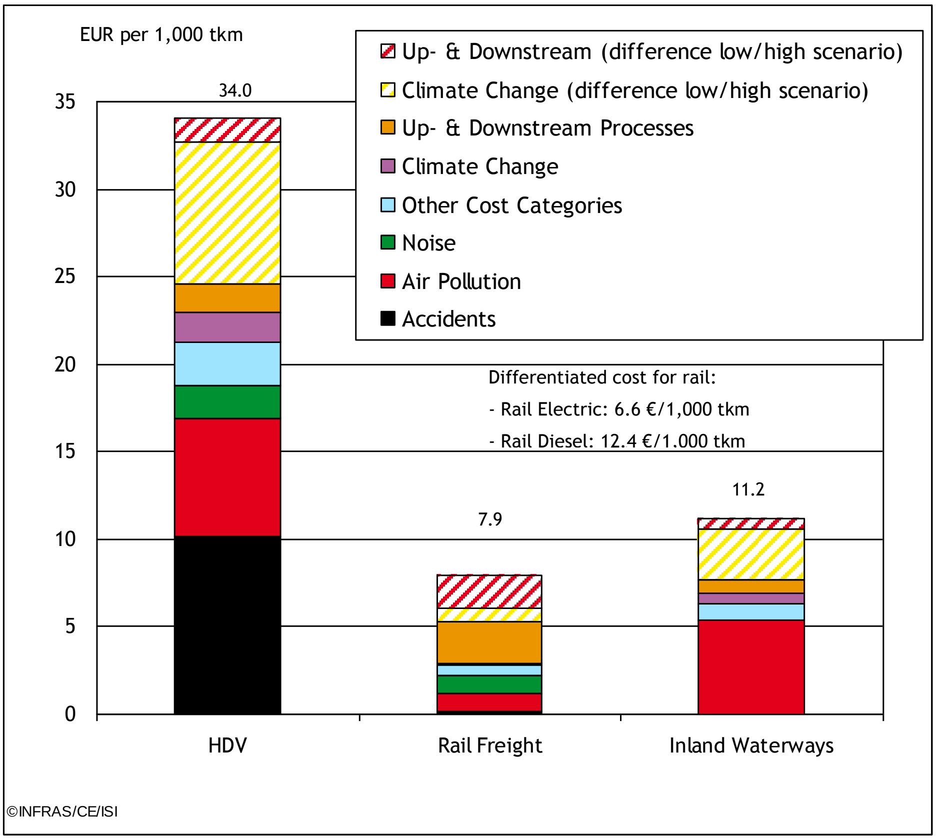


Other cost categories: Costs for nature & landscape, biodiversity losses (due to air pollution), soil and water pollution costs, additional costs in urban areas. Data do not include congestion costs.

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

Road Freight Total is the weighted average of all road freight transport modes (HDV 85&, LDV 15% of total tkm).

Figure 19 **Average external costs 2008 for EU-27*: freight transport (heavy freight transport; excluding congestion)**



Other cost categories: Costs for nature & landscape, biodiversity losses (due to air pollution), soil and water pollution costs, additional costs in urban areas. Data do not include congestion costs.

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

Table 14 below shows all average external costs by cost category and transport mode in detail.

Table 14 Average external costs 2008 for EU-27* by cost category and transport mode (excluding congestion)

	Average Costs per Cost Category												
	Passenger Transport							Freight Transport					
	Road				Rail	Aviation	Total	Road			Rail	Waterborne	Total
	Passenger cars	Buses & coaches	Motorcycles & mopeds	Total road passenger transport	Passenger transport	Passenger transport (cont.)		LDV	HDV	Total road freight transport	Freight transport	Freight transport	
Cost Category	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)
Accidents	32.3	12.3	156.6	33.6	0.6	0.5	29.0	56.2	10.2	17.0	0.2	0.0	13.4
Air pollution	5.5	6.0	11.8	5.7	2.6	0.9	5.2	17.9	6.7	8.4	1.1	5.4	7.1
Climate change high scenario	17.3	9.1	11.1	16.3	1.5	46.9	17.6	44.5	9.8	14.9	0.9	3.6	12.1
Climate change low scenario	*3.0*	*1.6*	*1.9*	*2.8*	*0.3*	*8.0*	*3.0*	*7.6*	*1.7*	*2.6*	*0.2*	*0.6*	*2.1*
Noise	1.7	1.6	14.4	2.0	1.2	1.0	1.9	6.3	1.8	2.5	1.0	0.0	2.1
Up- and downstream high scenario	5.7	2.8	3.6	5.4	8.1	7.1	5.7	14.3	3.0	4.7	4.2	1.3	4.4
Up- and downstream low scenario	*3.4*	*1.5*	*2.3*	*3.2*	*3.9*	*3.9*	*3.3*	*8.4*	*1.7*	*2.7*	*2.4*	*0.8*	*2.5*
Nature & landscape	0.6	0.3	0.5	0.6	0.2	0.6	0.6	0.9	0.7	0.7	0.0	0.4	0.6
Biodiversity losses	0.2	0.4	0.1	0.2	0.0	0.1	0.2	0.6	0.5	0.5	0.0	0.5	0.4
Soil & water pollution	0.3	0.9	0.3	0.4	0.5	0.0	0.4	1.8	0.8	1.0	0.4	0.0	0.8
Urban effects	1.0	0.4	0.8	0.9	0.6	0.0	0.8	3.1	0.5	0.9	0.1	0.0	0.7
Total (high scenario)	**64.7**	**33.8**	**199.2**	**65.1**	**15.3**	**57.1**	**61.3**	**145.6**	**34.0**	**50.5**	**7.9**	**11.2**	**41.7**
Total (low scenario)	*48.1*	*24.9*	*188.7*	*49.4*	*9.8*	*15.0*	*44.3*	*102.8*	*24.6*	*36.1*	*5.3*	*7.7*	*29.7*

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs.

Table 15 **Average external costs 2008 for EU-27* by cost category and transport mode: detailed results for rail transport (electric vs. diesel trains; excluding congestion)**

	Average Costs per Cost Category for rail transport					
	Rail Passenger			Rail Freight		
	Electric	**Diesel**	**Total Rail Passenger**	**Electric**	**Diesel**	**Total Rail Freight**
Cost Category	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 pkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)	€/(1,000 tkm*a)
Accidents	0.6	0.6	0.6	0.2	0.2	0.2
Air pollution	1.8	7.6	2.6	0.9	1.7	1.1
Climate change high scenario	0.0	10.4	1.5	0.0	3.9	0.9
Climate change low scenario	0.0	1.8	0.3	0.0	0.7	0.2
Noise	1.2	1.2	1.2	1.0	1.0	1.0
Up- & downstream high scenario	7.2	13.1	8.1	4.0	5.1	4.2
Up- & downstream low scenario	2.7	11.4	3.9	1.7	4.4	2.4
Nature & landscape	0.2	0.2	0.2	0.0	0.0	0.0
Biodiversity losses	0.0	0.0	0.0	0.0	0.0	0.0
Soil & Water pollution	0.5	0.5	0.5	0.4	0.4	0.4
Urban effects	0.6	0.6	0.6	0.1	0.1	0.1
Total (high scenario)	**12.0**	**34.1**	**15.3**	**6.6**	**12.4**	**7.9**
Total (low scenario)	*7.4*	*23.8*	*9.8*	*4.3*	*8.5*	*5.3*

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs.

Comparison to previous UIC study (INFRAS/IWW, 2004)

Comparing the average external costs of the present study to the previous UIC study (INFRAS/IWW, 2004), the results are similar. For passenger transport, the average costs per 1,000 pkm are slightly lower in the present study. For freight transport, the difference is bigger. However, the changes apply for all transport modes: the average costs of all modes are lower than in the previous study (see Table 16).

The reason for these changes is described in detail in Paragraph 4.2 for each cost category separately. In short, there are different effects leading to this result. One important reason is the inclusion of Eastern European countries, which generally led to lower average costs due to lower cost factors in these countries (lower price and income level, lower health costs, lower willingness-to-pay due to lower GDP/capita). Other reasons are the decrease in emissions (e.g. of some air pollutants and greenhouse gases) in the last years for all transport modes, several changes in methodology and new data sources.

What has remained quite stable compared to the previous UIC study is the cost ratio between the different transport modes compared to rail. Figure 20 and Figure 21 show the development of these ratios between the last UIC study (INFRAS/IWW, 2004) and the present study. Compared to the previous study, the development of average costs of rail transport has been better than for all other modes. This leads to the fact that the ratios between other modes and rail became higher (i.e. more in favour of rail transport). For passenger transport, the ratio between average costs of road and rail increased from 3.3 in the previous study to 4.3. The air/rail ratio increased from 2.3 to 3.7. For freight transport the average cost ratio between road and rail increased from 4.9 to 6.4 in the present study. The water/rail ratio for freight changed slightly from 1.3 to 1.4.

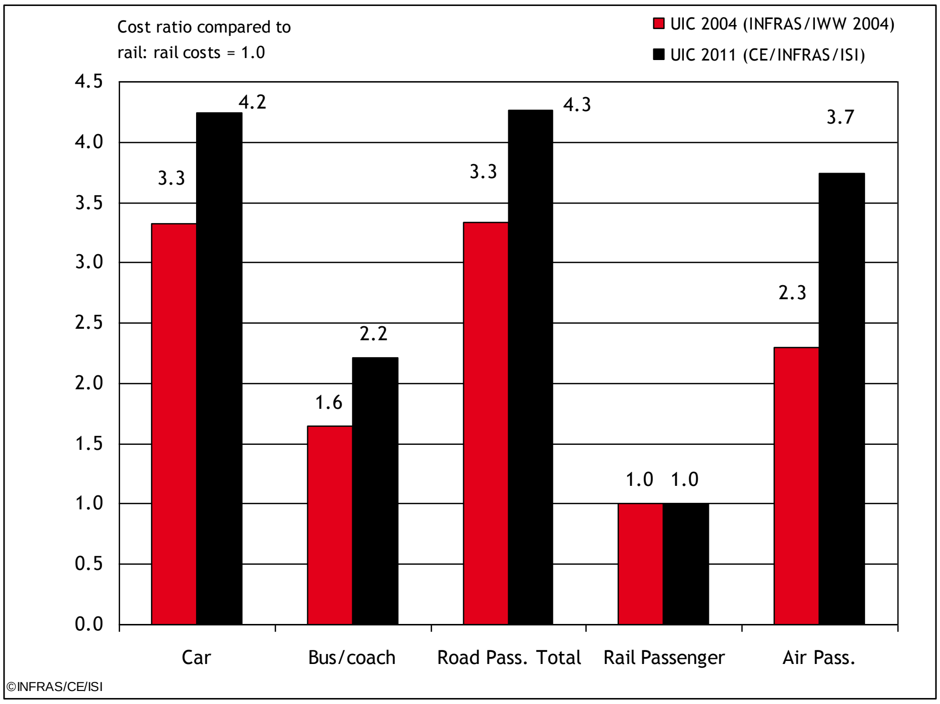
Table 16 Average cost per passenger- and tonne-km: comparison with previous UIC study (2004)

Transport	Transport mode	Present UIC study CE/INFRAS/ISI, 2011 (for 2008*)	Previous UIC study INFRAS/IWW, 2004 (for 2000*)
Passenger (€/1,000 pkm)	Passenger cars	64.7	76.0
	Buses and coaches	33.8	37.7
	Road passenger total	65.1	76.4
	Rail passenger	15.3	22.9
	Air passenger	57.1	52.5
Freight (€/1,000 tkm)	Road freight total	50.5	87.8
	HDV	34.0	71.2
	Rail freight	7.9	17.9
	Inland waterways	11.2	22.5

Data do not include congestion costs; using high estimate for climate costs.

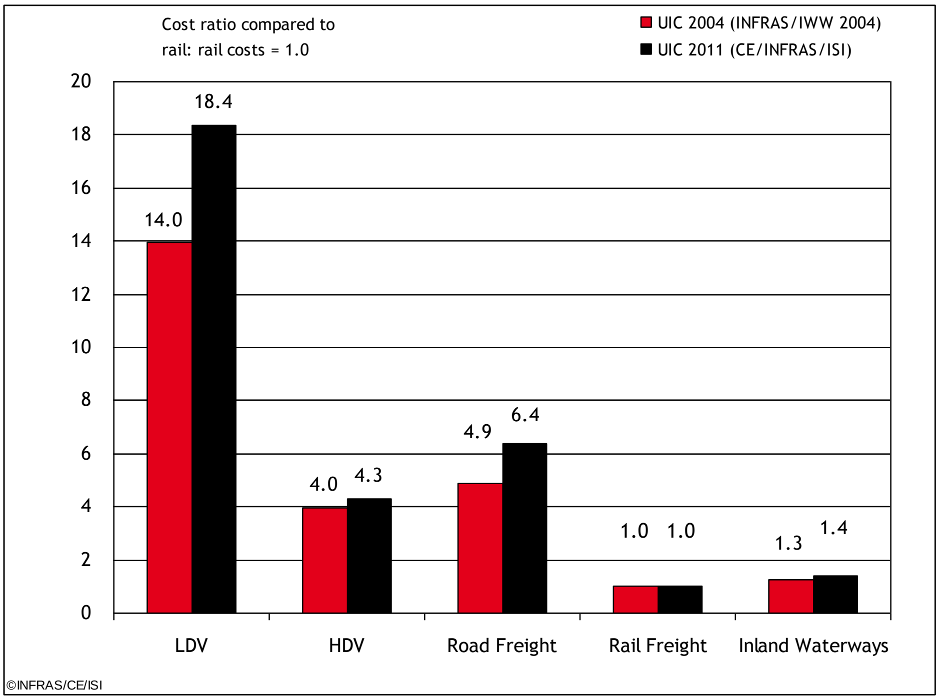
* Note that both reference year and price levels are different (2000 for the previous study and 2008 for this study)

Figure 20 **Average cost ratio compared to rail, present UIC study vs. previous study: passenger transport (excluding congestion)**



Data do not include congestion costs; using high estimate for climate costs.

Figure 21 **Average cost ratio compared to rail, present UIC study vs. previous study: freight transport (excluding congestion)**



Data do not include congestion costs; using high estimate for climate costs.

4.1.2 Total external costs

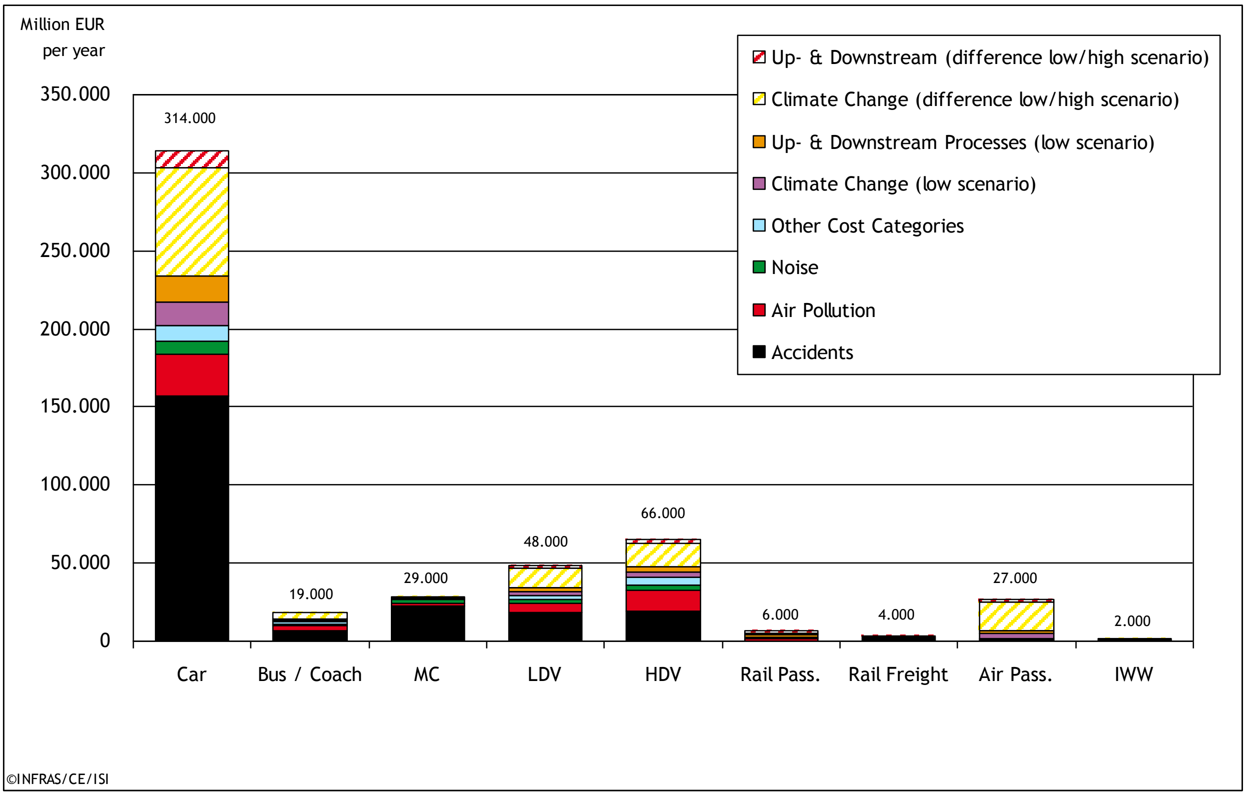
Figure 22 presents the total external costs of transport for EU-27 including Norway and Switzerland by transport mode and cost category. The total external costs (excluding congestion costs, with the high climate change scenario) amount to € 514 billion for 2008. This equals 4% of the total GDP in the same region.

The most important cost category is accident costs with 44% of the total costs (see Figure 24). Climate change costs (high scenario) contribute to 29% of the total costs, air pollution costs to 10% and up- and downstream effects due to energy production and distribution to slightly below 10% of the costs. Noise costs only accounts for 4% of the total costs. All other cost categories are of minor importance (≤ 1.5% of total costs).

Road transport is the predominant mode that causes by far most of the external costs (93% of the total costs). Air transport (only continental flights) are causing 5% of the costs, rail transport 2% and inland waterways 0.3% of the costs (see Figure 25). More than three-fourths of the total costs are due to passenger transport. Only 23% of the costs are caused by freight transport.

Total external costs per inhabitant in EU-27 is slightly higher than € 1,000 per year (for more details per country and mode see Table 19.

Figure 22 Total external costs 2008 for EU-27* (excluding congestion)



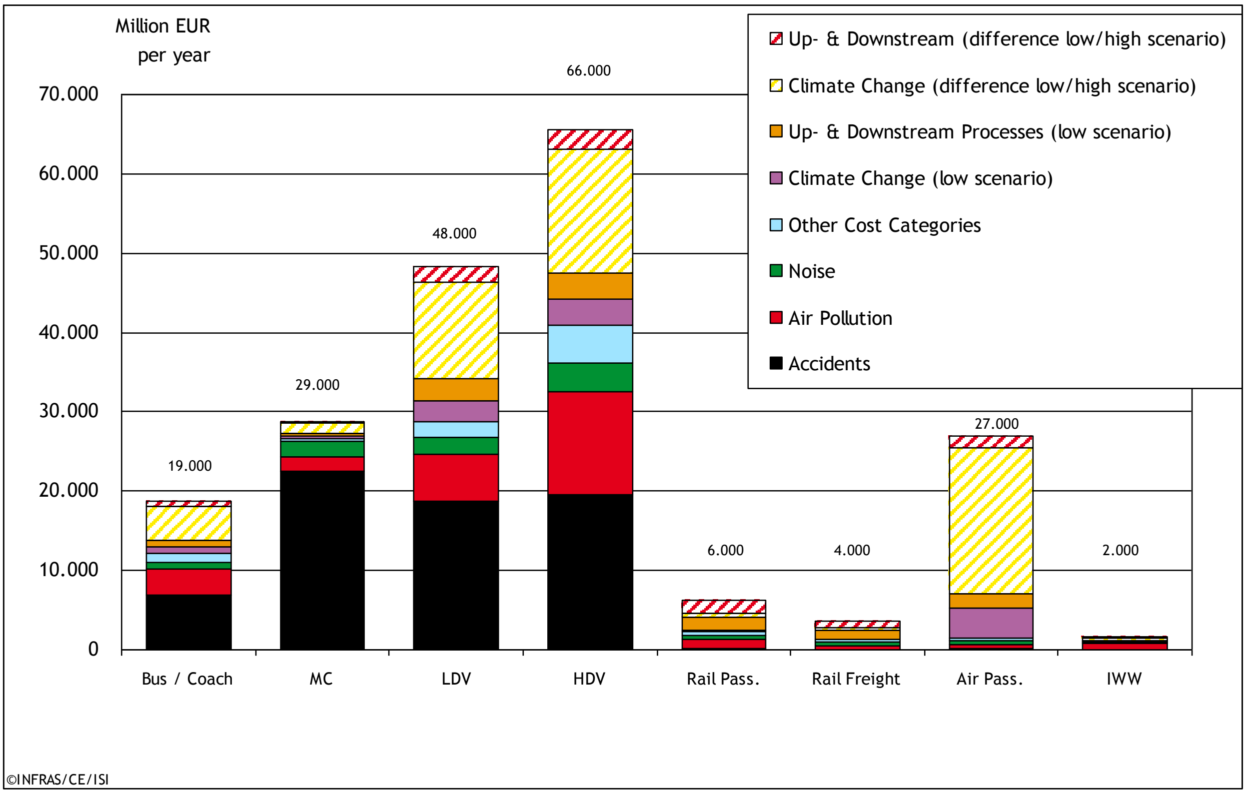
Other cost categories: Costs for nature and landscape, biodiversity losses (due to air pollution), soil and water pollution costs, additional costs in urban areas.
Data do not include congestion costs.

MC: Motorcycles, LDV: light duty vehicles, HDV: heavy duty vehicles, IWW: inland waterways.

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

Figure 23 shows the total costs without passenger cars, in order to enhance the visibility of the other transport modes.

Figure 23 Total external costs 2008 for EU-27*, without passenger car data (excluding congestion)

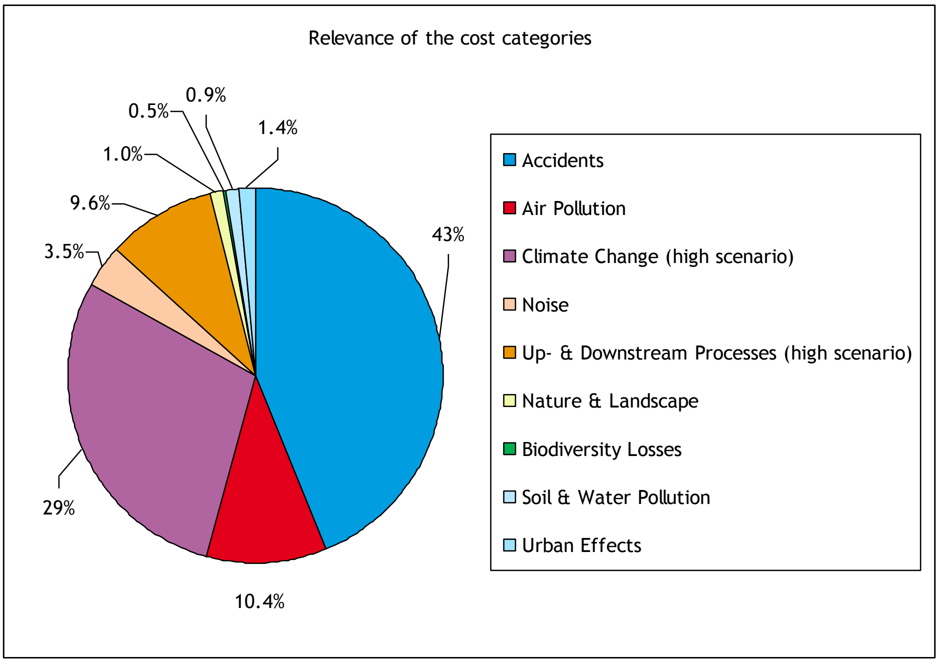


Other cost categories: Costs for nature and landscape, biodiversity losses (due to air pollution), soil and water pollution costs, additional costs in urban areas. Data do not include congestion costs.

MC: Motorcycles, LDV: light duty vehicles, HDV: heavy duty vehicles, IWW: inland waterways.

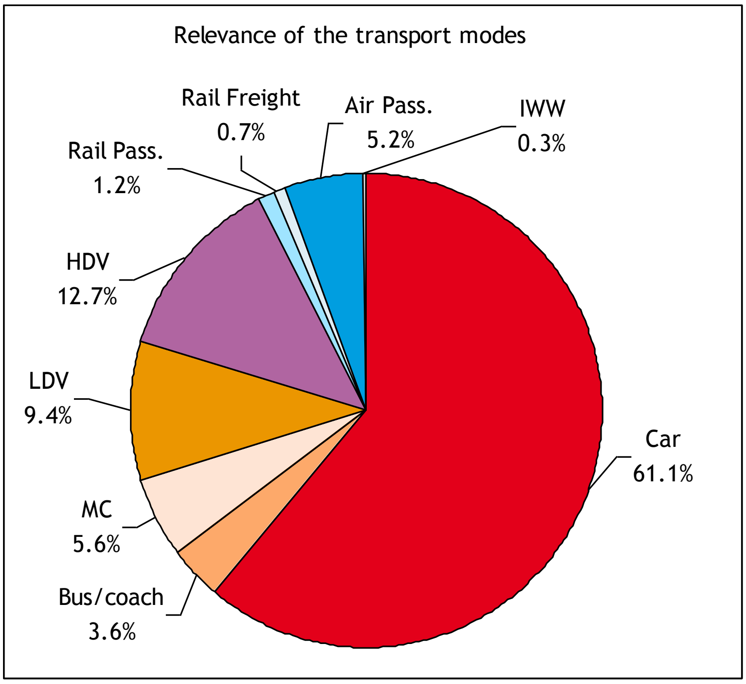
* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

Figure 24 Share of the different cost categories on total external costs 2008 for EU-27* (excluding congestion)



* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs; using high estimate for climate costs.

Figure 25 Share of the different transport modes on total external costs 2008 for EU-27* (excluding congestion)



* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs; using high estimate for climate costs.

Table 17 shows all average external costs by cost category and transport mode in detail.

In the subsequent Table 18, Table 19 and Figure 22 and Figure 23 the results per country are presented. It has to be noted that the accuracy level of the disaggregated results per country is in general considerably lower than on the aggregate EU level.

The results per country can differ due to many different reasons. Some of the most important reasons for different average costs are differences in:
- GDP per capita (PPP adjusted).
- Load factors (for all transport modes).
- Vehicle stock (share of efficient, low-emission vehicles).
- Share of diesel and electric trains.
- Electricity mix for rail.
- Population density (mainly for noise and air pollution cost).
- Accident risk.

Table 17 Total external costs 2008 for EU-27* by cost category and transport mode

Cost Category	Total Costs per Cost Category										
	Road							Rail		Aviation	Waterborne (freight)
	Passenger cars	Buses and coaches	Motorcycles & mopeds	LDV	HDV	Total road passenger transport	Total road freight transport	Passenger transport	Freight transport	Passenger transport (cont.)	Inland waterways
	Mio €/a	Mio €/a	Mio €/a	Mio €/a	Mio €/a	Mio €/a	Mio €/a	Mio €/a	Mio €/a	Mio €/a	Mio €/a
Accidents	157,105	6,839	22,584	18,677	19,604	186,528	38,282	238	71	223	0
Air pollution	26,636	3,347	1,696	5,933	12,995	31,678	18,928	1,092	483	426	782
Climate change high scen.	84,135	5,060	1,597	14,787	18,845	90,791	33,632	630	435	22,166	516
Climate change low scen.	*14,407*	*866*	*273*	*2,532*	*3,227*	*15,546*	*5,759*	*108*	*74*	*3,796*	*88*
Noise	8,201	865	2,076	2,094	3,537	11,143	5,631	477	476	457	0
Up- & downstream Processes high scenario	27,679	1,568	523	4,765	5,802	29,770	10,567	3,354	1,975	3,356	194
Up- & downstream Processes low scenario	*16,621*	*855*	*325*	*2,777*	*3,270*	*17,800*	*6,047*	*1,633*	*1,099*	*1,849*	*113*
Nature & landscape	3,008	149	75	284	1,293	3,232	1,577	75	21	296	64
Biodiversity losses	1,152	212	20	208	893	1,384	1,101	1	1	40	69
Soil & Water pollution	1,582	485	40	601	1,629	2,107	2,230	220	164	0	0
Urban effects	4,814	232	116	1,035	965	5,162	2,000	229	59	0	0
Total (high scenario)	**314,310**	**18,757**	**28,727**	**48,384**	**65,564**	**361,794**	**113,948**	**6,318**	**3,686**	**26,964**	**1,625**
Road congestion (delay costs): min.	98,416	4,836	2,439	13,827	26,695	105,691	40,522	:	:	:	:
Road congestion (delay costs): max.	161,331	7,729	3,841	27,633	42,660	172,901	70,293	:	:	:	:

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland; ":": not applicable. Total excluding congestion costs.

Table 18 Average external costs 2008 for EU-27* by country and transport mode (excluding congestion)

Average Costs per Country	Passenger Transport (€/1,000 pkm*a)							Freight Transport (€/1,000 tkm*a)					
	Road				Rail	Aviation	Total	Road			Rail	Waterborne	Total
Country	Passenger cars	Buses & coaches	Motorcycles & mopeds	Total road passenger	Passenger transport	Passenger (cont.)		LDV	HDV	Total road freight	Freight transport	Freight transport	
Austria	120.4	63.9	735.2	125.6	17.2	54.3	108.3	187.0	44.7	62.3	6.4	9.4	41.0
Belgium	77.9	24.7	327.0	73.2	11.1	53.6	67.8	251.5	38.2	58.8	6.7	13.5	44.7
Bulgaria	58.0	37.4	87.0	54.7	49.2	53.7	54.5	198.4	32.7	57.6	16.3	16.2	45.4
Czech Republic	60.1	22.2	90.4	55.2	36.1	52.9	53.9	126.0	39.8	51.8	8.5	15.8	42.8
Denmark	63.0	44.0	378.3	64.0	26.6	52.3	59.6	168.3	37.3	56.4	7.2	0.0	52.6
Estonia	35.2	16.8	58.9	32.5	44.4	54.1	34.0	75.4	22.6	28.5	6.1	0.0	19.1
Finland	59.4	32.3	345.5	59.5	8.5	54.2	56.5	126.3	29.7	41.1	4.6	15.9	32.5
France	56.3	31.9	329.0	58.7	6.9	63.0	53.9	114.5	37.3	58.2	7.1	12.3	50.7
Germany	85.3	48.0	347.2	87.0	21.5	59.0	80.7	175.5	35.4	52.9	9.3	10.5	39.3
Greece	37.7	17.6	106.2	40.8	27.7	54.5	42.1	170.8	32.1	51.5	13.4	0.0	50.6
Hungary	88.6	18.3	98.6	70.1	45.0	58.6	67.5	156.1	34.0	49.1	10.9	10.1	40.3
Ireland	27.3	36.6	248.9	30.0	23.4	50.8	34.1	115.0	42.2	54.7	32.1	0.0	54.6
Italy	47.7	31.1	158.6	50.4	11.3	59.5	48.9	247.9	26.1	45.8	5.2	24.1	41.4
Latvia	45.8	28.5	77.9	44.9	19.2	50.6	44.5	87.6	22.9	30.2	6.8	0.0	16.5
Lithuania	28.5	22.2	73.8	28.9	46.1	51.6	29.7	88.6	23.4	30.6	8.2	5.8	21.8
Luxembourg	114.8	56.4	980.8	118.2	29.5	56.7	109.2	102.3	30.0	37.4	19.3	15.7	36.3
Netherlands	72.4	29.8	944.6	74.2	11.6	53.5	67.4	159.1	42.0	60.3	7.9	12.1	42.7
Norway	64.6	47.0	170.7	65.7	10.5	62.1	63.2	108.8	34.9	44.5	4.7	0.0	39.3
Poland	45.6	29.6	66.7	45.0	18.9	53.3	43.8	73.1	33.5	38.8	10.4	10.5	32.7
Portugal	44.9	17.9	115.1	45.4	15.2	51.3	45.0	206.6	26.1	48.6	12.6	0.0	46.6
Romania	61.5	19.5	89.1	56.7	34.7	54.0	55.1	206.0	19.5	34.9	13.1	7.2	28.2
Slovakia	63.3	30.9	75.8	56.4	36.8	66.6	55.6	93.4	42.5	50.5	14.0	8.7	42.0
Slovenia	60.9	12.3	77.7	57.4	21.6	53.4	56.4	152.9	23.9	39.1	6.4	0.0	33.9
Spain	74.1	19.8	258.8	70.7	11.5	57.7	66.0	148.8	25.1	39.3	8.2	0.0	38.2
Sweden	62.8	36.7	474.0	63.8	8.9	56.3	60.0	116.4	24.0	32.8	2.6	0.0	22.8
Switzerland	74.6	34.9	234.9	76.8	7.5	57.9	64.4	201.6	57.9	74.9	4.2	10.1	46.6
UK	70.3	62.6	305.6	71.7	16.4	55.7	66.9	149.0	49.7	69.6	4.6	15.7	62.8
Total	**64.7**	**33.8**	**199.2**	**65.1**	**15.3**	**57.1**	**61.3**	**145.6**	**34.0**	**50.5**	**7.9**	**11.2**	**41.7**

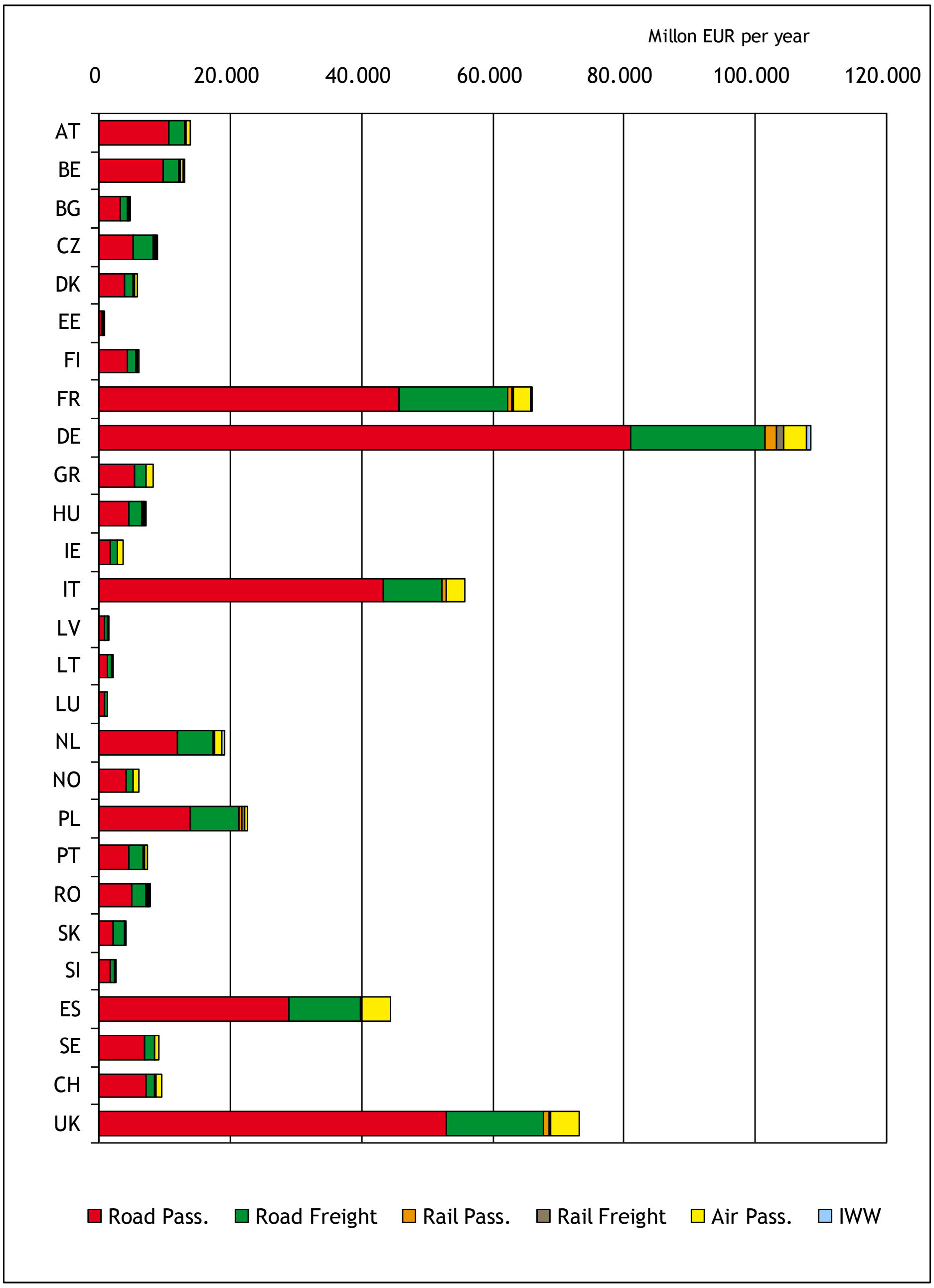
* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs; using high estimate for climate costs.

Table 19 **Total external costs per inhabitant and year (2008) for EU-27* by country and transport mode (excluding congestion)**

Country	Road		Rail		Aviation	Waterborne (freight)	Total
	Passenger	Freight	Passenger	Freight			
	€/inhab.	€/inhab.	€/inhab.	€/inhab.	€/inhab.	€/inhab.	€/inhab.
Austria	1,274	293	21	17	63	3	**1,671**
Belgium	913	234	11	5	45	11	**1,219**
Bulgaria	431	136	15	10	21	6	**619**
Czech Republic	498	295	23	13	29	0	**858**
Denmark	711	235	28	2	95	0	**1,071**
Estonia	323	176	9	27	34	0	**569**
Finland	804	272	7	9	67	0	**1,159**
France	716	257	10	5	41	2	**1,030**
Germany	984	251	20	13	43	8	**1,320**
Greece	489	154	4	1	82	0	**730**
Hungary	449	199	26	11	22	2	**710**
Ireland	388	262	10	1	178	0	**839**
Italy	726	151	9	2	45	0	**934**
Latvia	401	185	6	58	36	0	**687**
Lithuania	364	208	5	36	18	0	**632**
Luxembourg	1,882	809	21	11	93	12	**2,828**
Netherlands	725	341	11	3	56	33	**1,169**
Norway	881	223	6	4	169	0	**1,282**
Poland	368	194	9	14	12	0	**597**
Portugal	439	204	5	3	55	0	**707**
Romania	236	100	11	9	10	3	**369**
Slovakia	388	325	16	24	16	2	**770**
Slovenia	879	359	9	11	16	0	**1,273**
Spain	641	238	6	2	97	0	**983**
Sweden	751	167	7	7	76	0	**1,008**
Switzerland	935	182	18	7	116	0	**1,258**
UK	864	244	14	2	74	0	**1,198**
Total	**711**	**224**	**12**	**7**	**53**	**3**	**1,011**

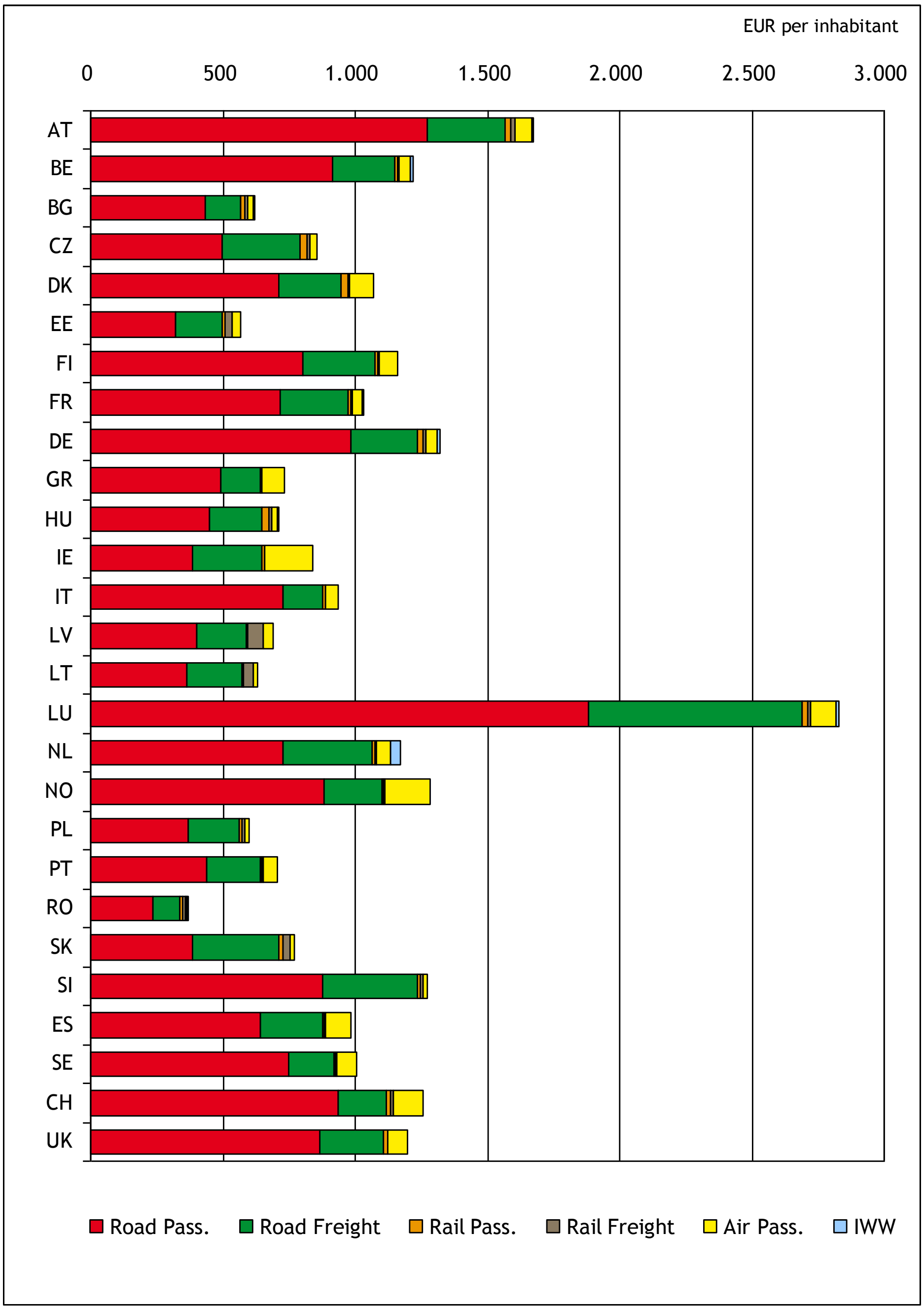
* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland. Data do not include congestion costs; using high estimate for climate costs.

Figure 26 Total external costs 2008 by country and transport mode (excluding congestion)



Data do not include congestion costs; using high estimate for climate costs.

Figure 27 Total external costs per inhabitant and year (2008) by country and transport mode (excluding congestion)



Data do not include congestion costs; using high estimate for climate costs.

4.2 Results 2008 per cost category

4.2.1 Accidents

Total external accident costs of transport in the EU-27, Norway and Switzerland in 2008 account for € 225 billion (see Table 20). More than 99% of the accident costs are caused by road transport. Passenger cars have with € 157 billion per year the largest share (70% of total accident costs). HDV, LDV and motorcycles each contribute to around 8-10% of the total accident costs. Rail (0.1%) and air transport (0.1%) only cause a minor part of the total external accident costs. The accident costs of rail passenger transport declined by around € 50 million between 2000 and 2008 for the EU-15, Norway and Switzerland. This reduction is largely the result of substantial decreases in accident fatalities within this transport mode.

Concentrating on the road transport as biggest contributor to the total external accident costs, several developments can be observed. The average costs of passenger transport are almost the same for 2008 and 2000 (EU-15, CH, NO). This also holds true for passenger cars, but not for motorcycles, where average accident costs have decreased by more than 10% since 2000. On the other side, accident costs of both light and heavy duty vehicles have seen a significant increase since the last study.

The main reason of these distinct movements lies within the newly applied accident allocation method in the road sector, i.e. the change from the monitoring perspective in the previous UIC study (INFRAS/IWW, 2004) to the damage potential (intrinsic risk) approach in the present study. The latter perspective takes into account that larger vehicles (i.e. heavy duty vehicles) expose greater danger to other road users, i.e. their damage potential. This means that more fatalities and injuries from accident are allocated to these vehicle categories and hence, accident costs will be higher for them. Consequently, more costs are now attributed to large, heavy vehicles such as HDV and LDV and less to smaller vehicles like motorcycles.

Regarding the development of total accident costs of road transport since 2000, also the reduced number of victims of road accidents has to be considered. Fatalities from road accidents in the EU fell by more than 30% in the last decade, which reduces the external accident costs. On the other hand, the increase of the analysed countries (EU-15 to EU-27 plus CH, NO) and therefore of the absolute victim numbers increases the accident costs. These two effects partly compensate each other.

The lower number of traffic accidents is the results of improved traffic safety which resulted from a broad range of technical, behavioural and other measures. The reduced accidents risks were partly off-set by the growing transport performances in Europe (passenger- and tonne-kilometres). Further, due to improvements in the transport data, performances used in this study cannot be directly compared to the data used in the previous UIC study.

If the monitoring approach had been applied like in the previous study (INFRAS/IWW, 2004), the average accident cost of road transport would have decreased due to the declining accident rate. The methodological change to the damage potential approach, however, lead to a higher number of accidents included: most of the accidents of non-motorised traffic (pedestrians and bikers) are now included too, and attributed to motorised traffic due to its higher damage potential (intrinsic risk). In the monitoring principle, these costs are not part of the motorised road transport, but attributed to the pedestrians and bikers.

Table 20 **Total and average external costs of accidents 2008 (data according to damage potential approach)**

Transport	Transport mode	Total costs (mio. €/year)	Average cost (Pass.: €/1,000 pkm Freight: €/1,000 tkm)
Total	**Total**	**225,340**	
Passenger	Passenger cars	157,100	32.3
	Buses and coaches	6,840	12.3
	Motorcycles	22,580	156.6
	Road passenger total	186,530	33.6
	Rail	240	0.6
	Air	220	0.5
Freight	LDV	18,680	56.2
	HDV	19,600	10.2
	Road freight total	38,280	17.0
	Rail	70	0.2
	Inland waterways	- *	- *

* No data available.

4.2.2 Air pollution

Air pollution due to transport emissions in the EU-27 plus Norway and Switzerland caused total costs of more than € 53 million in 2008. Almost 95% of the costs can be attributed to road transport, 3% to rail transport, 1.5% to inland waterways and 0.8% to air transport (only continental flights).

Looking at road transport, passenger cars are the main reason of air pollution costs. They are responsible for 50% of the total costs. Emissions of heavy duty vehicles (HDV) cause 24% of the total costs, LDV 11% (see Table 21).

The average costs of air pollution are highest for road transport. In passenger transport, the average costs of road transport are € 5.7 per 1,000 pkm, whereas the costs of rail transport are more than two times lower (€ 2.6 per 1,000 pkm).

In the case of road freight transport, the average air pollution costs are highest for LDV. The average costs of road freight are € 8.4 per 1,000 tkm. For rail transport the average costs are almost eight times lower (€ 1.1/1,000 tkm) than for road. For inland waterways the costs factor is € 5.4/1,000 tkm.

Table 21 Total and average external costs of air pollution 2008

Transport	Transport mode	Total costs (Mio. €/year)	Average cost (Pass.: €/1,000 pkm Freight: €/1,000 tkm)
Total	**Total**	**53,390**	
Passenger	Passenger cars	26,640	5.5
	Buses and coaches	3,350	6.0
	Motorcycles	1,700	11.8
	Road passenger total	31,680	5.7
	Rail	1,090	2.6
	Air	430	0.9
Freight	LDV	5,930	17.9
	HDV	13,000	6.7
	Road freight total	18,930	8.4
	Rail	490	1.1
	Inland Waterways	780	5.4

Overall, the average costs of air pollution are more than 50% lower than in the previous UIC study (INFRAS/IWW, 2004). There are several reasons for this development:

- Decrease in emission factors in road and rail transport, especially for particulate matter (PM). Different reasons led to a strong decrease in $PM_{2.5}$ emission factors (emissions in g per vehicle-km).
- Technical development, e.g. particle filters, efficiency gains.
- Regulations, leading to a shift to cleaner EURO-class vehicles.
- TREMOVE database is reflecting this technical and regulatory development within its emission factor data. According to the TREMOVE database, the emission factors for passenger cars, HDV and motorcycles have been reduced by more than 40% between 2000 and 2008, for LDV even by more than 50%. A short comparison with the Handbook of Emission Factors in Road Transport (HBEFA, FOEN, 2010) has supported the TREMOVE data. The development of road transport emission factors between 2000 and 2008 is very similar in HBEFA as in TREMOVE: PM exhaust emissions have been reduced by 38% for passenger cars and by 54% for HDV for the countries included there. Details about the development of emission factors are shown in Figure 32 in Annex A.
- Change of methodology from top-down approach (based on data on the number of exposed people) in the previous UIC study to a bottom-up approach (impact-pathway approach, based on emission data).
  This change led to slightly lower unit cost factors.
- Inclusion of new EU member states also led to a small decrease in unit costs, because the price level and GDP per capita is smaller in the new EU countries.
- The different transport data of the previous and the present UIC study also has a certain impact on the different average cost factors. Above all, changes in load factors are influencing the average costs per pkm and tkm (this is also influencing other cost categories).

4.2.3 Climate change

The total climate cost are mainly caused by road transport and aviation. Particularly passenger cars are responsible for the lion share of climate costs (57%), HDV for 13% and LDV for 10%. Also aviation has a large share in the climate cost, about 15% (see Table 22). Note that this is considerably lower than in the previous study (INFRAS/IWW, 2004). The difference is mainly due to a change in system boundaries. This time, we decided to use a European perspective, since this is the level where transport modes are in competition and cost data can be compared.

For all modes, the average climate costs (both low and high estimates) are relatively close to the values from the 2004 study. The main differences arise from some fuel efficiency improvements, differences in data basis and the, relatively small, differences in the valuation.

Table 22 Total and average external costs of climate change 2008

Transport	Transport mode	High scenario climate costs (€ 146/t CO_2)	Low scenario climate costs (€ 25/t CO_2)
Total costs (Mio. €/Year)			
Total	**Total**	**148,150**	**25,370**
Passenger	Passenger cars	84,130	14,410
	Buses and coaches	5,060	870
	Motorcycles	1,600	270
	Road passenger total	90,790	15,550
	Rail	630	110
	Air	22,170	3,800
Freight	LDV	14,790	2,530
	HDV	18,850	3,230
	Road freight total	33,630	5,760
	Rail	410	70
	Inland waterways	520	90
Average cost (passenger: €/1,000 pkm; freight: €/1,000 tkm)			
Passenger	Passenger cars	17.3	3.0
	Buses and coaches	9.1	1.6
	Motorcycles	11.1	1.9
	Road passenger total	16.3	2.8
	Rail	1.5	0.3
	Air	46.9	8.0
Freight	LDV	44.5	7.6
	HDV	9.8	1.7
	Road freight total	14.9	2.6
	Rail	0.9	0.2
	Inland waterways	3.6	0.6

4.2.4 Noise

Table 23 presents the results for the total and average noise costs. Road transport is responsible for more than 90% of the noise costs. Passenger cars have the largest share with about 45%. Relative to the share in vehicle-kilometres a high share of noise costs is caused by HDV (almost 20%) and LDV and motorcycles/mopeds (each almost 12%).

The total and average noise costs are lower than in the previous study (INFRAS/IWW, 2004). For most transport modes the costs are a factor 2 to 3 lower. There are two factors explaining this reduction in total noise costs.

First, the number of people exposed to noise levels > 55 dB (A) is lower than in the previous study (about 30%). This may be the result of noise abatement measures applied. However, also the application of a new, improved data basis for the number of people exposed has contributed to the lower numbers. In this study the number of people exposed to adverse noise levels are based on the noise maps of member states (see Paragraph 3.4), while the noise estimates in the previous study were based on much rougher estimates, as the detailed noise maps for all member states were not yet available.
Second, in this study the valuation of noise at higher noise levels is also ca. 30% lower.

Table 23 Total and average external costs of noise 2008 per vehicle-km and passenger- or tonne-km

Transport	Transport mode	Total costs (Mio. €/year)	Cost per vehicle-km (€/1,000vkm)	Cost per performance unit (€/1,000 pkm or €/ 1,000 tkm)
Total	**Total**	**18,184**		
Passenger	Passenger cars	8,201	2.9	1.7
	Buses and coaches	865	16.4	1.6
	Motorcycles	2,076	15.8	14.4
	Rail	477	140.9	1.2
	Air	457	87.5	1.0
Freight	LDV	2,094	3.5	6.3
	HDV	3,537	19.4	1.8
	Rail	476	563.5	1.0

4.2.5 Congestion

In contrast to the previous studies (INFRAS/IWW, 2000 and 2004), we have compared the network model results for congestion costs to national studies on road service quality for the UK, Germany, the Netherlands, Switzerland, France and Belgium. All these sources lead to considerably lower congestion cost values than we derive from European transport network models. The extrapolation of national findings to Europe lead to 13.2% of the delays due to road infrastructure scarcity compared to the application of the TRANS-TOOLS network model.

This huge deviation is caused by the huge link length, over-estimating the extent of traffic jams and the neglecting of secondary roads allocating more traffic to the primary road network in strategic European transport models. As on the other hand national studies, which are usually based on speed metering, loop detector data or traffic message records, underestimate smaller delays, we adjust both sources to narrow the range of possible congestion estimates. The factors used are -30% for the network model results and +40% for national meta study regression estimates.

On top of these, urban congestion costs are estimated based on marginal costs and a European city database. As congestion is very much depending on local conditions, such as transport network configurations or regulations, our European perspective will in most cases widely differ from specific national experiences. We thus stay in line with the other cost categories and report congestion costs only a geographically aggregated level.

Across the 27 countries investigated in this study we receive total social congestion costs, i.e. congestion driven delays between € 146 and 243 million. This is between 1.1 and 1.8% of GDP. The deadweight loss caused by congestion-related market failure provides figures from € 23.6 and 39.2 billion, which is between 0.2 and 0.3% of GDP. This bandwidth embraces the Infras/IWW (2000) findings of € 33 billion , but is below the Infras/IWW (2004) results of € 67 billion for the EU-17 countries. We thus have to adjust our previous findings downwards to some extent. But it should be highlighted that measuring congestion by nature is subject to strong assumptions and conventions. In the light of the considerable differences in methodologies and databases, the 50% difference between pure modelling work and transport statistics evaluation appears to be quite reasonable. The fall in congestion costs between the previous and the current study thus in no way indicates an improvement in travel quality on European roads.

The results of the cost estimates for 2008 are given in Table 24 by transport market and vehicle types in total costs and per transport unit.

Table 24 Total social losses and delay costs from road congestion in Europe 2008 in mio. €, 2008 price level

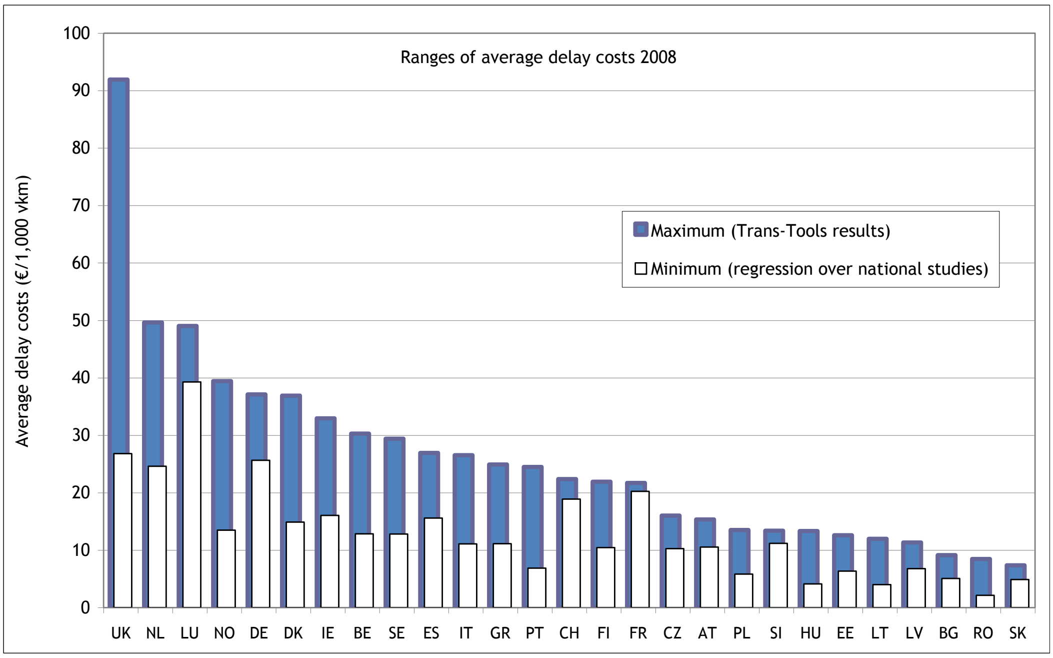
Transport	Transport mode	Total costs (Mio. €/year)		Average per vkm €/1,000 vkm		Average per vkm €/1,000 pkm or tkm	
		Max.	Min.	Max.	Min.	Max.	Min.
Delay costs	Total	**243,194**	**146,214**	**68.23**	**41.02**		
Passenger	Pass. cars	161,331	98,416	57.98	35.37	33.21	20.26
	Bus/coach	7,729	4,836	145.91	91.29	13.92	8.71
	Motorcycles	3,841	2,439	29.30	18.61	26.63	16.92
	Pass. total	172,901	105,691	58.29	35.63	31.11	19.02
Freight	LDV	27,633	13,827	66.55	33.30	83.18	41.62
	HDV	42,660	26,695	233.46	146.09	22.15	13.86
	Freight Total	70,293	40,522	117.55	67.77	31.13	17.95
Deadweight Loss	Total	**39,212**	**23,606**	**11.00**	**6.62**		
Passenger	Pass. cars	26,015	15,891	9.35	5.71	5.35	3.27
	Bus/coach	1,247	781	23.53	14.74	2.24	1.41
	Motorcycles	620	394	4.73	3.01	4.30	2.73
	Pass. total	27,881	17,066	9.40	5.75	5.02	3.07
Freight	LDV	4,450	2,229	10.72	5.37	13.40	6.71
	HDV	6,880	4,311	37.65	23.59	3.57	2.24
	Freight Total	11,331	6,540	18.95	10.94	5.02	2.90

In line with the previous external cost studies for UIC (and as mentioned in Section 3.5.2) we present the congestion-externality separately and will not add it up in terms of total external costs of transport. Delay costs, which we use as the main congestion indicator, are a mainly transport-sector internal and the social efficiency measure addresses different aspects of externalities. While from the transport efficiency perspective the separation of system-internal and system-external cost categories is irrelevant, it matters when comparing transport modes.

As concerns network types, € 11.8 million or 30% of the deadweight loss are attributable to urban congestion. In particular in and around urban agglomerations the re-vitalisation of attractive and powerful public transport systems together with the cut in road space and the extension of cycle lanes and pedestrian areas have drastically influenced the role of car traffic. Together with a stagnation in population numbers in Europe this trend may contribute to curb congestion to the benefit of more flexible and more inter-modal mobility patterns of citizens and commuters.

66% of congestion costs are attributable to car travel, and another 28.8% are borne by goods transport. In geographical terms, minimum average costs concentrate on the UK, the Benelux countries and Germany. But taking the maximum approach with TRANS-TOOLS network results, some smaller countries like Austria, Luxembourg and Denmark directly range behind the UK, taking the top position. Figure 28 reveals the great differences of the two approaches at the example of the average delay costs per country. The most significant difference is found for the UK, where TRANS-TOOLS computes average costs around € 90/1,000 vkm, while the national studies leads to only € 25/1,000 vkm. In the case of France, Switzerland and Luxemburg, on the contrary, the two approaches lead to rather similar results. Related to country size, France shows rather low congestion costs. Although intuitively astonishing, these results coincide with the country analysis in OECD (2007).

Figure 28 Ranges of average delay costs computed after TRANS-TOOLS and national studies 2008



Delay costs are roughly ten times the deadweight loss. They do not directly indicate economic losses, as these depend on the respective shape of speed flow curves, but they give a good indication of the perceived traffic quality by road users. As delay cost data is principally recorded by all road administrations, it is recommended to coordinate the assessment of road quality indicators on a European level in order to get a better idea of investment needs in alternative modes or new road space.

Conclusively we have to constitute that, although traffic models have become more reliable, network data is more accessible and single countries have improved statistics on road traffic quality than a decade ago, there is still no consistent database on congestion levels in Europe available. Thus, all estimates in this direction are based on model assumptions and can not easily be verified.

4.2.6 Other external costs

The most important other external cost category is the cost of up- and downstream effects related to energy production and distribution. The costs of up- and downstream effects account to € 49 billion per year in the high scenario of climate change costs (see Table 42). In the low scenario, the total costs of up- and downstream effects are € 29 billion per year.

The average costs of up- and downstream effects are similar as in the previous UIC study (INFRAS/IWW, 2004). The average cost factors for rail are considerably higher which has a methodological reason: in the last UIC study, the precombustion effect of rail electricity production has been covered within the air pollution category, whereas it is now part of the up- and downstream cost category.

82% of the total up- and downstream costs are caused by road transport: 61% by road passenger and 21% by road freight transport. Rail transport is responsible for 11%, air transport for 7% and inland waterways for 0.4% of the total costs. The average costs are highest for rail transport which can be attributed to the emissions occurring during the rail electricity production, mainly in countries with a high share of fossil fuels for electricity production.

Table 25 Total and average external costs of up- and downstream costs 2008 (high scenario of climate change)

Transport	Transport mode	Total costs (Mio. €/year)	Average cost (Pass.: €/1,000 pkm Freight: €/1,000 tkm)
Total	**Total**	**49,190**	
Passenger	Passenger cars	27,680	5.7
	Buses and coaches	1,570	2.8
	Motorcycles	520	3.6
	Road passenger total	29,770	5.4
	Rail	3,350	8.1
	Air	3,360	7.1
Freight	LDV	4,770	14.3
	HDV	5,800	3.0
	Road freight total	10,570	4.7
	Rail	1,950	4.2
	Inland waterways	190	1.3

Table 26 and Table 27 present the total and average costs of all other external cost categories: costs for nature and landscape, biodiversity losses (due to air pollution), soil and water pollution, additional costs in urban areas. The largest cost category is the additional cost in urban areas € 7.5 million per year, followed by the costs for nature and landscape (€ 5.3 million/a) and the soil and water pollution costs (€ 4.7 million/a). The smallest cost category is the cost of biodiversity losses due to air pollution (€ 2.6 million/a). 94% of the costs can be attributed to road transport (Table 26 and Table 27).

Table 26 Other external costs*: total costs 2008 per cost category (in mio. €/year)

Cost category	Road	Rail	Air	Water	Total
Costs for nature & landscape	4,810	100	300	60	**5,260**
Biodiversity losses (due to air pollution)	2,480	2	40	70	**2,600**
Soil and water pollution	4,340	380	- **	- **	**4,720**
Additional costs in urban areas	7,160	290	0	0	**7,450**
Sum of other external costs	**18,790**	**770**	**340**	**130**	**20,030**

* Other external costs: costs for nature & landscape, biodiversity losses (due to air pollution), soil and water pollution, additional costs in urban areas.
** No data available.

Table 27 Other external costs*: total and average costs 2008 per transport mode

Transport	Transport mode	Total costs (mio. €/year)	Average cost (Pass.: €/1,000 pkm Freight: €/1,000 tkm)
Total	**Total**	**20,030**	
Passenger	Passenger cars	10,560	2.2
	Buses and coaches	1,080	1.9
	Motorcycles	250	1.7
	Road passenger total	11,880	2.1
	Rail	530	1.3
	Air	340	0.7
Freight	LDV	2,130	6.4
	HDV	4,780	2.5
	Road freight total	6,910	3.1
	Rail	250	0.5
	Inland waterways	130	0.9

* Other external costs: costs for nature & landscape, biodiversity losses (due to air pollution), soil and water pollution, additional costs in urban areas.

4.3 Results corridor calculations

In this section, the average cost factors are applied to a set of corridors. This is done to demonstrate the use of the external cost indicators elaborated in this study and to provide a closer look at the level playing field of passenger and freight transport under specific competitive situations.

4.3.1 Corridor definition

Analysed are two corridors for passenger and freight transport, involving international east-west and north-south traffic. The selected corridors are also chosen to be relevant in terms of transport demand and covering various member states.

The following corridors have been elaborated:

Passenger transport
– Paris-Brussels.
– Berlin-Warsaw.

Freight transport:
- Rotterdam-Genova.
- Duisburg-Budapest.

For each of the four corridors three travel alternatives are investigated:
- Rail, road and aviation for passenger services. And
- Rail, road and inland waterways for freight shipments.

The corridors are assessed using average cost figures per country. For the single routes the following adaptations are made:
- Passenger transport Paris-Brussels: rail services are operated by Thalys high speed trains. As these show higher load rates than the national average we decrease the average rail external figures by 25%. Contrarily, air services are only provided by Brussels Airlines using small regional jets. Because of the lower than average load rates and the short distance we increase the average external costs by 20%.
- Passenger transport Berlin-Warsaw: Rail services are provided by Euro-City (EC) and Inter-City (IC) trains. As air flights are within a reasonable flying distance we assume no deviations from national average values.
- Freight transport Rotterdam–Genova: The main route for road haulage and rail is assumed to lead through Belgium, France and Switzerland to Italy. According to UIRR communications combined services on this most important European freight transport axis show rather high train load rates. Accordingly we decrease rail external costs by 10%. Inland waterway transport is only possible up to Basle on the Rhine. The residual journey to Genova is assumed by container trains through Switzerland.
- Freight transport Duisburg–Budapest. Road and rail transport are assumed to go via Austria and the Slovak Republic to Hungary. In inland navigation this involves the Rhine, the Rhine-Danube-Channel and the Danube. All modes are assessed according to national average values.

The corridor analyses were based on the data inputs indicated in Table 28.

Table 28 Data input used for corridor analyses

Category	Detail	Source
Route description	Distance by country and network type Travel time (additional information)	Online route planners, rail distance tables Estimates of access routes
Vehicle characteristics	Load factors Technology/Emission standards	Average national load factors with adaptation in specific cases
External costs	Marginal or average costs, all categories	This study

Load factors are of particular concern in particular in rail transport, as they directly scale the level of average external costs. By estimating corridor-specific load factors we thus move the average cost principle somewhat towards the idea of marginal costs.

We assume the following deviations from national average values:
- Thalys Paris-Brussels: Load factors in high speed transport are commonly well above the national average. Exact data on the line Paris-Brussels is not available, but we assume 25% higher load factor than the national averages.

– Passenger Berlin-Warsaw. Here IC/EC-trains are used, which are assume not to deviate very much from national average passengers per train.
– For the freight relations Rotterdam-Genova and Duisburg-Budapest we use national average tons per train as on these rather long corridors trains will be re-formatted when crossing national borders. Within the countries we thus can not identify corridor-specific load factors.
– HDV transport, however, is assumed to be carried out with 40 t truck-trailer-combinations only. These show 20% higher load factors (around 15 t) than the average across all HDVs (11.5 t).

The data describing the corridors in more detail is given by Table 29. Information on travel times has been collected were available, but is not used in the assessment framework. Congestion costs have also not been computed as they first must not be added up with other externalities and as congestion effects are very site and travel time specific and thus should not be averaged across entire corridors. As hauliers usually know the critical road sections and times rather well, they can influence the level of congestion borne and caused by them.

Table 29 Data input used for corridor analyses

Corridor 1 - Passenger transport Paris-Brussels				**Corridor 2 - Passenger transport Berlin-Warsaw**			
	Road	**Rail 1)**	**Air 2)**		**Road**	**Rail 1)**	**Air 2)**
	Car	**Rail (HST)**	**DC-10**		**Car**	**IC/EC**	**A321**
Load factor adjustment	1	1.25	1	Load factor adjustment	1	1	1
Distance (km)	305	312	270	Distance (km)	591	561	290
- FR	*220*	*215*	*200*	*- DE*	*101*	*82*	*70*
- BE	*85*	*97*	*70*	*- PL*	*490*	*479*	*220*
Time (h) 4)	03:22	01:20	01:55	Time (h) 4)	08:11	05:24	02:15
Corridor 3 - Freight transport Rotterdam-Genova				**Corridor 4 - Freight transport Duisburg-Budapest**			
	Road	**Rail 3)**	**IWW 3)**		**Road**	**Rail 3)**	**IWW 3)**
	HDV	**Rail**	**Ship+Rail**		**HDV**	**Rail**	**Ship**
Load factor adjustment	1.2	1	1	Load factor adjustment	1.2	1	1
Distance (km)	1179	1393	1240	Distance (km)	1205	1271	1569
- NL	*57*	*99*	*133*	*- DE*	*694*	*704*	*896*
- BE	*275*	*249*		*- AT*	*336*	*361*	*351*
- LU	*32*	*62*		*- SK*			*172*
- FR	*336*	*642*		*- HU*	*175*	*206*	*150*
- DE			*632*				
- CH	*289*		*284*				
- IT	*190*	*341*	*191*				
Time (h) 4)5)	16:58	n.a.	n.a.	Time (h) 4)5)	0.72	n.a.	n.a.

1) Plus access to and from railway station by road (5 km) and public transport (5 km).
2) Plus access to and from airports by road (20 km) and public transport (20 km).
3) Plus access to and from rail terminal/port by road haulage (50 km).
4) Without access and wait time in terminals, including check-in for air (1 h).
5) Data for illustration only, not used in corridor calculations.

4.3.2 Intermodal comparison

In brief, Table 30 summarises the results of the corridor analysis. The data are based on the high climate cost estimate.

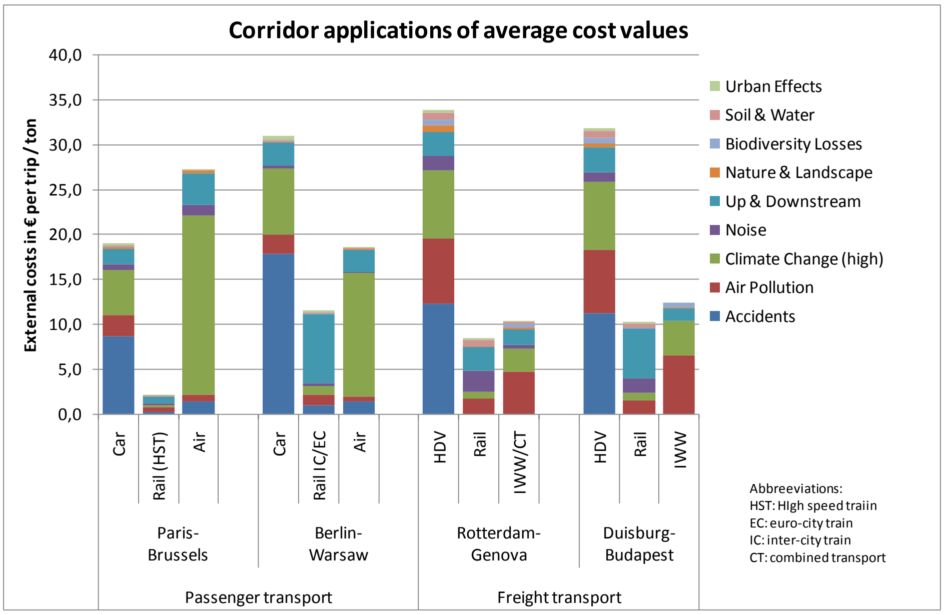
In all cases rail is the most favourable mode. Nevertheless, big difference have to be constituted for rail services between the different case studies. Comparing Paris-Brussels to Berlin-Warsaw two issues are at stake: population densities and income levels are still lower in Poland compared to France and the Benelux countries. Second, the rail link from Berlin to Warsaw is considerably shorter than the route by road. Also in freight transport rail has the lowest environmental costs, but here IWW transport comes very close.

Table 30 Brief corridor results

	Passenger transport		Freight transport	
	Paris-Brussels	Berlin-Warsawa	Rotterdam-Genova	Duisburg-Budapest
Road	19.00	30.98	33.84	31.88
Rail	2.16	6.99	8.40	10.26
Air	27.21	18.48		
Inland waterways			10.34	12.42

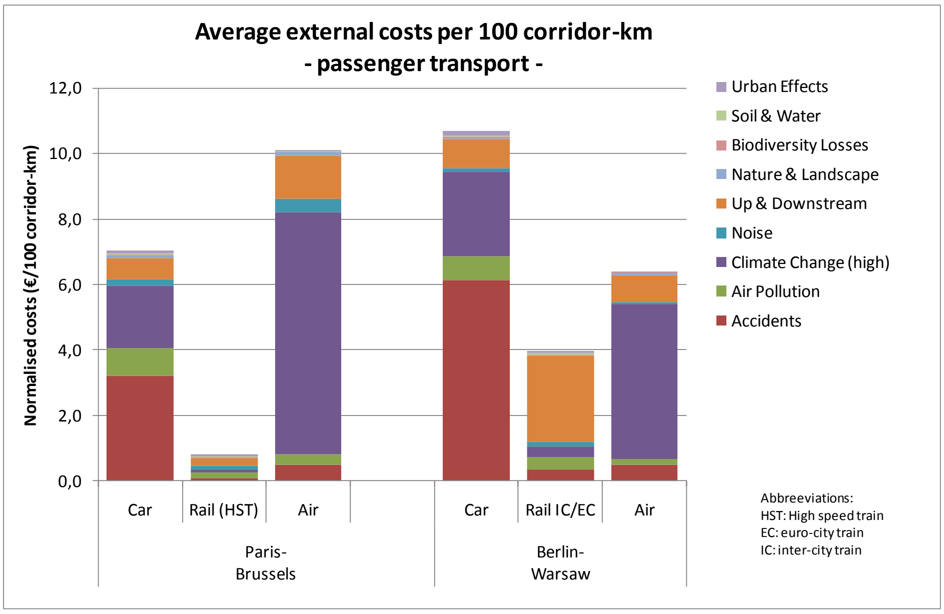
The total cost on the corridors are the sum of the various external costs. A more detailed comparison for the passenger and freight services, distinguishing by cost categories, is given in Figure 29.

Figure 29 Corridor results for passenger and freight transport in Euro per passenger or tonne shipped



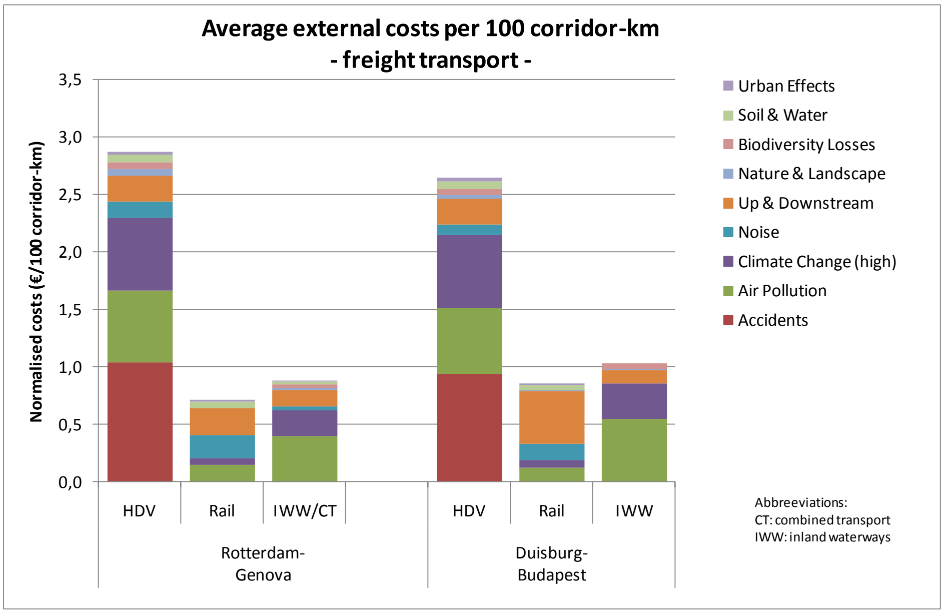
The subsequent Figure 30 for passenger transport and Figure 31 for freight services present the above values normalised to €/100 corridor-km. The corridor length is determined by the least distance of the three modes considered, excluding access from and to terminals.

Figure 30 Corridor results passenger transport per passenger and 100 corridor kilometres



The most surprising results in terms of passenger transport is the very low values for the high speed connection from Paris to Brussels in absolute terms and in comparison to the IC/EC service from Berlin to Warsaw. The main driving factors are the high load factors of the Thalys trains. This demonstrates the high relevance of demand parameters for intermodal comparisons.

Figure 31 Corridor results freight transport per ton and 100 corridor kilometres



A deeper analysis of the level playing field of transport modes would require the assessment of location and regional conditions alongside the transport routes on the basis of geographical data. This was not foreseen in the frame of this study.

5 Results: Marginal Costs in Different Traffic Situations

5.1 Overview: Aggregated results

So far, only total and average costs have been presented. However, just as the previous UIC external cost studies for 2000 and 2004, this study also covers *marginal* external costs.

The methodology for calculating marginal external costs was already included in Chapter 3. Marginal external costs depend on a broad range of cost drivers like the type of region (population density), type of road, vehicle type, fuel type, load factor, driver, etc. In this chapter we present the results for various regions and/or road types, vehicle technologies (petrol, diesel, electric) and traffic situations (just for noise costs: day/night; thin/dense). For other cost drivers, e.g. Euro standards, the EU average has been used.

Table 31 shows the marginal external costs per passenger-km or tonne-km for the various transport modes and road types. Just like for average costs, rail has by far the lowest costs per passenger-km or tonne-km. The ratios between the marginal external costs of the various modes are comparable to what was found for the average costs.

At the same time it becomes clear that the differences between various road types are considerable. The marginal costs in urban areas are much higher than in non-urban areas. The external costs for road transport are lowest on motorways.

It should be noted that road congestion cost are not included here. These costs can range up to more than € 1 per vehicle-km for passenger cars which is close to € 600 per 1,000 vehicle-km. This makes it clear that in specific situations with very congested roads, congestion can be an important cost element in the overall marginal cost.

Table 31 Marginal external cost at day-time without congestion (€ per 1,000 pkm or tkm)

Mode	Metropolitan	Other urban	Non-urban	Non-urban motorways
Car	87	79	44	30
Motorcycles/mopeds	271	254	106	40
Buses & coaches	44	40	24	18
LDV	297	247	111	81
HDV	71	67	29	20
Rail passenger	19	15	12	
Rail freight			6	
Aviation passenger			56	
Inland waterways (freight)			10	

NB: Based on the high estimate of climate cost and including accident, air pollution, climate, noise (day time) and up- & downstream costs.

Table 32 shows the shares of various cost categories for various road types in the case of passenger cars and trucks. It becomes clear that in urban areas, accident costs are about half of the marginal external costs, while in non-urban areas and particularly motorways the cost emissions are dominant, in particularly those of climate change.

Table 32 Share of various cost categories in the marginal external cost of passenger cars and trucks at day-time without congestion

	Metropolitan	Other urban	Non-urban	Non-urban motorways
Car				
Accidents	49%	54%	38%	11%
Air pollution	18%	10%	9%	14%
Climate change	20%	22%	39%	57%
Up- & downstream	7%	7%	13%	19%
Noise	6%	7%	0%	0%
HDV				
Accidents	55%	57%	34%	4%
Air pollution	16%	12%	21%	31%
Climate change	14%	15%	34%	49%
Up- & downstream	4%	4%	10%	15%
Noise	11%	12%	0%	1%

NB: Based on the high estimate of climate cost and including accident, air pollution, climate, noise and up- & downstream costs.

5.2 Results 2008 per cost category

5.2.1 Accidents

Table 33 and Table 34 present the marginal external accident costs, i.e. the costs induced by an additional vehicle-km. The marginal accident costs are given for three different road types (motorways, outside urban areas, urban areas) as well as for all roads.

Table 33 shows the results based on the responsibility (guilt) approach, that are directly based on the UNITE study. For transport modes not indicated in Table 33 (i.e. rail and air transport) average costs can be used as a proxy as they do approximately represent the marginal costs.

Table 33 Marginal accident costs for cars and HDV and different road types: *responsibility approach* (derived from UNITE case study for Switzerland)

	Car				HDV			
	Motorways	Outside urban	Urban	All roads	Motorways	Outside urban	Urban	All roads
Country	€ct/vkm	€ct/vkm	€ct/vkm	€ct/vkm	€ct/vkm	€ct/vkm	€ct/vkm	€ct/vkm
Austria	0.66	3.41	8.67	2.50	0.07	0.85	3.35	0.54
Belgium	0.61	3.15	8.01	2.31	0.34	4.10	16.15	2.62
Bulgaria	0.41	2.11	5.37	1.55	0.12	1.45	5.73	0.93
Czech Republic	1.02	5.30	13.46	3.88	0.22	2.60	10.25	1.66
Denmark	0.48	2.48	6.31	1.82	0.07	0.82	3.24	0.53
Estonia	0.68	3.54	8.98	2.59	0.20	2.43	9.58	1.55
Finland	0.56	2.93	7.44	2.14	0.13	1.60	6.30	1.02
France	0.45	2.32	5.88	1.69	0.25	2.99	11.81	1.91
Germany	0.41	2.14	5.43	1.56	0.20	2.35	9.28	1.50
Greece	1.69	8.81	22.37	6.44	0.43	5.21	20.57	3.33
Hungary	1.08	5.62	14.26	4.11	0.29	3.43	13.54	2.19
Ireland	0.74	3.84	9.76	2.81	0.25	2.98	11.75	1.90
Italy	0.57	2.98	7.57	2.18	0.15	1.75	6.91	1.12
Latvia	1.50	7.79	19.78	5.69	0.58	6.98	27.55	4.46
Lithuania	0.66	3.42	8.68	2.50	0.20	2.35	9.26	1.50
Luxembourg	0.88	4.57	11.60	3.34	0.46	5.53	21.81	3.53
Netherlands	0.24	1.27	3.21	0.93	0.10	1.23	4.84	0.78
Norway	0.50	2.58	6.55	1.88	0.13	1.61	6.34	1.03
Poland	0.61	3.16	8.02	2.31	0.18	2.17	8.56	1.39
Portugal	0.42	2.17	5.51	1.59	0.20	2.34	9.25	1.50
Romania	0.36	1.85	4.69	1.35	0.11	1.27	5.00	0.81
Slovakia	0.70	3.66	9.30	2.68	0.21	2.52	9.92	1.61
Slovenia	0.98	5.11	12.98	3.74	0.29	3.51	13.84	2.24
Spain	0.38	1.96	4.98	1.43	0.19	2.31	9.13	1.48
Sweden	0.41	2.14	5.44	1.57	0.13	1.57	6.19	1.00
Switzerland	0.24	1.23	3.13	0.90	0.32	3.81	15.03	2.43
United Kingdom	0.27	1.41	3.59	1.03	0.11	1.35	5.32	0.86
Total (EU-27)	0.38	1.98	5.03	1.45	0.15	1.81	7.15	1.16

NB: Data are based on high values from UNITE, where average risk is non internalised, i.e. total accident risk assumed to be extern

5.2.2 Air pollution

The following tables show the results of marginal air pollution costs per vehicle-km. The results are based on differentiated average costs. Since dose-response functions and exposure calculations for air pollution costs are linear functions, marginal air pollution costs are approximately equal to average air pollution costs.

The data in Table 34 and Table 35 are differentiated by transport mode, fuel type (road: gasoline, diesel; rail: electric, diesel) and region type for road and rail transport (metropolitan, other urban, non-urban areas). Table 34 shows marginal costs per vehicle-km (or train-km, plane-km, vessel-km), Table 35 marginal costs per pkm and tkm.

It should be noted that air pollution cost also differ considerably between vehicle technologies, particularly the Euro standards. A new Euro-6 truck has much lower air pollution costs than an older Euro-2 truck. The same is true for other modes. As vehicle regulation in road transport has developed fast and fleet renewal is faster than in other modes, the variation between vehicles is largest for road transport. However, the Euro standards are no cost driver for the other cost categories and therefore in this chapter the marginal cost data have not been differentiated to Euro standard.

Table 34 Marginal air pollution costs 2008, in €/1,000 vkm (average for EU-27)

Transport mode	Fuel type	Metropolitan	Other urban	Non-urban	All regions (average)
Road					
Passenger cars	Gasoline	14.8	8.6	4.9	6.2
	Diesel	40.4	18.7	9.4	12.6
	Total	27.3	13.9	7.3	9.6
Motorcycles	Gasoline	35.0	16.7	9.7	12.9
Buses/coaches	Diesel	122.5	77.7	54.1	63.2
LDV	Gasoline	19.4	13.3	7.2	7.7
	Diesel	76.4	32.1	12.1	15.4
	Total	70.8	30.3	11.4	14.3
HDV	Diesel	120.5	83.4	64.3	71.1
Rail					
Rail passenger	Electric	681.7	274.7	188.5	254.3
	Diesel	1,316.6	550.1	427.5	578.6
	Total	877.5	355.2	238.8	332.7
Rail freight	Electric	-	-	456.0	456.0
	Diesel	-	-	878.4	878.4
	Total	-	-	554.7	554.7
Air and water					
Aviation passenger					81.5
Inland waterways					4,781

Table 35 Marginal air pollution costs 2008, in €/1,000 pkm or tkm (average for EU-27)

Transport mode	Fuel type	Metropolitan	Other urban	Non-urban	All regions (average)
Road					
Passenger cars	Gasoline	8.5	4.9	2.8	3.5
	Diesel	23.1	10.7	5.4	7.2
	Total	15.7	8.0	4.2	5.5
Motorcycles	Gasoline	31.8	15.2	8.8	11.8
Buses/coaches	Diesel	11.7	7.4	5.2	6.0
LDV	Gasoline	24.2	16.6	9.0	9.6
	Diesel	95.5	40.1	15.1	19.2
	Total	88.5	37.9	14.2	17.9
HDV	Diesel	11.4	7.9	6.1	6.7
Rail					
Rail passenger	Electric	4.8	1.9	1.3	1.8
	Diesel	17.3	7.2	5.6	7.6
	Total	7.0	2.8	1.9	2.6
Rail freight	Electric			0.9	0.9
	Diesel			1.7	1.7
	Total			1.1	1.1
Air and Water					
Aviation passenger					0.9
Inland waterways					5.4

Data in €/1,000 pkm for passenger cars, motorcycles, buses & coaches, rail passenger and air.
Data in €/1,000 tkm for LDV, HDV, rail freight and inland waterways.

5.2.3 Climate change

The marginal climate change costs are, like the air pollution costs, equal to the average costs.

The data in Table 36 are differentiated by transport mode and fuel type (road: gasoline, diesel; rail: electric, diesel). It shows the results for both the low and the high scenario for the CO_2 shadow price.
The marginal cost results are not differentiated by region type since these differences are quite small and in order to keep the amount of data not too large.

Table 36 **Marginal climate change costs 2008, in €/1,000 vkm and €/1,000 pkm or tkm (average for EU-27)**

Transport mode	Fuel type	Low scenario (25 €/t CO_2)		High scenario (146 €/t CO_2)	
		€ per 1,000 vkm	€ per 1,000 pkm or tkm	€ per 1,000 vkm	€ per 1,000 pkm or tkm
Road					
Passenger cars	Gasoline	5.5	3.1	31.9	18.3
	Diesel	4.9	2.8	28.9	16.5
	Total	5.2	3.0	30.2	17.3
Motorcycles	Gasoline	2.1	1.9	12.2	11.1
Buses/coaches	Diesel	16.4	1.6	95.5	9.1
LDV	Gasoline	6.4	7.9	37.1	46.4
	Diesel	6.1	7.6	35.4	44.2
	Total	6.1	7.6	35.6	44.5
HDV	Diesel	17.7	1.7	103.1	9.8
Rail					
Rail passenger	Electric	0.0	0.0	0.0	0.0
	Diesel	135.8	1.8	792.9	10.4
	Total	32.8	0.3	191.8	1.5
Rail freight	Electric	0.0	0.0	0.0	0.0
	Diesel	348.0	0.7	2,032.1	3.9
	Total	81.3	0.2	474.7	0.9
Air and Water					
Aviation passenger		726.2	8.0	4,241.2	46.9
Inland waterways		540.2	0.6	3,155.0	3.6

Data in €/1,000 pkm for passenger cars, motorcycles, buses & coaches, rail passenger and air.
Data in €/1,000 tkm for LDV, HDV, rail freight and inland waterways.

5.2.4 Noise

European average unit values for marginal noise costs are presented in Table 37. These unit values are transferred to country specific marginal cost values by adjusting for differences in GDP/capita between countries. Marginal noise costs for aviation are not available for various types of regions. They are estimated at € 26 to 52 per 1,000 vkm (based on average noise cost estimates, see Paragraph 3.4.4). This should be regarded as a very rough estimate.

Table 37 Unit values for marginal noise costs for road and rail (€/1,000 vkm, price level 2008)

Mode	Time of day	Traffic situation	Urban	Suburban	Rural
Car	Day	Dense	9.0	0.5	0.2
		Thin	21.9	1.4	0.1
	Night	Dense	16.5	0.9	0.1
		Thin	39.9	2.6	0.4
MC	Day	Dense	18.1	1.1	0.1
		Thin	43.8	2.8	0.4
	Night	Dense	32.9	1.9	0.2
		Thin	79.8	5.2	0.6
Bus	Day	Dense	45.1	2.5	0.4
		Thin	109.6	7.0	0.8
	Night	Dense	82.3	4.6	0.7
		Thin	199.5	13.0	1.5
LDV	Day	Dense	45.1	2.5	0.4
		Thin	109.6	7.0	0.8
	Night	Dense	82.3	4.6	0.7
		Thin	199.5	13.0	1.5
HDV	Day	Dense	83.0	4.6	0.7
		Thin	201.4	13.0	1.5
	Night	Dense	151.4	8.5	1.3
		Thin	367.0	2.37	2.7
Passenger train	Day	Dense	280.1	12.35	15.4
		Thin	553.5	24.41	30.4
	Night		923.8	40.75	50.8
Freight train	Day	Dense	496.7	24.50	30.6
		Thin	1,198.4	47.45	59.2
	Night		2,026.2	80.20	100.1

5.2.5 Congestion

Marginal congestion costs denote the costs that road users impose upon one another when competing for scarce road space. We can distinguish between current external marginal costs, which just account for the prevailing mutual disturbance, and optimal external costs. The latter describe the residual marginal external costs per road under an optimal internalisation scheme. In order to give an idea of the charges that have to be levied on road users to combat congestion in an as much as possible economically sound way, hereinafter we refer to optimal marginal external congestion costs when we simply write about marginal costs.

Marginal costs of road congestion vary extremely with traffic conditions. Across all road categories they may range from dominating all other externalities to zero within a relatively short period of time. Further we face the difficulty that speed-flow relationships, which constitute the core element in computing marginal congestion costs, loose statistical significance. Moreover, beyond the point of highest throughput, more demand even results in decreasing throughput coupled with decreasing speeds.

We thus give mean values by typical traffic situations to indicate the magnitude and the variability of marginal congestion costs. Here we depart from the values proposed in the EC Handbook (CE/INFRAS/ISI, 2008a). We consider EU-15 countries for price deflation as the underlying willingness-to-pay studies refer to this area rather than to the enlarged European Union. Referring to EUROSTAT data we use a GDP per capita growth factor in real terms of 11.1% to update the EU handbook values to 2008 prices and income levels.

The main driving factors of marginal congestion costs are speed-flow relationships, road vehicle capacity demand, the value of travel time (VOT), and the occupancy of vehicles in terms of passengers and tons of freight. Of these, speed-flow curves, capacity and load factors do not change much over time. The update of marginal congestion cost figures thus may concentrate on VOT, which is again closely linked to income levels. Table 38 presents the IMPACT values updated to 2008 prices.

Table 38 Recommended maximum congestion charges by road type (€$_{2008}$ per VKM)

Area and road type	Passenger cars			Goods vehicles			HDV
	Min.	Centr.	Max	Min.	Centr.	Max.	PCU
Large urban areas (> 2,000,000)							
Urban motorways	0.33	0.56	1.00	1.17	1.94	3.50	3.89
Urban collectors	0.22	0.56	1.33	0.56	1.39	3.33	2.78
Local streets centre	1.67	2.22	3.33	3.33	4.44	6.67	2.22
Local streets cordon	0.56	0.83	1.11	1.11	1.67	2.22	2.22
Small and medium urban areas (< 2,000,000)							
Urban motorways	0.11	0.28	0.44	0.39	0.98	1.56	3.89
Urban collectors	0.06	0.33	0.56	0.14	0.83	1.39	2.78
Local streets cordon	0.11	0.33	0.56	0.22	0.67	1.11	2.22
Rural areas							
Motorways*	0.00	0.11	0.22	0.00	0.39	0.78	3.89
Trunk roads*	0.00	0.06	0.17	0.00	0.14	0.26	2.78

Source: Updated from CE/INFRAS/ISI, 2008a.

Marginal congestion costs clearly rise with the size of agglomeration areas, as here a shift to outside roads is often not possible and as large urban areas attract traffic from surrounding towns. Astonishingly, by far the highest values are found for the smaller streets in agglomerations. This phenomenon may be explained by the much higher effect of a single car than in case of larger and highly occupied infrastructures.

The average of all road types in large agglomerations arrives at a central value for passenger cars around € 1 per kilometre in congested peak hours. Assuming a travel distance of incoming commuters within a central business district of a few kilometres, we may arrive at something around € 5 to 10 per day. This is not far from the price level of the London congestion charge (10 GBP per day). But it deviates much from far the urban tolls in Norwegian and Swedish cities.

Our analysis did not look into urban areas in detail. In the specific case, marginal costs may be well influenced by the availability of alternative modes and by the handing of traffic approaching the area from outside. But the large number of studies, in particular coming from the UK, should give a reasonable idea of the level and variation of marginal congestion costs.

5.2.6 Up- and downstream costs

The marginal change costs for up- and downstream processes are, like the air pollution costs, equal to the average costs, since they only cover the cost of energy production and distribution. Since the difference between the upstream cost of diesel and gasoline production and distribution is very small, there are no differentiated data by fuel type, except for rail transport (electric, diesel).

Table 39 Marginal up- and downstream costs 2008, in €/1,000 vkm and €/1,000 pkm or tkm

Transport mode	Fuel type	Low climate change scen. (25 €/t CO_2)		High climate change scen. (146 €/t CO_2)	
		€ per 1,000 vkm	€ per 1,000 pkm or tkm	€ per 1,000 vkm	€ per 1,000 pkm or tkm
Road					
Passenger Cars		6.0	3.4	9.9	5.7
Motorcycles		2.5	2.3	4.0	3.6
Buses/coaches		16.1	1.5	29.6	2.8
LDV		6.7	8.4	11.5	14.3
HDV		17.9	1.7	31.8	3.0
Rail					
Rail passenger	Electric	378	2.7	1,028	7.2
	Diesel	873	11.4	1,003	13.1
	Total	497	3.9	1,022	8.1
Rail freight	Electric	905	1.7	2,106	4.0
	Diesel	2,328	4.4	2,663	5.1
	Total	1,238	2.4	2,236	4.2
Air and Water					
Aviation passenger		354	3.9	642	7.1
Inland waterways		688	0.8	1,187	1.3

Data in €/1,000 pkm for passenger cars, motorcycles, buses & coaches, rail passenger and air.
Data in €/1,000 tkm for LDV, HDV, rail freight and inland waterways.

6 Discussion and Conclusions

6.1 Discussion of the results

This study shows that the total external cost of transport in the EU-27 without Malta and Cyprus, but including Norway and Switzerland in 2008 amount to more than € 500 billion. This is about 4% of the total GDP. About 77% of the costs are caused by passenger transport and 23% by freight.

With 93%, road transport is responsible for the lion share of the external costs. Passenger cars have a share of about 61%, followed by trucks (13%), vans (9%), two-wheelers (6%) and buses (4%). From the non-road modes, aviation (only intra-EU flights are included) has the largest share in external costs with about 5%. Rail transport is responsible for less than 2% and inland shipping for only 0.3%. Sea shipping was not included in this study.

The high share of the road transport modes can be explained by the high share of road in the overall transport volumes as well as their relatively high average external costs per passenger-km or tonne-km. Comparing the average external costs per passenger-km shows that the external costs of passenger cars or aviation are both about four times those of rail transport. For freight transport we see a similar pattern. The average external costs per tonne-km of trucks are more than four times higher than those of rail transport. The average external costs of inland navigation are about 1.4 times higher.

For road transport (and therefore also for all transport), the predominant cost categories are accidents and emissions (climate change and air pollution). For air transport, climate change costs are the main category.

Marginal external costs have also been calculated, distinguishing between various network types, vehicle technologies and traffic situations. These results show that the marginal external costs for road are also much higher than for rail transport. It becomes clear that the differences between various network types are considerable. The marginal costs in urban areas are much higher than in non-urban areas. The external costs for road transport are lowest on motorways.

Moreover, the share of various cost categories depends strongly on the type of network. In urban areas, accident costs constitute about half of the marginal external costs, while in non-urban areas and particularly motorways the costs of emissions are dominant, in particularly those of climate change.

6.2 Discussion of methodology and data quality

The external costs presented in this study have been based on the latest scientific literature on external cost estimation. The scientific basis for the five core cost categories (accidents, air pollution, climate change, noise and congestion) is quite advanced. The data basis is generally good, but differs per mode and cost category. The methodologies applied in this report built on the previous UIC external cost studies, a broad range of EU research projects (particularly NEEDS, UNITE, HEATCO and GRACE) and last but not least the meta-analysis and recommendations of the IMPACT Handbook on external costs.

The valuation of climate cost is the most uncertain one, which is closely linked to uncertain but potentially very dramatic damages of climate change. Also mitigation costs for meeting the long-term GHG reduction targets (e.g. 80% in 2050) are still not clear. With the new transport-specific CO_2 reduction target of 60% in 2050 compared to 1990, cost estimates for meeting this target would be an extremely useful element in external cost estimation. Further research on this topic, particularly developing a cost curve for the long-term GHG reduction target in transport, for various oil price scenarios, is recommended.

The accident, noise and congestion costs depend strongly on traffic situation and local circumstances. Therefore, the marginal cost estimates for these cost categories should be regarded as relatively rough EU average values. For noise and accidents, marginal cost data have been based on UNITE case studies, which deserve to be updated. For all three cost categories, cost can differ considerably in specific situations. More general, the data basis for congestion costs, is relatively weak and is recommended as subject for further study (across all transport modes).

Other subjects that are recommended for further studying are the following:
- Upstream costs of fuel and electricity production (including external costs of oil spills and nuclear power production).
- External costs related to the security of energy supply.
- External costs related to transport infrastructure and vehicles.
- Costs of nature and landscape.
- Costs of water pollution (shipping).

6.3 Policy application

The results of this study can be used for various purposes. The total and average cost estimates provide a strong basis for comparing the environmental burden of various transport modes. They could also be used for general policy development.

Another application of the external cost estimates could be within the area of cost benefit analysis (CBA). This could be for transport infrastructure projects but also for other types of projects for which a CBA is needed.

Last but not least, the results of the study can also be used as a basis for pricing strategies. Depending on the aim of the instrument, marginal or average cost estimates could be applied. Marginal cost estimates are particularly important for pricing measures that are based on the economic principle of marginal social cost pricing, while the average cost estimates are rather relevant from the perspective of equity (every transport mode paying its external costs). For specific pricing instruments more detailed or specific estimates might be considered.

How to internalise the various external costs that were discussed in this report, is beyond the scope of this study. In IMPACT Deliverable 3 (CE et al., 2008b), a broad assessment was made of internalisation strategies per cost category and transport mode. A summary of the recommended approaches is for illustrative reasons included in the text box below.

Strategy for internalisation of external costs – recommendations from IMPACT (summary)
Especially for road transport, differentiated kilometre based charges are recommended for internalisation of air pollution, noise and congestion costs. Preferably these charges should be differentiated to vehicle characteristics (including Euro standard and particulate filters), location and time of the day. A special focus should be given to traffic in urban areas and sensitive areas such as Transalpine freight traffic, since marginal costs are higher in these areas.

External accident costs can be internalised either by a kilometre-based charge (differentiated to relevant parameters like location, vehicle type and driver characteristics) or via charging insurance companies for these external costs based on accident rates. The latter option is to be preferred but requires further study. For congestion costs local road pricing schemes can be a good alternative to differentiated kilometre based charges. For aviation and maritime shipping, the number of visits to (air)ports could be taken as charge base.

The main recommended internalisation approaches for climate change costs are carbon content based fuel taxes. Also emission trading is a good option, particularly for maritime shipping and aviation.

Source: Summary of IMPACT Deliverable 3 (CE/INFRAS/ISI, 2008b).

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Annex A General Input Data

Overview on data availability

Table 40 presents sources and information about the data used in the calculations.

Table 40 Overview on data sources

	Sources	Based on	Remarks/comparability (INFRAS/IWW, 2004)
Transport Volumes			
Road	– EUROSTAT – TREMOVE database – EU energy and transport in figures (pocketbook PB)	– National statistics – Model calculations – Various statistics	Similar but improved data basis. Significant differences for heavy duty vehicles: corrected/improved data, considerably lower
Rail	– UIC – EUROSTAT	– National statistics – National statistics	Similar but improved database
Aviation	– TREMOVE database	– Model calculations	
Inland waterways	– EUROSTAT (vkm, tkm) – TREMOVE (tkm)	– National statistics – Model calculations	Similar but improved data basis
Emissions			
Road	Emission factors: – TREMOVE database – PM non-exhaust: Ecoplan/INFRAS (2008)	– Model calculations – Emission factors from EMEP data (www.ceip.at)	Similar data basis as in INFRAS/IWW 2004, where TRENDS data were used. TREMOVE is the updated model of TRENDS. Updated data for PM non-exhaust (PM_{10}).
Rail	Emission factors: – TREMOVE database – PM non-exhaust: Ecoplan/INFRAS (2008)	– Model calculations – Emission factors from EMEP data (www.ceip.at)	
Aviation	Total emissions: – TREMOVE database	– Model calculations	Updated data basis
Inland waterways	Emission factors: – TREMOVE database	– Model calculations	Updated data basis
Infrastructure			
Road	– EUROSTAT pocketbook: EU energy and transport in figures	– Various statistics	Similar but updated data basis
Rail	– UIC – SFOS (CH) – (EUROSTAT)	– Statistics of railway companies – National statistics – National statistics	Updated database
Aviation	– EU energy and transport in figures	– EUROSTAT & national statistics	

	Sources	Based on	Remarks/comparability (INFRAS/IWW, 2004)
Inland waterways	– EUROSTAT, Statistical pocketbook	– National statistics	Similar but improved data basis
Accidents			
Road	– CARE Database	– National statistics	Improved data basis with respect to differentiation
Rail	– UIC data – EUROSTAT	– Statistics of railway companies	Similar but updated data basis.
Aviation	– EUROSTAT, AEA, ICAO	– National and international statistics	
Inland waterways	– Not relevant	– Not relevant	

As can be seen in Table 40 the TREMOVE database (TREMOVE, 2010) delivers data for several areas. TREMOVE is a policy assessment model, which is designed to study the effects of different transport and environment policies on the transport sector. The first TREMOVE project (version 2.52) has been financed by the European Commission, DG Environment. The model estimates values for both passenger and freight transport for the period 1995-2030. Therefore a complete set of data is available for:
- Modes of transport: road, rail, waterborne transport, air; different types of vehicles; passenger and freight transport.
- Countries: 31 countries, including EU-27 countries, Norway and Switzerland.
- Regions: metropolitan, other urban, non-urban.
- Fuel types: electric, rail and road diesel, gasoline, natural gas, kerosene, ship gasoil.
- Environmental nuisances, i.e. air emissions: CO_2, N_2O, CH_4, PM_{10} (exhaust and non-exhaust), NO_x, SO_2, NMVOC (inter alia).
- Time span: 1995–2030.

How TREMOVE data has been used is described within the relevant annex chapter.

In the majority of the cases data for the non-EU countries (i.e. Norway and Switzerland) are included in the above listed sources. E.g. the TREMOVE database also contains data for Norway and Switzerland. In some cases (rail traffic performances and infrastructure, traffic performances of HDV) national statistics from Switzerland (BFS) have been used. This has also been done if the listed sources did not comprehend data for a single country.

Table 41 Socio economic data by country

		GDP	Total population	GDP per capita	GDP per capita PPS	Country adjustment factor	Area
	Unit	Bln. €	No.	€ p.c.	€ p.c.	EU-27 = 100	Sqkm
	Base Year	2008	2008	2008	2008	2008	2008
	Source	EUROSTAT	EUROSTAT	EUROSTAT	EUROSTAT	EUROSTAT	EUROSTAT
Country	**Abbrev.**						
Austria	AT	282	8,318,592	33,884	31,000	123	83,879
Belgium	BE	345	10,666,866	32,313	28,900	115	30,528
Bulgaria	BG	34	7,640,238	4,466	10,400	41	111,002
Czech Republic	CZ	148	10,381,130	14,245	20,200	80	78,867
Denmark	DK	233	5,475,791	42,556	30,100	120	43,098
Estonia	EE	16	1,340,935	11,987	16,900	67	45,288
Finland	FI	184	5,300,484	34,748	29,300	117	338,419
France	FR	1,949	63,982,881	30,454	27,000	108	632,834
Germany	DE	2,496	82,217,837	30,356	29,000	116	357,108
Greece	GR	239	11,213,785	21,326	23,600	94	131,957
Hungary	HU	106	10,045,401	10,506	16,100	64	93,028
Ireland	IE	182	4,401,335	41,309	33,900	135	69,797
Italy	IT	1,568	59,619,290	26,298	25,500	102	301,336
Latvia	LV	23	2,270,894	10,145	14,300	57	64,559
Lithuania	LT	32	3,366,357	9,566	15,500	62	65,300
Luxembourg	LU	39	483,799	81,332	69,300	276	2,586
Netherlands	NL	596	16,405,399	36,322	33,600	134	41,543
Norway	NO	309	4,737,171	65,282	47,900	191	323,782
Poland	PL	362	38,115,641	9,508	14,100	56	312,685
Portugal	PT	172	10,617,575	16,192	19,700	78	92,090
Romania	RO	140	21,528,627	6,491	10,400	42	238,391
Slovakia	SK	65	5,400,998	11,994	18,100	72	49,035
Slovenia	SI	37	2,010,269	18,473	22,800	91	20,273
Spain	ES	1,089	45,283,259	24,038	25,700	103	505,987
Sweden	SE	334	9,182,927	36,397	30,700	122	441,370
Switzerland	CH	341	7,593,494	44,950	35,300	141	41,285
United Kingdom	UK	1,819	61,179,256	29,731	29,100	116	243,069
TOTAL	**TT**	**13,139**	**508,780,231**	**25,825**	**25,100**	**100**	**4,759,095**

GDP p.c. PPS and the adjustment factor for RO are 2007 data, sqkm for BG, IT & SI also 2007, for LU, PL & ES 2006, for UK 2004.

The gross domestic product (GDP) is the result of all production activity of country residents at market prices, normally calculated in national currencies. In order to facilitate a comparison with other countries the GDP of each country is converted into a common currency, in case of the EU Euro (since the beginning of 1999), by means of its official exchange rate. As GDP is normally larger in countries with higher population, it is often depicted in per capita values, taking into account the number of persons living in a country.

To reflect the actual purchasing power in each country and to remove distortions due to price-level differences between countries, purchasing power parities (PPPs) are calculated and used as a factor of conversion (exchange rate from national currency to PPS). These parities are obtained as a weighted average of relative price ratios regarding a homogeneous basket of goods and services, comparable and representative for each Member State. Hence, the 'comparable volume' values of GDP obtained in this way are expressed in terms of purchasing power standards (PPS), a unit that is independent of any national currency.

Traffic volumes
Traffic volumes from different sources (EUROSTAT, UIC, EU energy and transport in figures Pocketbook, TREMOVE, national statistics) have been compared. This process allows for a validation of the finally used data and augments their accurateness. The exact approach is described for each mode of transport.

Road Transport
Beside the TREMOVE database values from EUROSTAT and from the Pocketbook are available. Data for passenger traffic performances (i.e. passenger-kilometres) for passenger cars and buses are taken from the Pocketbook as this source turns out to be the most accurate and complete. However in the case of motorcycles and mopeds neither the Pocketbook nor EUROSTAT deliver data for the relevant countries. In this case TREMOVE values are used. Concerning freight traffic performances consistent values from the Pocketbook and EUROSTAT are taken for HDV. Tonne-kilometres for LDV are being calculated from vehicle-kilometres using a constant load factor for all countries.

Due to a lack of vehicle-kilometre data for passenger transport in official statistics TREMOVE data are used for this variable. Where a comparison of the latter with statistical values was possible, TREMOVE data have been corrected and rescaled by an appropriate factor. This was done for vkm of passenger cars in seventeen countries. For HDV-vkm values from EUROSTAT are taken. HDV-LDV-split factors from several national statistics are then used to calculate LDV-vkm.

The following tables show the aggregated mileage data (Table 42) and traffic performance (Table 43) for road passenger and freight transport.

Table 42 Road transport data, vehicle-kilometres by country

		Vehicle kilometres						
		Passenger transport				Freight transport		
		Total	Car	Buses & coaches	Two-wheelers	Total	HDV	LDV
	Unit	Mio. vkm	Mio. vkm	Mio. vkm	Mio. vkm	Mio. vkm	Mio. vkm	Mio. vkm
	Base Year	2008	2008	2008	2008	2008	2008	2008
	Source		National stat.	TREMOVE	TREMOVE		EUROSTAT	EUROSTAT & nat.stat.
Country	**Abbrev.**							
Austria	AT	53,548	50,386	1,717	1,445	9,186	3,154	6,032
Belgium	BE	68,851	66,077	1,097	1,677	7,800	2,678	5,122
Bulgaria	BG	23,218	17,844	2,548	2,825	5,167	1,774	3,393
Czech Republic	CZ	38,746	32,834	1,215	4,697	15,623	5,364	10,259
Denmark	DK	37,379	35,585	1,220	573	6,300	2,163	4,137
Estonia	EE	3,693	3,214	141	338	1,756	603	1,153
Finland	FI	47,412	45,806	940	666	7,847	2,694	5,153
France	FR	427,975	412,933	4,655	10,388	116,351	20,794	95,557
Germany	DE	617,957	596,399	8,061	13,497	92,583	31,787	60,796
Greece	GR	42,060	29,018	1,661	11,381	8,936	3,068	5,868
Hungary	HU	31,546	26,251	988	4,307	9,597	3,295	6,302
Ireland	IE	23,411	22,349	718	345	6,912	2,373	4,539
Italy	IT	310,740	267,967	9,637	33,136	33,259	11,419	21,840
Latvia	LV	7,286	6,404	172	710	3,000	1,030	1,970
Lithuania	LT	8,176	7,272	92	812	4,791	1,645	3,146
Luxembourg	LU	5,172	4,965	123	83	2,039	700	1,339
Netherlands	NL	108,265	106,449	967	849	27,511	9,386	18,125
Norway	NO	47,739	45,677	785	1,277	5,872	2,016	3,856
Poland	PL	120,128	107,488	2,589	10,051	49,226	16,901	32,325
Portugal	PT	48,571	43,131	1,028	4,413	10,582	3,633	6,949
Romania	RO	34,603	29,012	650	4,941	9,670	3,320	6,350
Slovakia	SK	15,860	13,175	866	1,820	10,416	3,576	6,840
Slovenia	SI	13,123	10,535	96	2,492	4,145	1,423	2,722
Spain	ES	293,514	280,572	3,538	9,405	60,108	20,637	39,471
Sweden	SE	67,309	65,480	1,074	755	8,531	2,929	5,602
Switzerland	CH	54,905	51,948	432	2,526	4,445	1,716	2,729
United Kingdom	UK	415,208	403,557	5,963	5,688	76,317	22,647	53,670
TOTAL	**TT**	**2,966,397**	**2,782,328**	**52,972**	**131,097**	**597,969**	**182,725**	**415,244**

For passenger cars, data from TREMOVE had to be taken for some of the countries.

Table 43 Road transport data, traffic performances (pkm, tkm) by country

		Traffic performances						
		Passenger transport				Freight transport		
		Total	Car	Buses & coaches	Mopeds & motorcycles	Total	HDV	LDV
	Unit	Mio. pkm	Mio. pkm	Mio. pkm	Mio. pkm	Mio. tkm	Mio. tkm	Mio. tkm
	Base year	2008	2008	2008	2008	2008	2008	2008
	Source		PB	PB	TREMOVE		EUROSTAT	EUROSTAT & nat.stat.
Country	Abbrev.							
Austria	AT	84,424	73,283	9,551	1,590	39,139	34,313	4,826
Belgium	BE	133,115	110,900	20,370	1,845	42,454	38,356	4,098
Bulgaria	BG	60,147	43,200	13,839	3,108	18,036	15,322	2,714
Czech Republic	CZ	93,635	72,380	16,088	5,167	59,084	50,877	8,207
Denmark	DK	60,822	52,862	7,329	631	22,790	19,480	3,310
Estonia	EE	13,324	10,500	2,453	371	8,277	7,354	923
Finland	FI	71,673	63,400	7,540	733	35,158	31,036	4,122
France	FR	780,152	720,173	48,553	11,426	282,750	206,304	76,446
Germany	DE	930,639	852,272	63,520	14,847	390,169	341,532	48,637
Greece	GR	134,619	100,000	22,100	12,519	33,544	28,850	4,694
Hungary	HU	64,392	42,000	17,654	4,738	40,801	35,759	5,042
Ireland	IE	56,909	49,030	7,500	379	21,033	17,402	3,631
Italy	IT	859,920	719,558	103,912	36,450	196,883	179,411	17,472
Latvia	LV	20,268	17,000	2,487	781	13,920	12,344	1,576
Lithuania	LT	42,315	38,000	3,421	893	22,936	20,419	2,517
Luxembourg	LU	7,702	6,700	910	92	10,453	9,382	1,071
Netherlands	NL	160,434	147,000	12,500	934	92,659	78,159	14,500
Norway	NO	63,507	57,743	4,360	1,404	23,680	20,595	3,085
Poland	PL	311,347	273,500	26,791	11,056	190,790	164,930	25,860
Portugal	PT	102,784	87,000	10,930	4,854	44,650	39,091	5,559
Romania	RO	89,816	70,500	13,880	5,436	61,466	56,386	5,080
Slovakia	SK	37,146	26,395	8,750	2,001	34,748	29,276	5,472
Slovenia	SI	30,765	24,878	3,146	2,741	18,438	16,261	2,177
Spain	ES	410,345	339,100	60,900	10,345	274,559	242,983	31,576
Sweden	SE	108,010	98,422	8,758	830	46,852	42,370	4,482
Switzerland	CH	92,451	83,573	6,100	2,778	18,402	16,218	2,184
United Kingdom	UK	737,257	679,000	52,000	6,257	214,413	171,477	42,936
TOTAL	**TT**	**5,557,918**	**4,858,369**	**555,343**	**144,206**	**2,258,082**	**1,925,887**	**332,195**

To show external costs for different vehicle categories (e.g. different passenger car categories like petrol/Diesel) traffic volume shares from TREMOVE are applied to the aggregated road transport vehicle-kilometres and transport performance data.

Rail Transport

With respect to rail data all four sources (UIC, EUROSTAT, Pocketbook, TREMOVE) are available. A comparison of traffic performances shows the overall values to be within in a range of less than 10% for both passenger and freight transport (for the latter without UIC data). Also for train-kilometres overall values do not differ largely between the data sources. Therefore UIC data is used. In case of abnormal deviations (as UIC does not include all railway associations in some countries) EUROSTAT values are taken.

To allocate overall train-kilometres to the different traction types split factors are used. These factors represent the ratio of train-kilometres with a special traction type (e.g. diesel locomotives) and of overall passenger (or freight) train-kilometres. Hence, split factors are taken from the source that delivers the train-km data (i.e. UIC or EUROSTAT), expect for four countries where no such differentiation is available and TREMOVE split factors are used. To allocate traffic performances (pkm, tkm) to the different traction types only TREMOVE split factors are used (other sources do not deliver data in this differentiation).

Table 44 Rail transport data, train-kilometres by country

		Train kilometres															
		All types of traction			Diesel locomotives			Electric locomotives			Diesel Railcars		Electric Railcars		Relative share of electric rail		
		Total	Passenger	Freight	Total	Passenger	Freight	Total	Passenger	Freight	Total	Passenger	Total	Passenger	Passenger	Freight	Total
	Unit	Mln. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	Mio. train-km	% of total train-km	% of total train-km	% of total train-km
	Base year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
	Source	UIC	UIC	UIC	UIC	UIC	UIC	UIC	UIC	UIC	UIC	UIC	UIC	UIC			
Country	Abbrev.																
Austria	AT	144	97	47	8	4	3	90	46	44	13	13	33	33	82%	93%	85%
Belgium	BE	96	81	14	3	0	3	29	20	9	6	6	58	56	93%	76%	90%
Bulgaria	BG	36	24	12	3	1	2	24	15	9	3	3	5	5	82%	80%	82%
Czech Republic	CZ	153	121	32	13	8	6	73	46	27	54	54	13	13	49%	82%	56%
Denmark	DK	61	58	4	6	5	2	2	0	2	28	27	26	26	45%	43%	45%
Estonia	EE	7	4	3	4	0	3	0	0	0	1	1	2	2	59%	0%	30%
Finland	FI	53	35	18	7	1	6	29	17	12	2	2	16	16	92%	66%	83%
France	FR	517	409	108	31	18	13	188	95	93	63	63	235	233	80%	88%	82%
Germany	DE	919	687	233	170	117	53	504	327	177	123	121	123	123	65%	76%	68%
Greece	GR	21	18	3	7	5	2	1	0	1	11	11	2	2	13%	20%	14%
Hungary	HU	107	88	19	13	9	4	66	51	15	24	24	4	4	62%	81%	65%
Ireland	IE	14	14	1	10	9	1	0	0	0	2	2	2	2	18%	0%	17%
Italy	IT	342	290	53	20	15	5	236	188	48	34	34	52	52	83%	91%	84%
Latvia	LV	18	8	11	11	1	11	0	0	0	3	3	4	4	55%	0%	23%
Lithuania	LT	16	5	10	12	2	10	0	0	0	3	3	1	1	22%	0%	8%
Luxembourg	LU	7	6	1	0	0	0	4	3	1	0	0	3	3	98%	67%	94%
Netherlands	NL	122	111	11	2	0	2	36	29	6	4	4	80	78	97%	78%	95%
Norway	NO	44	34	10	5	3	3	14	7	7	3	3	21	21	82%	74%	80%
Poland	PL	203	123	80	26	15	12	119	51	68	9	9	49	48	80%	85%	82%
Portugal	PT	43	32	11	10	6	4	10	5	5	9	8	14	13	58%	51%	56%
Romania	RO	88	67	21	25	19	6	50	35	15	12	12	1	1	54%	71%	58%
Slovakia	SK	52	31	20	8	4	4	32	16	16	9	9	2	2	58%	79%	66%
Slovenia	SI	20	12	8	2	0	1	9	2	7	4	4	5	5	65%	80%	71%
Spain	ES	210	177	32	14	7	7	41	16	25	23	23	132	132	83%	78%	82%
Sweden	SE	141	94	48	8	4	4	103	60	43	5	5	26	25	91%	92%	91%
Switzerland	CH	208	177	31	2	0	2	116	86	29	0	0	90	90	100%	95%	99%
United Kingdom	UK	511	482	28	74	51	23	207	201	6	49	49	181	181	79%	20%	76%
TOTAL	**TT**	**4,154**	**3,283**	**871**	**496**	**303**	**193**	**1,980**	**1,317**	**663**	**496**	**491**	**1,182**	**1,172**	**76%**	**77%**	**76%**

Table 45 Rail transport data, traffic performances (pkm, tkm) by country

		Traffic performances (pkm, tkm)								Rel. share of electric rail	
		All types of traction		Diesel locomotives		Electric locomotives		Diesel Railcars	Electric Railcars		
		Passenger	Freight	Passenger	Freight	Passenger	Freight	Passenger	Passenger	Passenger	Freight
	Unit	Mio. pkm	Mio. tkm	Mio. pkm	Mio. tkm	Mio. pkm	Mio. tkm	Mio. pkm	Mio. pkm	% of total pkm	% of total tkm
	Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
	Source	UIC	EUROSTAT	UIC	EUROSTAT	UIC	EUROSTAT	UIC	UIC		
Country	**Abbrev.**										
Austria	AT	10,275	21,915	602	1,111	7,676	20,804	149	1,849	93%	95%
Belgium	BE	10,404	8,572	3	1,839	4,233	6,733	160	6,008	98%	79%
Bulgaria	BG	2,335	4,693	175	553	1,521	4,140	30	608	91%	88%
Czech Republic	CZ	6,759	15,437	643	1,425	4,163	14,012	996	956	76%	91%
Denmark	DK	5,836	1,866	2,137	813	340	1,053	1,501	1,857	38%	56%
Estonia	EE	274	5,943	14	5,943	0	0	55	204	75%	0%
Finland	FI	4,052	10,777	357	4,159	2,902	6,618	0	793	91%	61%
France	FR	88,624	40,627	6,230	4,097	33,039	36,530	4,066	45,290	88%	90%
Germany	DE	76,929	115,652	3,709	11,845	45,239	103,807	5,847	22,134	88%	90%
Greece	GR	1,657	786	1,000	660	0	126	657	0	0%	16%
Hungary	HU	5,848	9,874	507	1,357	4,359	8,517	791	192	78%	86%
Ireland	IE	1,976	103	1,814	103	0	0	29	133	7%	0%
Italy	IT	46,998	23,831	1,568	739	43,828	23,092	111	1,490	96%	97%
Latvia	LV	749	19,581	79	19,581	0	0	77	593	79%	0%
Lithuania	LT	398	14,748	131	14,748	0	0	88	179	45%	0%
Luxembourg	LU	345	279	2	49	235	230	4	103	98%	83%
Netherlands	NL	15,313	6,984	0	1,222	1,846	5,762	1,092	12,375	93%	83%
Norway	NO	2,705	3,621	368	503	496	3,118	305	1,537	75%	86%
Poland	PL	17,958	52,043	1,336	6,689	12,937	45,354	31	3,655	92%	87%
Portugal	PT	3,814	2,549	500	906	1,229	1,643	332	1,754	78%	64%
Romania	RO	6,880	15,236	1,654	3,138	4,363	12,098	863	0	63%	79%
Slovakia	SK	2,279	9,299	197	1,147	1,225	8,152	349	508	76%	88%
Slovenia	SI	834	3,520	30	721	375	2,799	114	315	83%	80%
Spain	ES	23,343	10,475	2,552	1,885	6,516	8,590	1,904	12,370	81%	82%
Sweden	SE	7,156	23,116	0	1,082	3,501	22,034	181	3,474	97%	95%
Switzerland	CH	18,366	12,265	0	431	13,612	11,834	0	4,754	100%	96%
United Kingdom	UK	52,027	24,831	9,243	19,955	15,061	4,876	6,035	21,688	71%	20%
TOTAL	**TT**	**414,134**	**458,623**	**34,851**	**106,702**	**208,697**	**351,921**	**25,767**	**144,819**	**85%**	**77%**

Data sources or base years for train-kilometres that differ from indicated declarations in Table 44 are summarised in Table 46.

Table 46 Countries with different data sources and base years (train-km)

	Passenger transport	Freight transport
EUROSTAT (instead of UIC)	Estonia, Hungary, Latvia, Norway, Sweden	Denmark, France, Netherlands, Norway, Poland, Slovakia, Sweden
National statistics	Switzerland (BFS)	Switzerland (BFS)
Other base year than indicated	Hungary (2007)	Poland (2000) France (2005) Denmark (2006) Netherlands (2007)

Table 47 Rail transport data, load factors by country (passenger/train and ton/train)

		All types of traction		Diesel locomotives		Electric locomotives		Diesel railcars	Electric railcars
		Passenger	Freight	Passenger	Freight	Passenger	Freight	Passenger	Passenger
	Unit	p/train	t/train	p/train	t/train	p/train	t/train	p/train	p/train
Country	**Abbrev.**								
Austria	AT	106	464	136	327	167	475	11	56
Belgium	BE	128	599	72	577	215	755	28	107
Bulgaria	BG	97	405	146	244	102	444	10	122
Czech Republic	CZ	56	476	84	254	90	527	19	72
Denmark	DK	101	496	466	454	1,061	689	55	73
Estonia	EE	78	1,732	43	1,732	0	0	50	98
Finland	FI	116	593	309	664	174	555	0	51
France	FR	217	375	349	306	349	392	64	194
Germany	DE	112	497	32	224	138	586	48	180
Greece	GR	90	276	192	288	0	226	61	0
Hungary	HU	67	522	55	385	86	553	33	54
Ireland	IE	145	175	193	175	0	0	17	54
Italy	IT	162	454	105	149	233	486	3	28
Latvia	LV	98	1,850	112	1,850	0	0	28	143
Lithuania	LT	73	1,449	86	1,458	0	0	33	147
Luxembourg	LU	56	286	811	150	75	354	41	36
Netherlands	NL	138	615	0	495	63	911	299	159
Norway	NO	79	372	133	195	72	436	89	73
Poland	PL	146	647	90	578	253	670	3	76
Portugal	PT	121	227	86	207	235	341	44	135
Romania	RO	103	710	87	508	126	791	74	0
Slovakia	SK	73	457	52	264	76	510	38	247
Slovenia	SI	71	418	109	540	151	426	30	62
Spain	ES	132	324	357	265	414	341	84	94
Sweden	SE	76	485	0	281	58	517	39	139
Switzerland	CH	104	395	0	265	158	402	0	53
United Kingdom	UK	108	882	181	882	75	882	122	120
TOTAL	**TT**	**126**	**527**	**115**	**554**	**158**	**531**	**53**	**124**

Aviation

Transport data for aviation are based on EUROSTAT data. However, EUROSTAT data only includes comprehensive data about the number of flights and the number of passengers per country and flight type (domestic, continental, intercontinental). Therefore, the passenger-km and flight-km data had to be calculated with the average flight lengths based on national statistics data. Results are shown in Table 48.
Please note that the data only include continental flights, which means all domestic flights and flights within the EU (plus NO and CH). For avoiding double counting, only departing flights are included.

Table 48 Air transport data, passenger-kilometres and flight-km by country

Traffic performance: Continental flights (domestic & intra-EU incl. NO/CH)			
	Unit	Mio. pkm	Mio. flight-km
	Base Year	2008	2008
	Source	EUROSTAT	EUROSTAT
Country	Abbrev.		
Austria	AT	9,691	133
Belgium	BE	8,906	122
Bulgaria	BG	3,029	29
Czech Republic	CZ	5,681	79
Denmark	DK	9,969	128
Estonia	EE	853	16
Finland	FI	6,506	90
France	FR	41,776	544
Germany	DE	60,383	720
Greece	GR	16,832	150
Hungary	HU	3,777	46
Ireland	IE	15,434	133
Italy	IT	45,470	476
Latvia	LV	1,628	23
Lithuania	LT	1,192	19
Luxembourg	LU	792	20
Netherlands	NL	17,111	195
Norway	NO	12,915	196
Poland	PL	8,437	107
Portugal	PT	11,279	116
Romania	RO	3,884	51
Slovakia	SK	1,258	15
Slovenia	SI	586	14
Spain	ES	75,962	667
Sweden	SE	12,370	147
Switzerland	CH	15,207	204
United Kingdom	UK	81,426	788
TOTAL	**TT**	**472,354**	**5,226**

Waterborne Transport

Transport performance data (tkm) for inland waterways are taken from EUROSTAT (Statistical Pocketbook 2010). Since no reliable data for vehicle-km of inland waterways are available, these data have been calculated on the basis of the tkm, using load factor data from TREMOVE[21].

[21] Including a correction factor, that has been derived from Dutch load factor data.

Table 49 Inland waterways data, ton-kilometres and vehicle-kilometres by country

Country	Abbrev.	Inland waterways	
		Mio. tkm	Mio. vkm
Austria	AT	2,359	1.8
Belgium	BE	8,746	12.9
Bulgaria	BG	2,890	6.8
Czech Republic	CZ	28	0.0
Denmark	DK	0	0.0
Estonia	EE	0	0.0
Finland	FI	80	0.1
France	FR	8,896	10.0
Germany	DE	64,056	62.6
Greece	GR	0	0.0
Hungary	HU	2,250	2.1
Ireland	IE	0	0.0
Italy	IT	76	0.1
Latvia	LV	0	0.0
Lithuania	LT	13	0.0
Luxembourg	LU	367	0.5
Netherlands	NL	45,296	57.7
Norway	NO	0	0.0
Poland	PL	277	0.4
Portugal	PT	0	0.0
Romania	RO	8,687	7.3
Slovakia	SK	1,101	0.9
Slovenia	SI	0	0.0
Spain	ES	0	0.0
Sweden	SE	0	0.0
Switzerland	CH	43	0.0
United Kingdom	UK	149	0.2
TOTAL	**TT**	**145,313**	**163.6**

Emission factors

Emission factors for air pollutants and greenhouse gas emissions are taken from the TREMOVE database (TREMOVE, 2010). TREMOVE is a transport and emission simulation model developed for the European Commission. The model has been developed by Transport & Mobility Leuven and the Catholic University of Leuven. The model estimates transport demand, the modal split, the vehicle stock turnover, the emission of air pollutants for 31 European countries. The data are also available for many differentiations: by vehicle and fuel type, by region type and by road type.

For the emission of CO_2, N_2O, CH_4 (greenhouse gases) as well as $PM_{2.5}$ (exhaust), NO_x, SO_2 and NMVOC, emission factors from the TREMOVE model have been adapted. For these pollutants, TREMOVE data were available for exhaust emissions and also well-to-tank emissions (precombustion) for upstream effects.

Only non-exhaust emissions of particles (PM_{10}) could not be taken from TREMOVE due to lack of data. Non-exhaust emissions of particles (PM_{10}) of road and rail transport have been calculated on the basis of EMEP emission database (EMEP: European Monitoring and Evaluation Programme; EMEP, 2009).
The following tables show the emission factors of the most important greenhouse gases and air pollutants for all transport modes.

Table 50 CO_2 (exhaust) emission factors

	Passenger transport						Freight transport				
	Road				Rail	Aviation	Road			Rail	Waterborne
Unit	Passenger cars	Buses & coaches	Motorcycles	Total road passenger transport	Passenger transport	Passenger transport (incl. LTO)	LDV	HDV	Total road freight transport	Freight transport	Inland waterways
	g/vkm	g/vkm	g/vkm	g/vkm	g/train-km	g/vkm	g/vkm	g/vkm	g/vkm	g/train-km	g/vkm
Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
Source	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE
Country											
Austria	188	586	84	198	942	11,980	268	634	394	802	25,400
Belgium	195	615	79	198	401	11,778	240	751	415	4,089	20,660
Bulgaria	174	566	51	202	1,338	16,804	221	617	357	2,200	21,312
Czech Republic	188	556	77	186	1,334	11,787	221	721	393	1,666	22,226
Denmark	198	626	80	211	4,932	13,128	213	707	383	5,809	n,a,
Estonia	226	623	65	226	4,498	8,896	231	627	367	36,355	n,a,
Finland	213	648	81	220	217	12,869	232	712	397	4,762	21,667
France	196	636	84	198	1,043	14,200	254	663	327	1,137	19,882
Germany	212	672	94	215	1,928	14,844	276	680	415	3,036	21,667
Greece	185	581	79	172	6,467	19,830	219	633	361	6,934	n,a,
Hungary	193	552	74	188	1,530	13,342	225	599	353	2,936	22,664
Ireland	186	630	76	198	6,435	19,045	200	633	349	13,336	n,a,
Italy	188	652	86	192	879	17,610	271	707	421	494	19,882
Latvia	223	669	84	220	4,655	11,251	230	616	362	41,610	n,a,
Lithuania	203	598	71	194	9,069	10,210	222	656	371	35,202	21,667
Luxembourg	196	618	76	204	50	6,398	209	670	367	5,371	20,660
Netherlands	210	747	74	214	188	14,193	256	741	422	2,843	21,317
Norway	207	608	69	210	757	13,155	214	679	373	2,949	n,a,
Poland	181	576	69	180	1,366	13,071	215	665	369	1,815	14,939
Portugal	192	615	75	190	2,720	16,553	221	760	406	5,436	n,a,
Romania	186	561	56	175	2,293	12,715	224	610	357	5,932	22,825
Slovakia	189	544	84	197	1,797	13,703	218	546	331	2,290	22,694
Slovenia	192	596	75	172	1,269	6,838	223	661	373	1,437	n,a,
Spain	191	607	57	192	1,018	20,654	211	699	378	3,149	n,a,
Sweden	230	585	81	234	112	15,210	225	684	382	900	n,a,
Switzerland	208	630	64	205	0	12,151	240	661	403	583	21,667
United Kingdom	231	820	97	237	1,123	17,795	234	815	406	7,434	21,317
TOTAL	**204**	**647**	**79**	**206**	**1,314**	**15,887**	**242**	**696**	**381**	**3,420**	**21,431**

Data source: TREMOVE (2010).

Table 51 $PM_{2.5}$ (exhaust) emission factors

	Passenger transport						Freight transport				
	Road				Rail	Aviation	Road			Rail	Waterborne
	Passenger cars	Buses & coaches	Motorcycles	Total road passenger transport	Passenger transport	Passenger transport (incl. LTO)	LDV	HDV	Total road freight transport	Freight transport	Inland waterways
Unit	g/vkm	g/vkm	g/vkm	g/vkm	g/train-km	g/vkm	g/vkm	g/vkm	g/vkm	g/train-km	g/vkm
Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
Source	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE
Country											
Austria	0.030	0.130	0.071	0.034	0.610	n.a.	0.051	0.083	0.062	0.520	12.0
Belgium	0.034	0.114	0.022	0.035	0.260	n.a.	0.094	0.134	0.107	2.649	9.9
Bulgaria	0.022	0.118	0.045	0.036	0.867	n.a.	0.051	0.166	0.091	1.425	10.2
Czech Republic	0.029	0.103	0.090	0.038	0.865	n.a.	0.045	0.202	0.099	1.079	10.7
Denmark	0.016	0.155	0.053	0.021	3.195	n.a.	0.064	0.116	0.081	3.764	n.a.
Estonia	0.020	0.123	0.023	0.024	2.914	n.a.	0.087	0.113	0.096	23.554	n.a.
Finland	0.042	0.113	0.045	0.043	0.141	n.a.	0.190	0.158	0.179	3.085	10.4
France	0.035	0.110	0.038	0.036	0.676	n.a.	0.052	0.103	0.061	0.737	9.5
Germany	0.018	0.138	0.034	0.020	1.249	n.a.	0.045	0.098	0.063	1.967	10.4
Greece	0.006	0.090	0.048	0.021	4.190	n.a.	0.025	0.156	0.070	4.492	n.a.
Hungary	0.027	0.086	0.083	0.037	0.991	n.a.	0.088	0.124	0.100	1.902	10.9
Ireland	0.012	0.091	0.031	0.015	4.169	n.a.	0.087	0.066	0.080	8.640	n.a.
Italy	0.023	0.127	0.057	0.030	0.570	n.a.	0.084	0.154	0.108	0.320	9.5
Latvia	0.023	0.146	0.047	0.029	3.016	n.a.	0.065	0.089	0.074	26.958	n.a.
Lithuania	0.032	0.110	0.017	0.032	5.876	n.a.	0.101	0.195	0.134	22.807	10.4
Luxembourg	0.029	0.090	0.043	0.031	0.032	n.a.	0.052	0.122	0.076	3.479	9.9
Netherlands	0.017	0.135	0.038	0.018	0.122	n.a.	0.001	0.143	0.050	1.842	10.2
Norway	0.018	0.095	0.046	0.020	0.490	n.a.	0.066	0.144	0.093	1.911	n.a.
Poland	0.015	0.110	0.069	0.022	0.885	n.a.	0.050	0.125	0.075	1.176	7.5
Portugal	0.019	0.111	0.074	0.026	1.762	n.a.	0.091	0.195	0.127	3.522	n.a.
Romania	0.020	0.128	0.031	0.023	1.485	n.a.	0.050	0.163	0.089	3.843	11.0
Slovakia	0.024	0.126	0.133	0.042	1.164	n.a.	0.114	0.153	0.127	1.484	10.9
Slovenia	0.020	0.102	0.027	0.022	0.822	n.a.	0.052	0.129	0.079	0.931	n.a.
Spain	0.031	0.102	0.049	0.032	0.659	n.a.	0.087	0.154	0.110	2.040	n.a.
Sweden	0.013	0.098	0.036	0.014	0.073	n.a.	0.063	0.110	0.079	0.583	n.a.
Switzerland	0.009	0.130	0.048	0.011	0.000	n.a.	0.056	0.122	0.081	0.378	10.4
United Kingdom	0.021	0.129	0.029	0.022	0.728	n.a.	0.075	0.127	0.090	1.437	10.2
TOTAL	**0.024**	**0.120**	**0.052**	**0.027**	**0.851**	**n.a.**	**0.062**	**0.129**	**0.082**	**2.106**	**10.3**

Data source: TREMOVE (2010).

Table 52 PM_{10} (non-exhaust) emission factors

	Emission factors - PM_{10} (non-exhaust)									
	Passenger transport						Freight transport			
	Road				Rail	Aviation	Road			Rail
	Passenger cars	Buses & coaches	Motorcycles	Total road passenger transport	Passenger transport	Passenger transport (incl. LTO)	LDV	HDV	Total road freight transport	Freight transport
Unit	g/vkm	g/vkm	g/vkm	g/vkm	g/train-km	g/vkm	g/vkm	g/vkm	g/vkm	g/train-km
Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
Source	EMEP 2009	EMEP 2009	EMEP 2009	EMEP 2009	EMEP 2009	EMEP 2009	EMEP 2009	EMEP 2009	EMEP 2009	EMEP 2009
Country										
Austria	0.050	0.105	0.044	0.052	5.10	0.0	0.055	0.108	0.074	13.85
Belgium	0.050	0.102	0.044	0.051	5.10	0.0	0.057	0.108	0.075	13.85
Bulgaria	0.051	0.105	0.045	0.056	5.10	0.0	0.059	0.115	0.078	13.85
Czech Republic	0.051	0.099	0.045	0.052	5.10	0.0	0.059	0.111	0.077	13.85
Denmark	0.050	0.105	0.044	0.052	5.10	0.0	0.061	0.111	0.078	13.85
Estonia	0.053	0.107	0.045	0.054	5.10	0.0	0.059	0.108	0.076	13.85
Finland	0.051	0.109	0.044	0.052	5.10	0.0	0.060	0.115	0.079	13.85
France	0.051	0.107	0.044	0.051	5.10	0.0	0.056	0.115	0.066	13.85
Germany	0.051	0.103	0.044	0.051	5.10	0.0	0.055	0.112	0.074	13.85
Greece	0.052	0.107	0.045	0.052	5.10	0.0	0.060	0.112	0.078	13.85
Hungary	0.049	0.100	0.043	0.050	5.10	0.0	0.059	0.103	0.074	13.85
Ireland	0.051	0.108	0.044	0.053	5.10	0.0	0.061	0.115	0.080	13.85
Italy	0.050	0.103	0.044	0.051	5.10	0.0	0.055	0.107	0.073	13.85
Latvia	0.052	0.107	0.045	0.053	5.10	0.0	0.059	0.111	0.077	13.85
Lithuania	0.051	0.100	0.045	0.051	5.10	0.0	0.059	0.102	0.074	13.85
Luxembourg	0.054	0.116	0.046	0.055	5.10	0.0	0.067	0.130	0.088	13.85
Netherlands	0.051	0.106	0.044	0.051	5.10	0.0	0.055	0.110	0.074	13.85
Norway	0.051	0.102	0.044	0.051	5.10	0.0	0.058	0.117	0.078	13.85
Poland	0.051	0.104	0.044	0.051	5.10	0.0	0.059	0.109	0.076	13.85
Portugal	0.050	0.096	0.044	0.051	5.10	0.0	0.058	0.107	0.075	13.85
Romania	0.049	0.100	0.043	0.049	5.10	0.0	0.059	0.102	0.074	13.85
Slovakia	0.050	0.099	0.044	0.052	5.10	0.0	0.059	0.103	0.074	13.85
Slovenia	0.051	0.109	0.045	0.051	5.10	0.0	0.058	0.108	0.075	13.85
Spain	0.051	0.104	0.045	0.052	5.10	0.0	0.058	0.114	0.077	13.85
Sweden	0.052	0.110	0.045	0.052	5.10	0.0	0.058	0.116	0.078	13.85
Switzerland	0.050	0.103	0.044	0.050	5.10	0.0	0.055	0.114	0.078	13.85
United Kingdom	0.053	0.109	0.045	0.053	5.10	0.0	0.061	0.123	0.079	13.85
TOTAL	**0.051**	**0.105**	**0.044**	**0.052**	**5.10**	**0.0**	**0.057**	**0.112**	**0.074**	**13.85**

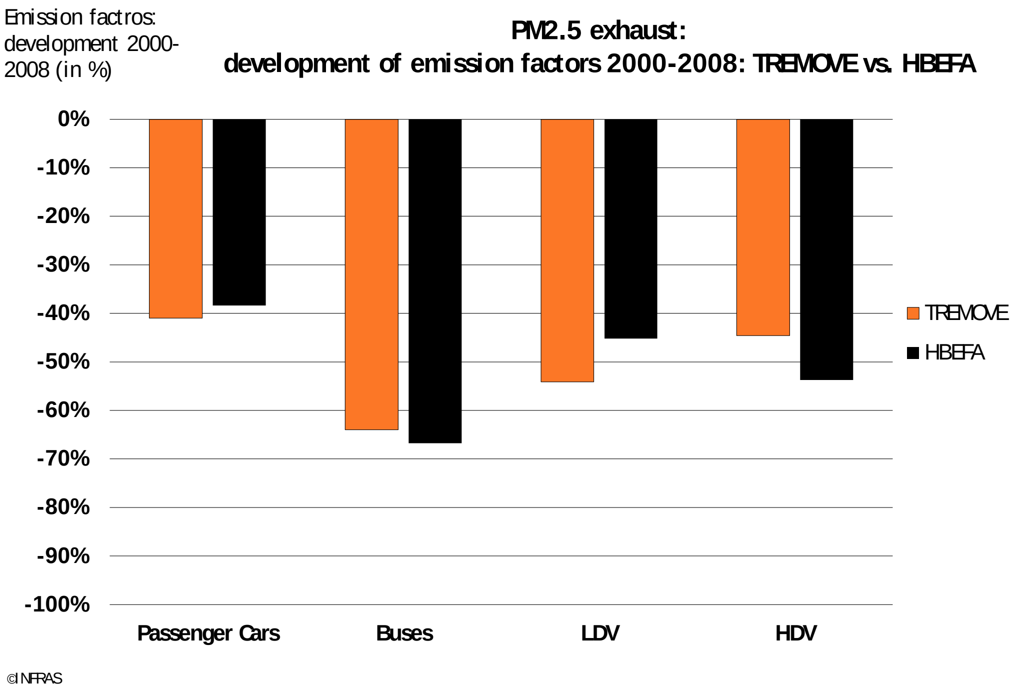
Data source: EMEP (2009). There are no non-exhaust emissions for air and water transport.

Table 53 Nitrogen oxide (NO_x, exhaust)

	Emission factors - NO_x (exhaust)										
	Passenger transport						Freight transport				
	Road				Rail	Aviation	Road			Rail	Waterborne
	Passenger cars	Buses & coaches	Motorcycles	Total road passenger transport	Passenger transport	Passenger transport (incl. LTO)	LDV	HDV	Total road freight transport	Freight transport	Inland waterways
Unit	g/vkm	g/vkm	g/vkm	g/vkm	g/train-km	g/vkm	g/vkm	g/vkm	g/vkm	g/train-km	g/vkm
Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
Source	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE	TREMOVE
Country											
Austria	0.555	5.474	0.235	0.704	0.368	7.62	0.481	5.536	2.216	0.313	416.4
Belgium	0.574	5.340	0.259	0.642	0.157	7.33	1.033	6.982	3.075	1.596	344.2
Bulgaria	0.465	5.199	0.213	0.954	0.523	10.59	0.696	6.549	2.706	0.859	354.4
Czech Republic	0.512	5.020	0.180	0.613	0.521	7.41	0.694	7.626	3.074	0.650	370.1
Denmark	0.474	5.934	0.215	0.648	1.925	8.58	0.877	6.543	2.823	2.268	n.a.
Estonia	0.657	5.222	0.245	0.794	1.756	5.54	0.955	5.891	2.650	14.192	n.a.
Finland	0.506	5.301	0.243	0.597	0.085	8.89	1.060	7.308	3.205	1.859	358.6
France	0.603	5.080	0.240	0.643	0.407	10.26	0.600	5.874	1.542	0.444	329.6
Germany	0.479	5.611	0.271	0.542	0.753	10.25	0.484	5.916	2.349	1.185	358.6
Greece	0.412	4.552	0.214	0.522	2.524	13.64	1.382	6.588	3.170	2.707	n.a.
Hungary	0.667	4.700	0.184	0.727	0.597	8.29	0.794	5.883	2.541	1.146	378.0
Ireland	0.317	4.845	0.218	0.454	2.512	12.03	0.901	5.069	2.332	5.206	n.a.
Italy	0.528	5.274	0.236	0.644	0.343	12.68	0.600	6.820	2.736	0.193	329.6
Latvia	0.505	5.510	0.224	0.595	1.817	7.00	0.767	5.428	2.367	16.243	n.a.
Lithuania	0.391	4.918	0.278	0.431	3.540	6.35	0.865	7.062	2.992	13.742	358.6
Luxembourg	0.589	4.784	0.217	0.683	0.019	3.97	0.873	6.242	2.717	2.096	344.2
Netherlands	0.434	5.456	0.251	0.478	0.074	8.82	0.883	6.902	2.937	1.110	353.8
Norway	0.594	4.703	0.235	0.652	0.295	10.19	0.862	6.620	2.839	1.151	n.a.
Poland	0.481	5.230	0.175	0.558	0.533	8.36	0.668	6.324	2.610	0.709	258.0
Portugal	0.552	5.173	0.211	0.619	1.062	10.92	1.007	7.869	3.363	2.122	n.a.
Romania	0.501	5.424	0.257	0.558	0.895	8.20	0.976	6.438	2.851	2.316	380.4
Slovakia	0.720	5.545	0.109	0.913	0.701	8.88	0.823	5.629	2.473	0.894	378.1
Slovenia	0.485	4.872	0.313	0.484	0.496	4.25	0.644	6.257	2.571	0.561	n.a.
Spain	0.613	5.057	0.205	0.653	0.397	14.62	1.013	6.950	3.051	1.229	n.a.
Sweden	0.382	5.116	0.256	0.456	0.044	10.76	0.885	6.311	2.748	0.351	n.a.
Switzerland	0.457	5.599	0.231	0.487	0.000	7.62	0.770	6.122	2.836	0.228	358.6
United Kingdom	0.441	5.715	0.211	0.513	0.438	11.93	1.019	7.138	2.835	0.866	353.8
TOTAL	**0.514**	**5.313**	**0.226**	**0.587**	**0.513**	**10.89**	**0.755**	**6.488**	**2.507**	**1.269**	**355.5**

Data source: Tremove (2010).

Figure 32 Development of emission factors between 2000 and 2008 according to TREMOVE (2010) and HBEFA (2010)



Emissions

Total emissions are calculated by multiplying the emission factors with the transport volume data shown above (vehicle-km, train-km). Total emissions of the most important greenhouse gases and air pollutants are shown below.

Table 54 Carbon dioxide (CO_2, exhaust)

		Emission data - CO_2 (exhaust)										
		Passenger transport						Freight transport				
		Road				Rail	Aviation	Road			Rail	Waterborne
		Passenger cars	Buses & coaches	Motorcycles	Total road passenger transport	Passenger transport	Passenger transport (cont.)	LDV	HDV	Total road freight transport	Freight transport	Inland waterways
	Unit	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
	Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
Country	Abbrev.											
Austria	AT	9,460,328	1,005,988	121,412	10,587,728	91,065	1,596,195	1,616,583	1,999,334	3,615,917	37,845	44,524
Belgium	BE	12,856,623	675,207	132,999	13,664,828	32,661	1,441,396	1,229,478	2,010,076	3,239,553	58,533	267,185
Bulgaria	BG	3,102,455	1,441,594	144,784	4,688,833	32,364	494,980	750,241	1,094,046	1,844,287	25,505	145,294
Czech Republic	CZ	6,187,575	675,264	360,097	7,222,936	161,365	926,418	2,268,558	3,868,968	6,137,526	53,978	528
Denmark	DK	7,062,944	763,502	45,608	7,872,055	284,424	1,679,747	881,532	1,528,253	2,409,785	21,854	0
Estonia	EE	725,207	88,071	21,895	835,173	15,843	138,242	266,006	377,805	643,812	124,770	0
Finland	FI	9,760,594	609,169	53,832	10,423,594	7,621	1,151,835	1,196,955	1,917,156	3,114,111	86,581	1,470
France	FR	80,828,067	2,962,122	872,166	84,662,355	426,365	7,730,820	24,280,954	13,788,032	38,068,987	123,272	198,408
Germany	DE	126,411,940	5,418,445	1,271,233	133,101,618	1,324,285	10,685,772	16,768,168	21,615,073	38,383,242	706,455	1,356,656
Greece	GR	5,373,775	965,008	896,693	7,235,476	118,461	2,967,000	1,286,337	1,941,540	3,227,877	19,733	0
Hungary	HU	5,078,237	544,810	319,641	5,942,688	134,068	610,536	1,417,754	1,972,326	3,390,079	55,559	48,490
Ireland	IE	4,164,720	452,062	26,265	4,643,047	87,937	2,528,096	908,779	1,502,008	2,410,787	7,841	0
Italy	IT	50,373,267	6,284,127	2,855,780	59,513,174	254,983	8,381,779	5,910,025	8,076,565	13,986,589	25,919	1,695
Latvia	LV	1,429,537	114,849	59,402	1,603,789	35,398	263,468	453,268	633,970	1,087,237	440,479	0
Lithuania	LT	1,474,281	54,885	57,886	1,587,052	49,261	192,774	699,115	1,079,845	1,778,960	358,325	232
Luxembourg	LU	972,149	75,934	6,290	1,054,373	306	127,962	279,558	469,220	748,779	5,237	11,212
Netherlands	NL	22,356,948	722,823	63,020	23,142,791	20,868	2,767,442	4,644,569	6,957,572	11,602,141	32,313	1,230,819
Norway	NO	9,459,302	476,873	88,164	10,024,339	25,857	2,580,368	823,734	1,368,255	2,191,989	28,705	0
Poland	PL	19,475,702	1,492,374	692,188	21,660,263	167,893	1,395,244	6,937,960	11,244,830	18,182,791	146,011	5,614
Portugal	PT	8,273,966	632,226	332,987	9,239,179	85,952	1,914,932	1,533,597	2,761,144	4,294,741	61,040	0
Romania	RO	5,397,697	364,675	277,877	6,040,249	152,503	646,806	1,424,681	2,025,755	3,450,436	127,326	167,498
Slovakia	SK	2,493,854	471,390	153,222	3,118,465	56,278	210,378	1,491,034	1,953,388	3,444,422	46,571	21,196
Slovenia	SI	2,017,736	57,388	187,658	2,262,782	14,816	94,715	606,194	940,965	1,547,159	12,109	0
Spain	ES	53,606,100	2,147,356	533,976	56,287,431	180,347	13,767,244	8,312,662	14,432,559	22,745,221	101,789	0
Sweden	SE	15,035,993	627,890	61,038	15,724,921	10,517	2,239,525	1,258,936	2,002,847	3,261,783	42,852	0
Switzerland	CH	10,825,350	271,926	161,995	11,259,271	0	2,475,570	656,364	1,133,485	1,789,849	18,127	687
United Kingdom	UK	93,026,918	4,886,739	551,854	98,465,511	541,781	14,020,589	12,548,737	18,452,224	31,000,961	209,210	3,563
TOTAL	**TT**	**567,231,266**	**34,282,697**	**10,349,960**	**611,863,923**	**4,313,217**	**83,029,833**	**100,451,778**	**127,147,242**	**227,599,020**	**2,977,938**	**3,505,071**

Table 55 $PM_{2.5}$ (exhaust)

		Passenger transport						Freight transport				
		Road				Rail	Aviation	Road			Rail	Waterborne
		Passenger cars	Buses & coaches	Motorcycles	Total road passenger transport	Passenger transport	Passenger transport (cont.)	LDV	HDV	Total road freight transport	Freight transport	Inland waterways
	Unit	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
	Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
Country	Abbrev.											
Austria	AT	1,512	224	103	1,839	59	n.a.	306	262	568	25	21
Belgium	BE	2,257	125	37	2,418	21	n.a.	479	358	837	38	129
Bulgaria	BG	401	300	127	828	21	n.a.	174	294	468	17	70
Czech Republic	CZ	942	125	421	1,487	105	n.a.	463	1,083	1,546	35	0
Denmark	DK	552	189	30	771	184	n.a.	263	250	513	14	0
Estonia	EE	63	17	8	88	10	n.a.	100	68	169	81	0
Finland	FI	1,902	106	30	2,038	5	n.a.	980	425	1,405	56	1
France	FR	14,602	510	391	15,503	276	n.a.	4,958	2,148	7,106	80	95
Germany	DE	10,911	1,112	452	12,475	858	n.a.	2,731	3,127	5,857	458	649
Greece	GR	185	150	547	881	77	n.a.	147	479	627	13	0
Hungary	HU	716	85	358	1,159	87	n.a.	556	407	963	36	23
Ireland	IE	277	65	11	353	57	n.a.	395	156	551	5	0
Italy	IT	6,295	1,222	1,899	9,416	165	n.a.	1,835	1,756	3,591	17	1
Latvia	LV	150	25	34	209	23	n.a.	129	92	221	285	0
Lithuania	LT	234	10	13	258	32	n.a.	318	322	640	232	0
Luxembourg	LU	143	11	4	158	0	n.a.	69	85	154	3	5
Netherlands	NL	1,839	131	32	2,001	14	n.a.	25	1,346	1,371	21	590
Norway	NO	817	75	58	950	17	n.a.	254	291	545	19	0
Poland	PL	1,645	285	698	2,628	109	n.a.	1,609	2,104	3,714	95	3
Portugal	PT	819	114	327	1,260	56	n.a.	634	710	1,344	40	0
Romania	RO	569	83	152	804	99	n.a.	318	540	859	82	81
Slovakia	SK	313	109	242	664	36	n.a.	779	546	1,325	30	10
Slovenia	SI	211	10	66	287	10	n.a.	143	183	326	8	0
Spain	ES	8,647	360	457	9,464	117	n.a.	3,428	3,188	6,616	66	0
Sweden	SE	833	105	27	966	7	n.a.	354	323	677	28	0
Switzerland	CH	452	56	121	629	0	n.a.	152	210	362	12	0
United Kingdom	UK	8,285	771	165	9,221	351	n.a.	4,008	2,887	6,895	40	2
TOTAL	**TT**	**65,571**	**6,375**	**6,810**	**78,756**	**2,794**	**n.a.**	**25,609**	**23,639**	**49,248**	**1,834**	**1,680**

Table 56 PM$_{10}$ (non-exhaust)

		Passenger transport						Freight transport			
		Road				Rail	Aviation	Road			Rail
		Passenger cars	Buses & coaches	Motorcycles	Total road passenger transport	Passenger transport	Passenger transport (cont.)	LDV	HDV	Total road freight transport	Freight transport
	Unit	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
	Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
Country	Abbrev.										
Austria	AT	2,544	180	64	2,788	493	0	334	342	676	654
Belgium	BE	3,319	112	74	3,505	415	0	293	290	583	198
Bulgaria	BG	913	268	126	1,306	123	0	200	204	404	161
Czech Republic	CZ	1,689	120	211	2,020	616	0	608	596	1,203	449
Denmark	DK	1,797	128	25	1,950	294	0	252	240	492	52
Estonia	EE	170	15	15	200	18	0	68	65	133	48
Finland	FI	2,337	102	29	2,469	179	0	308	309	617	252
France	FR	20,994	496	461	21,951	2,083	0	5,313	2,383	7,696	1,502
Germany	DE	30,284	834	596	31,714	3,499	0	3,319	3,555	6,874	3,224
Greece	GR	1,504	178	509	2,191	93	0	352	343	695	39
Hungary	HU	1,288	98	186	1,572	447	0	372	339	711	262
Ireland	IE	1,137	78	15	1,230	70	0	277	273	550	8
Italy	IT	13,376	993	1,448	15,817	1,478	0	1,207	1,227	2,434	727
Latvia	LV	334	18	32	384	39	0	115	115	230	147
Lithuania	LT	374	9	36	419	28	0	184	168	352	141
Luxembourg	LU	268	14	4	286	31	0	89	91	180	14
Netherlands	NL	5,389	103	37	5,529	565	0	992	1,036	2,027	157
Norway	NO	2,313	80	56	2,449	174	0	223	235	458	135
Poland	PL	5,449	268	446	6,163	626	0	1,895	1,836	3,731	1,114
Portugal	PT	2,172	98	195	2,465	161	0	402	387	790	156
Romania	RO	1,422	65	213	1,701	339	0	374	339	713	297
Slovakia	SK	665	86	80	831	160	0	401	368	769	282
Slovenia	SI	541	10	112	664	59	0	158	153	311	117
Spain	ES	14,345	369	420	15,135	903	0	2,307	2,349	4,657	448
Sweden	SE	3,378	118	34	3,530	478	0	324	341	665	660
Switzerland	CH	2,613	45	111	2,768	900	0	150	196	345	431
United Kingdom	UK	21,295	651	257	22,203	2,458	0	3,281	2,777	6,057	390
TOTAL	**TT**	**141,908**	**5,539**	**5,794**	**153,240**	**16,728**	**0**	**23,799**	**20,556**	**44,355**	**12,063**

Table 57 Nitrogen oxide (NO_x, exhaust)

		Passenger transport						Freight transport				
		Road				Rail	Aviation	Road			Rail	Waterborne
		Passenger cars	Buses & coaches	Motorcycles	Total road passenger transport	Passenger transport	Passenger transport (cont.)	LDV	HDV	Total road freight transport	Freight transport	Inland waterways
	Unit	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton	Ton
	Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
Country	**Abbrev.**											
Austria	AT	27,957	9,400	340	37,698	36	1,015	2,902	17,459	20,361	15	730
Belgium	BE	37,915	5,860	434	44,209	13	897	5,291	18,698	23,988	23	4,452
Bulgaria	BG	8,289	13,247	603	22,140	13	312	2,363	11,618	13,981	10	2,416
Czech Republic	CZ	16,820	6,099	844	23,762	63	582	7,116	40,908	48,024	21	9
Denmark	DK	16,870	7,240	123	24,233	111	1,098	3,630	14,153	17,783	9	0
Estonia	EE	2,112	738	83	2,933	6	86	1,102	3,552	4,654	49	0
Finland	FI	23,174	4,982	162	28,318	3	796	5,461	19,686	25,147	34	24
France	FR	248,871	23,647	2,496	275,014	166	5,587	57,327	122,135	179,462	48	3,289
Germany	DE	285,880	45,230	3,657	334,767	517	7,381	29,419	188,056	217,475	276	22,455
Greece	GR	11,970	7,562	2,435	21,967	46	2,041	8,111	20,211	28,323	8	0
Hungary	HU	17,512	4,642	793	22,947	52	379	5,003	19,383	24,386	22	809
Ireland	IE	7,075	3,479	75	10,629	34	1,597	4,091	12,028	16,119	3	0
Italy	IT	141,455	50,820	7,830	200,105	100	6,035	13,103	77,880	90,983	10	28
Latvia	LV	3,234	945	159	4,338	14	164	1,510	5,591	7,101	172	0
Lithuania	LT	2,843	451	226	3,521	19	120	2,721	11,617	14,338	140	4
Luxembourg	LU	2,924	588	18	3,530	0	79	1,169	4,369	5,539	2	187
Netherlands	NL	46,206	5,278	213	51,698	8	1,720	16,012	64,780	80,792	13	20,429
Norway	NO	27,115	3,690	300	31,105	10	1,998	3,323	13,347	16,669	11	0
Poland	PL	51,683	13,541	1,761	66,985	66	892	21,607	106,889	128,495	57	97
Portugal	PT	23,805	5,315	931	30,052	34	1,263	6,995	28,590	35,584	24	0
Romania	RO	14,521	3,526	1,272	19,319	60	417	6,196	21,375	27,571	50	2,791
Slovakia	SK	9,484	4,801	199	14,485	22	136	5,631	20,128	25,759	18	353
Slovenia	SI	5,105	469	780	6,354	6	59	1,754	8,904	10,658	5	0
Spain	ES	171,961	17,891	1,929	191,781	70	9,747	39,968	143,431	183,399	40	0
Sweden	SE	25,012	5,495	193	30,700	4	1,584	4,956	18,485	23,441	17	0
Switzerland	CH	23,727	2,416	583	26,726	0	1,552	2,102	10,505	12,607	7	11
United Kingdom	UK	177,792	34,081	1,199	213,072	211	9,399	54,693	161,654	216,347	24	59
TOTAL	**TT**	**1,431,314**	**281,435**	**29,640**	**1,742,388**	**1,684**	**56,938**	**313,555**	**1,185,431**	**1,498,986**	**1,105**	**58,143**

Accidents

Road transport

Table 58 **Road accident data 2008: Allocation to transport modes according to damage potential approach**

		ROAD (damage potential/intrinsic risk approach)													
		Fatalities							Serious Injuries						
		Total	Car + taxi	Bus	Motor-cycles/ mopeds	HDV	LDV	Other	Total	Car + taxi	Bus	Motor-cycles/ mopeds	HDV	LDV	Other
	Unit	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
	Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
	Source	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE
Country	**Abbrev.**														
Austria	AT	675	432	9	57	110	36	31	12,063	8,201	169	1,451	621	512	1,109
Belgium	BE	889	582	21	63	114	79	30	6,065	4,303	88	426	460	458	330
Bulgaria	BG	1,061	662	32	54	98	160	55	9,827	7,031	238	664	387	1,031	476
Czech Republic	CZ	1,074	684	27	41	165	99	58	3,744	2,636	61	260	278	248	261
Denmark	DK	404	246	10	19	60	56	13	2,833	1,967	53	306	146	251	110
Estonia	EE	135	78	4	6	31	0	16	331	250	15	12	30	8	16
Finland	FI	336	149	13	25	105	29	15	3,169	2,392	53	322	166	128	109
France	FR	4,259	2,744	76	448	583	324	84	34,957	25,059	467	4,198	1,846	2,378	1,009
Germany	DE	4,482	2,933	68	312	601	374	194	70,770	48,876	665	5,954	3,465	3,849	7,961
Greece	GR	1,528	914	30	243	134	173	34	1,876	1,182	21	397	79	156	41
Hungary	HU	993	603	31	42	166	98	53	7,227	4,909	168	649	548	503	450
Ireland	IE	295	17	10	18	39	9	202	858	120	13	17	43	40	625
Italy	IT	4,794	3,338	99	668	261	155	273	25,865	17,135	437	3,332	1,675	2,671	617
Latvia	LV	313	215	10	12	46	12	18	785	593	35	28	71	19	39
Lithuania	LT	498	342	16	19	73	19	29	1,248	943	56	45	113	30	62
Luxembourg	LU	35	26	1	6	2	0	0	296	217	6	36	24	0	13
Netherlands	NL	684	385	12	55	104	83	45	9,352	6,062	92	989	475	1,040	694
Norway	NO	256	156	7	20	47	16	10	867	654	15	88	45	35	30
Poland	PL	5,420	3,861	137	152	1,107	0	163	15,998	12,447	346	677	1,895	0	633
Portugal	PT	860	453	18	96	103	167	23	2,588	1,575	31	281	179	456	66

ROAD (damage potential/intrinsic risk approach)															
		Fatalities							Serious Injuries						
		Total	Car + taxi	Bus	Motor-cycles/ mopeds	HDV	LDV	Other	Total	Car + taxi	Bus	Motor-cycles/ mopeds	HDV	LDV	Other
	Unit	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
	Base Year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
	Source	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE	CARE
Romania	RO	3,072	1,917	94	156	284	463	158	9,508	6,803	230	642	374	998	461
Slovakia	SK	611	350	25	20	171	7	38	1,793	1,027	64	27	359	26	290
Slovenia	SI	238	136	4	22	7	38	31	1,357	740	9	165	22	88	333
Spain	ES	3,078	1,817	65	332	431	378	55	16,940	11,222	286	2,182	1,097	1,749	404
Sweden	SE	391	239	11	30	72	24	15	3,645	2,751	61	370	191	147	125
Switzerland	CH	357	228	5	30	58	19	16	4,780	3,250	67	575	246	203	439
United Kingdom	UK	2,658	1,826	115	135	365	188	29	27,135	20,849	1,038	1,854	1,316	1,540	538
TOTAL	**TT**	**39,396**	**25,334**	**950**	**3,081**	**5,338**	**3,006**	**1,687**	**275,877**	**193,193**	**4,782**	**25,945**	**16,151**	**18,564**	**17,242**

Source: CARE database/PIN report.

Table 59 Rail accident data 2008, based on 2002-2008 average annual values

		Rail	
		Fatalities	Injuries
	Unit	No.	No.
	Base Year	Average 02-08	Average 02-08
	Source	UIC	UIC
Country	**Abbrev.**		
Austria	AT	4.7	12.7
Belgium	BE	2.3	8.6
Bulgaria	BG	4.5	10.3
Czech Republic	CZ	4.3	26.3
Denmark	DK	0.3	11.4
Estonia	EE	0.0	0.0
Finland	FI	0.4	0.9
France	FR	10.3	12.9
Germany	DE	12.4	98.6
Greece	GR	1.1	20.9
Hungary	HU	8.9	112.4
Ireland	IE	0.3	0.0
Italy	IT	11.3	29.0
Latvia	LV	0.0	0.0
Lithuania	LT	0.0	0.0
Luxembourg	LU	0.0	1.9
Netherlands	NL	0.0	0.8
Norway	NO	0.2	15.3
Poland	PL	11.0	140.0
Portugal	PT	5.1	49.6
Romania	RO	24.5	18.0
Slovakia	SK	1.0	10.9
Slovenia	SI	0.3	4.7
Spain	ES	5.1	17.6
Sweden	SE	0.3	2.0
Switzerland	CH	2.2	4.2
United Kingdom	UK	3.8	3.6
TOTAL	**TT**	**114**	**612**

Source: UIC, for UK EUROSTAT values are taken.

Note: In some cases these data differ from some other sources, which probably has to do with differences in definitions, scope or allocation. However, the impacts on the final results are negligible, because the share of accident costs in the total external costs of rail transport is extremely small.

Noise

Noise cost values

Table 60-Table 62 give an overview of the used noise costs for people exposed to different noise level bands. The values below are based on HEATCO, 2006a. The HEATCO values are bundled in dB ranges corresponding to the ranges for which the number of exposed people are reported.

Table 60 **Noise Costs (€$_{2008}$/person/year) for different noise levels: road**

Countries	Noise levels Lden in dB(A)				
	55-59	60-64	65-69	70-74	75-79
Austria	86	147	209	328	437
Belgium	82	141	200	314	419
Bulgaria	36	61	87	132	175
Czech Republic	70	119	169	260	343
Denmark	85	146	207	326	435
Estonia	60	103	146	220	290
Finland	81	138	196	307	409
France	77	133	188	295	394
Germany	71	121	171	272	363
Greece	66	113	160	249	331
Hungary	57	98	139	213	282
Ireland	108	186	263	409	543
Italy	73	125	177	280	373
Latvia	52	88	125	189	249
Lithuania	52	89	126	190	250
Luxembourg	129	221	313	485	643
Netherlands	86	147	208	328	438
Norway	114	195	276	431	573
Poland	38	65	92	143	190
Portugal	53	91	129	202	270
Romania	45	78	110	165	217
Slovakia	67	114	162	245	323
Slovenia	68	116	165	255	338
Spain	75	129	183	285	378
Sweden	84	144	204	319	425
Switzerland	79	136	192	307	411
United Kingdom	81	138	196	308	411

Table 61 **Noise Costs (€$_{2008}$/person/year) for different noise levels: rail**

Countries	Noise levels Lden in dB(A)				
	55-59	60-64	65-69	70-74	75-79
Austria	25	86	147	267	377
Belgium	24	82	141	256	360
Bulgaria	10	36	61	107	149
Czech Republic	20	70	119	210	293
Denmark	24	85	146	265	374
Estonia	17	60	103	177	247
Finland	23	81	138	250	353
France	22	77	133	241	340
Germany	20	71	121	221	312
Greece	19	66	113	201	283

Countries	Noise levels Lden in dB(A)				
	55-59	60-64	65-69	70-74	75-79
Hungary	16	57	98	173	242
Ireland	31	108	186	331	466
Italy	21	73	125	227	321
Latvia	15	52	88	153	213
Lithuania	15	52	89	153	213
Luxembourg	37	129	221	393	551
Netherlands	25	86	147	267	377
Norway	33	114	195	350	492
Poland	11	38	65	116	163
Portugal	15	53	91	164	232
Romania	13	45	78	133	184
Slovakia	19	67	114	196	274
Slovenia	19	68	116	207	290
Spain	21	75	129	231	325
Sweden	24	84	144	259	365
Switzerland	23	79	136	250	354
United Kingdom	23	81	138	251	354

Table 62 Noise Costs (€$_{2008}$/person/year) for different noise levels: aviation

Countries	Noise levels Lden in dB(A)				
	55-59	60-64	65-69	70-74	75-79
Austria	133	228	323	476	620
Belgium	128	219	310	457	594
Bulgaria	56	96	135	195	251
Czech Republic	109	186	264	381	492
Denmark	132	227	321	473	615
Estonia	93	160	226	324	417
Finland	125	214	303	446	580
France	120	205	291	429	558
Germany	110	188	266	394	513
Greece	103	176	250	364	472
Hungary	88	152	215	312	403
Ireland	167	287	407	595	772
Italy	113	194	275	406	528
Latvia	79	136	193	278	357
Lithuania	80	137	194	279	359
Luxembourg	200	343	485	709	918
Netherlands	133	228	323	477	620
Norway	177	303	429	628	814
Poland	59	101	144	209	271
Portugal	82	140	199	294	382
Romania	71	121	171	244	314
Slovakia	103	177	251	360	464
Slovenia	105	180	255	372	482
Spain	117	200	283	414	537
Sweden	130	223	316	464	603
Switzerland	123	210	298	444	579
United Kingdom	125	214	303	447	582

Noise exposure values
Table 63-Table 65 give an overview of the number of people exposed to noise from road, rail and aviation. The data are mainly based on AEA, 2010. Some data have been updated with data from CIRCA, 2010. Data for Switzerland were taken from FOEN, 2009.
Data from AEA, 2010 and CIRCA, 2009 have been extrapolated to all people living in areas with a population density over 500/km^2. For the extrapolated part it is assumed that traffic density is half of the intensity in the reported areas and the average exposure level is therefore 3 dB lower as compared to the reported areas. Furthermore a correction has been made to correct for reported major roads and rail tracks which are in areas with a density > 500/km^2. For aviation noise it was assumed that the all exposed people have been reported in AEA, 2010.

Table 63 Number of people (in millions) exposed to noise from roads

Country	Noise levels Lden in dB(A)					
	55-59	60-64	65-69	70-74	>75	Total
Austria	1.33	0.76	0.48	0.11	0.00	2.69
Belgium	1.35	0.81	0.36	0.16	0.02	2.70
Bulgaria	0.75	1.04	0.68	0.18	0.00	2.66
Czech Republic	1.41	0.92	0.47	0.20	0.05	3.05
Denmark	0.53	0.35	0.19	0.04	0.00	1.11
Estonia	0.06	0.03	0.01	0.00	0.00	0.10
Finland	0.29	0.21	0.09	0.02	0.00	0.61
France	6.46	4.33	2.97	1.55	0.38	15.69
Germany	4.95	2.94	1.84	0.76	0.12	10.61
Greece	1.13	1.57	1.04	0.27	0.01	4.02
Hungary	0.50	0.49	0.53	0.34	0.10	1.97
Ireland	0.43	0.63	0.25	0.14	0.03	1.48
Italy	8.53	2.77	1.39	0.50	0.13	13.32
Latvia	0.30	0.27	0.16	0.09	0.03	0.85
Lithuania	0.28	0.22	0.07	0.01	0.00	0.58
Luxembourg	0.04	0.02	0.01	0.00	0.00	0.07
Netherlands	1.75	1.20	0.50	0.06	0.00	3.52
Norway	0.46	0.31	0.18	0.07	0.02	1.04
Poland	2.68	2.43	1.59	0.69	0.13	7.53
Portugal	0.91	0.85	0.56	0.23	0.04	2.59
Romania	1.90	1.73	0.91	0.31	0.07	4.91
Slovakia	0.35	0.43	0.32	0.18	0.06	1.34
Slovenia	0.14	0.09	0.06	0.02	0.00	0.31
Spain	5.40	4.69	3.03	1.27	0.25	14.63
Sweden	0.53	0.32	0.19	0.08	0.02	1.14
Switzerland	1.91	1.08	0.46	0.12	0.02	3.58
United Kingdom	15.89	14.65	3.85	1.37	0.16	35.93
Total	60.29	45.14	22.17	8.79	1.62	138.01

Adapted from EEA, 2010 and CIRCA, 2010; Data for Switzerland are based on FOEN, 2009.

Table 64 Number of people (in millions) exposed to noise from rail

Country	Noise levels Lden in dB(A)					
	55-59	60-64	65-69	70-74	>75	Total
Austria	0.340	0.225	0.129	0.063	0.017	0.773
Belgium	0.140	0.070	0.036	0.019	0.004	0.269
Bulgaria	0.021	0.006	0.001	0.000	0.000	0.028
Czech Republic	0.153	0.126	0.097	0.019	0.000	0.395
Denmark	0.048	0.016	0.006	0.002	0.000	0.072
Estonia	0.015	0.009	0.004	0.001	0.000	0.030
Finland	0.082	0.061	0.027	0.000	0.000	0.171
France	2.299	0.533	0.307	0.170	0.122	3.431
Germany	2.684	1.146	0.414	0.131	0.074	4.450
Greece	0.031	0.009	0.002	0.000	0.000	0.042
Hungary	0.175	0.066	0.026	0.010	0.001	0.278
Ireland	0.013	0.008	0.003	0.001	0.000	0.025
Italy	0.289	0.231	0.122	0.050	0.026	0.719
Latvia	0.035	0.023	0.007	0.001	0.000	0.067
Lithuania	0.012	0.006	0.001	0.000	0.000	0.020
Luxembourg	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.341	0.177	0.078	0.025	0.004	0.625
Norway	0.005	0.003	0.002	0.001	0.001	0.012
Poland	0.587	0.338	0.159	0.056	0.009	1.147
Portugal	0.022	0.012	0.008	0.007	0.004	0.054
Romania	0.248	0.132	0.021	0.002	0.000	0.403
Slovakia	0.227	0.149	0.078	0.029	0.005	0.488
Slovenia	0.014	0.007	0.002	0.000	0.000	0.023
Spain	0.064	0.026	0.011	0.002	0.000	0.104
Sweden	0.143	0.072	0.026	0.010	0.003	0.254
Switzerland	0.133	0.092	0.050	0.018	0.007	0.301
United Kingdom	0.766	0.517	0.260	0.076	0.009	1.629
Total	8.890	4.060	1.877	0.694	0.290	15.811

Adapted from EEA, 2010 and CIRCA, 2010; Data for Switzerland are based on FOEN, 2009.

Table 65 Number of people (in millions) exposed to noise from aviation

County	Noise levels Lden in dB(A)					
	55-59	60-64	65-69	70-74	>75	Total
Austria	0.008	0.001	0.000	0.000	0.000	0.009
Belgium	0.035	0.011	0.004	0.000	0.000	0.050
Bulgaria	0.052	0.032	0.021	0.001	0.000	0.105
Czech Republic	0.006	0.002	0.000	0.000	0.000	0.007
Denmark	0.001	0.001	0.000	0.000	0.000	0.001
Estonia	0.001	0.000	0.000	0.000	0.000	0.001
Finland	0.001	0.000	0.000	0.000	0.000	0.001
France	1.347	0.032	0.002	0.000	0.000	1.381
Germany	0.356	0.085	0.007	0.001	0.000	0.449
Greece	0.013	0.002	0.000	0.000	0.000	0.015
Hungary	0.222	0.065	0.002	0.001	0.000	0.290
Ireland	0.003	0.000	0.000	0.000	0.000	0.003
Italy	0.158	0.049	0.010	0.001	0.000	0.218
Latvia	0.002	0.001	0.000	0.000	0.000	0.003
Lithuania	0.009	0.003	0.001	0.000	0.000	0.013
Luxembourg	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	0.063	0.006	0.001	0.000	0.000	0.070
Norway	0.005	0.001	0.000	0.000	0.000	0.007
Poland	0.049	0.010	0.004	0.003	0.000	0.066
Portugal	0.003	0.001	0.000	0.000	0.000	0.005
Romania	0.012	0.011	0.006	0.000	0.000	0.029
Slovakia	0.002	0.001	0.000	0.000	0.000	0.002
Slovenia	0.000	0.000	0.000	0.000	0.000	0.000
Spain	0.135	0.019	0.006	0.001	0.000	0.160
Sweden	0.006	0.001	0.000	0.000	0.000	0.006
Switzerland	0.158	0.074	0.017	0.002	0.000	0.251
United Kingdom	0.789	0.214	0.056	0.010	0.001	1.069
Total	3.432	0.620	0.136	0.020	0.001	4.210

Adapted from EEA, 2010 and CIRCA, 2010; Data for Switzerland are based on FOEN, 2009.

Infrastructure

Infrastructure data for all modes are needed to determine infrastructure area and total costs for nature and landscape. In the following data of infrastructure lengths resp. the number of airports in each country are presented.

Table 66 Infrastructure data, railway values for AT, PT, CH from 2007

		Traffic infrastructure											
		Road					Rail			Aviation	Waterways		
		Motorways	Highways	Secondary roads	Other roads	Total	Electrified lines	Lines not electrified	Total	Airports	Canals (navigable)	Rivers & lakes	Total
	Unit	Km	Km	Km	Km	Km	Km	Km	Km	No.	Km	Km	Km
	Base Year	2007	2007	2007	2007	2007	2008	2008	2008	2008	2010	2010	2010
	Source	PB	PB	PB	PB	PB	UIC	UIC	UIC	PB	various	residual	PB
Country	Abbrev.												
Austria	AT	1,696	10,410	23,652	71,059	106,817	3,816	2,440	6,256	6	0	351	351
Belgium	BE	1,763	12,613	1,349	137,870	153,595	2,955	558	3,513	5	880	652	1,532
Bulgaria	BG	418	2,975	16,032	0	19,425	2,827	1,317	4,144	4	0	470	470
Czech Republic	CZ	657	6,191	48,736	74,919	130,503	3,078	6,408	9,486	4	52	612	664
Denmark	DK	1,111	2,755	69,331	0	73,197	620	1,511	2,131	9	0	0	0
Estonia	EE	96	3,896	12,473	41,547	58,012	147	771	919	2	0	320	320
Finland	FI	700	12,629	13,466	51,365	78,160	3,067	2,852	5,919	21	125	9,552	9,677
France	FR	10,958	9,861	377,377	628,987	1,027,183	15,401	14,500	29,901	60	4,183	1,189	5,372
Germany	DE	12,594	40,420	178,180	413,000	644,194	21,933	15,865	37,798	40	1,729	5,580	7,309
Greece	GR	1,103	10,189	30,864	75,600	117,756	264	2,288	2,552	33	6	0	6
Hungary	HU	858	6,746	23,579	158,760	189,943	2,848	5,044	7,892	3	121	1,319	1,440
Ireland	IE	269	5,159	11,645	79,447	96,520	75	2,678	2,752	10	0	0	0
Italy	IT	6,588	19,290	156,258	496,894	679,030	11,927	4,934	16,861	39	203	1,359	1,562
Latvia	LV	0	1,647	18,532	49,608	69,787	273	2,133	2,406	2	0	12	12
Lithuania	LT	309	6,387	14,625	59,394	80,715	122	1,643	1,765	3	0	425	425
Luxembourg	LU	147	837	1,891	0	2,875	362	13	375	1	0	37	37
Netherlands	NL	2,582	2,430	7,899	122,559	135,470	2,195	701	2,896	5	3,745	2,470	6,215
Norway	NO	239	27,091	27,073	38,466	92,869	2,552	1,562	4,114	42	0	0	0
Poland	PL	663	17,859	28,455	211,934	258,910	11,856	7,771	19,627	10	247	3,391	3,638
Portugal	PT	2,613	5,883	4,406	0	12,902	1,460	1,382	2,842	10	0	124	124
Romania	RO	281	15,837	64,775	0	80,893	3,974	6,803	10,777	9	91	1,688	1,779
Slovakia	SK	365	3,374	14,144	25,942	43,825	1,577	2,045	3,622	3	0	251	251
Slovenia	SI	579	976	4,921	32,233	38,709	503	725	1,228	1	0	0	0
Spain	ES	13,014	12,832	140,165	501,053	667,064	8,770	6,271	15,041	40	0	70	70
Sweden	SE	1,806	13,519	83,131	326,984	425,440	8,707	2,315	11,022	31	70	320	390
Switzerland	CH	1,383	381	18,136	51,446	71,346	5,107	0	5,107	6	0	1,240	1,240
United Kingdom	UK	3,673	49,016	122,281	245,027	419,997	5,318	10,900	16,218	46	191	874	1,065
TOTAL	**TT**	**66,465**	**301,203**	**1,513,376**	**3,894,094**	**5,775,137**	**121,733**	**105,430**	**227,163**	**445**	**11,643**	**32,306**	**43,949**

Road infrastructure data from the Pocketbook grants the best comparability with data used in the 2004 study.

In countries where railway infrastructure data from UIC is more than 5% smaller than reported values by EUROSTAT, the latter are being used. This is the case for Austria, Estonia, Germany, Ireland, Latvia and Sweden. For Switzerland national statistics (Swiss Federal Statistical Office, SFOS) are taken. To get values for electrified and non electrified railways in countries with EUROSTAT data, the split from the UIC data is applied.

For aviation infrastructure only airports with more than 15,000 passengers carried per year are being counted.

Electricity mix of railways

Table 67 shows the electricity mix of railways used in the present study. It is based on the EcoPassenger study from IFEU (IFEU, 2010).

Table 67 Energy split of electricity consumption used by railways in 2007

Country	Source	Solid fuels	Oil	Gas	Nuclear	Renewables	Other
AT	/UIC 2009/	0.00%	0.00%	0.00%	0.00%	89.65%	10.35%
BE	/UIC 2009/	13.63%	0.00%	16.56%	57.95%	2.11%	9.74%
BG	/UIC 2009/	56.73%	0.99%	3.91%	29.15%	9.22%	0.00%
CH	/UIC 2009/	0.00%	0.00%	0.00%	26.47%	73.53%	0.00%
CZ	/UIC 2009/	57.31%	0.00%	0.00%	40.65%	2.04%	0.00%
DE	/UIC 2009/	45.95%	0.00%	8.78%	29.86%	14.02%	1.40%
DK	/UIC 2009/	49.42%	2.69%	17.47%	0.00%	26.24%	4.18%
ES	/UIC 2009/	25.07%	0.78%	24.73%	19.50%	29.91%	0.00%
FI	/UIC 2009/	0.00%	0.00%	0.00%	26.35%	33.86%	39.79%
FR	/UIC 2009/	4.02%	1.76%	3.27%	85.65%	4.91%	0.39%
GR	/EUROSTAT 2009/	53.76%	14.95%	22.28%	0.00%	9.01%	0.00%
HR	/UIC 2009/	10.47%	21.81%	0.00%	31.60%	36.12%	0.00%
HU	/UIC 2009/	17.97%	1.46%	38.72%	36.52%	4.64%	0.68%
IE	/EUROSTAT 2009/	26.33%	6.81%	55.37%	0.00%	11.50%	0.00%
IT	/UIC 2009/	28.10%	7.21%	35.17%	0.00%	29.50%	0.03%
LU	/EUROSTAT 2009/	0.00%	0.00%	71.91%	0.00%	28.09%	0.00%
ME	/IEA 2007/	67.23%	0.87%	0.19%	0.00%	31.57%	0.13%
NL	/UIC 2009/	23.31%	0.00%	51.79%	9.11%	9.76%	6.02%
NO	/UIC 2009/	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
PL	/UIC 2009/	93.70%	0.00%	1.91%	0.00%	0.00%	4.40%
PT	/EUROSTAT 2009/	25.33%	9.95%	27.98%	0.00%	36.74%	0.00%
RO	/UIC 2009/	40.52%	1.08%	17.66%	12.97%	26.92%	0.86%
RS	/IEA 2007/	67.23%	0.87%	0.19%	0.00%	31.57%	0.13%
SE	/UIC 2009/	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
SI	/UIC 2009/	48.17%	0.98%	6.15%	30.05%	13.66%	0.98%
SK	/UIC 2009/	26.02%	0.00%	4.44%	57.78%	11.77%	0.00%
UK	/UIC 2009/	33.09%	0.97%	43.66%	14.87%	5.95%	1.46%
*except Serbia and Montenegro (Reference year 2006) UIC 2009: railway mix, other sources: national mix							

Source: IFEU, 2010.

Annex B Comparison of Recent European Studies on Transport Costs

Table 68 Comparison of different European Studies on External Costs of Transport

	UIC Update Study 2011 (CE/INFRAS/ISI, 2011)	UIC Update Study 2004 (INFRAS/IWW, 2004)	IMPACT Handbook (CE/INFRAS/ISI, 2008)	ILFD Study (INFRAS/ISI, 2010)	Allianz pro Schiene Study (INFRAS/ISI/IER, 2007)
Base Year	2008	2000	n.a.	2008	2005
Focus	Total and average external costs of all transport modes, focus on road, rail and air in EU-27, CH and NO. Additionally: marginal cost	Total and average external costs of all transport modes in EU-15, CH and NO. Additionally: marginal cost data.	Handbook with methods and default values/cost factors for pricing in Europe: focus on marginal external cost information.	Funding and financing systems as well as level of cost coverage of transport modes (road, rail, air) in Germany, including external costs.	Update of external costs for four transport modes (road, rail. air, water) in Germany, based on the UIC Study 2004.
Transport data	National statistics (EUROSTAT, DG MOVE), railway statistics (UIC) and model calculations (TREMOVE database) where statistical data are missing.	Model calculations for road & air transport and IWW (TRENDS1 database), for rail TRENDS1 data have been calibrated with UIC statistics.	n.a.	National statistics (Verkehr in Zahlen, Destatis, Kraftfahrt-Bundesamt) and statistics from the Deutsche Bahn DB.	Model calculations, national and railway statistics. Road: TREMOD Rail: UIC, DESTATIS, TREMOD Air: TREMOD, DESTATIS Infrastructure: DESTATIS
Emission data	All emission data from the TREMOVE database (model calculations).	All emission data from the TRENDS1 database (model calculations).	n.a.	No emission data, as external costs are directly computed with cost factors and transport data.	All data from the TREMOD database (model calculation).
System boundaries: **- generally**	Data have been transformed according the territory perspective where possible.	Territory perspective where possible, otherwise nationality perspective.	n.a.	Territory perspective for rail and road transport.	All data have been transformed according the territory perspective.
- air transport	European perspective (all continental flights, departing).	World perspective (all continental & intercontinental flights, departing).	n.a.	World perspective as UIC 2004 (all departing cont. & intercont. flights from Germany).	Inland perspective (only domestic flights within Germany).

	UIC Update Study 2011 (CE/INFRAS/ISI, 2011)	UIC Update Study 2004 (INFRAS/IWW, 2004)	IMPACT Handbook (CE/INFRAS/ISI, 2008)	ILFD Study (INFRAS/ISI, 2010)	Allianz pro Schiene Study (INFRAS/ISI/IER, 2007)
Most important cost categories (additional data sources, methodology, unit costs, allocation mechanism)					
Noise costs	✓ Top-down approach, including annoyance and health related costs ✓ Unit costs based on HEATCO (as recommended by IMPACT) ✓ Number of people affected by noise based on noise maps Costs per person affected (DE): ✓ Road (72 dB): 281 $€_{2008}$ ✓ Rail (72 dB): 230 $€_{2008}$ ✓ Air (72 dB): 403 $€_{2008}$	✓ Top-down approach, including willingness to pay for disturbed people and costs of increased health risk (fatalities and medical costs) ✓ Unit costs based on UNITE Costs per person affected (DE): ✓ Road (70-75 dB): 371 $€_{2000}$ ✓ Rail (70-75 dB): 265 $€_{2000}$ ✓ Air (70-75 dB): 371 $€_{2000}$	✓ Focus on marginal costs ✓ Unit costs based on HEATCO Costs per person affected (DE): ✓ Road (72 dB): 247 $€_{2002}$ ✓ Rail (72 dB): 204 $€_{2002}$ ✓ Air (72 dB): 354 $€_{2002}$	✓ Cost factors from INFRAS/ISI/IER, 2007 for each transport mode	✓ INFRAS/IWW, 2004 and UBA online data for noise affected people ✓ Quantification of rent reductions and health damages from noise exposure ✓ Updated unit costs from INFRAS/IWW, 2004
Air pollution costs	✓ According to IMPACT: Bottom-up approach, based on damage costs per ton of pollutant; including health effects, building & material damages, crop losses and impacts on ecosystems. ✓ Non-exhaust emissions of PM_{10} based on EMEP database ✓ Unit cost factors based on HEATCO/UBA (IMPACT) and NEEDS Unit costs for $PM_{2.5}$, Germany (2008): ✓ Metropolitan: 430,500 €/t ✓ Urban: 138,800 €/t ✓ Non-urban: 83,900 €/t	✓ Top-down approach, based on damage costs per additional case (e.g. disease or death due to PM emission); including health effects, building & material damages, crop losses. ✓ Non-exhaust emissions of PM_{10} based on Swiss data ✓ Cost factors based on WHO, 1999 and UIC, 2000 Unit costs for air pollution health effects, EU average (2000): ✓ Long-term mortality (for adults): 915,000 €/life lost (61% of VSL 1.5 Mio. €) ✓ Hospital admission: 8,620 €/admission ✓ Chronic bronchitis: 229,000 € per incidence	✓ Bottom-up approach, based on damage costs per ton of pollutant; including health effects, building & material damages, crop losses and impacts on ecosystems. ✓ Unit cost factors based on HEATCO/UBA ($PM_{2.5}$ and PM10) and CAFE CBA (NO_x, NMVOC, SO_2) Unit costs for $PM_{2.5}$, Germany (2000): ✓ Metropolitan: 384,500 €/t ✓ Urban: 124,000 €/t ✓ Non-urban: 75,000 €/t	✓ Cost factors from INFRAS/ISI/IER, 2007 for each transport mode	✓ Bottom-up approach, based on damage costs per ton of pollutant; Costs for health effects, crop losses, additional costs for damages to buildings and infrastructure ✓ Unit cost factors based on ExternE (EC, 2005) Unit costs for $PM_{2.5}$, Germany (2005): ✓ Urban roads: 176,200 €/t ✓ Non-urban roads: 83,700 €/t ✓ Motorways: 91,400 €/t

	UIC Update Study 2011 (CE/INFRAS/ISI, 2011)	UIC Update Study 2004 (INFRAS/IWW, 2004)	IMPACT Handbook (CE/INFRAS/ISI, 2008)	ILFD Study (INFRAS/ISI, 2010)	Allianz pro Schiene Study (INFRAS/ISI/IER, 2007)
Climate change costs	✓ Avoidance cost approach ✓ Lower value: 25 €$_{2008}$/t CO_2 (based on EU GHG reduction target for 2020) ✓ Upper value: 146 €$_{2008}$/t CO_2 (based on the 2˚C objective → CO_2 eq. level below 450 ppm) ✓ RFI for CO_2 emissions of air transport: 2	✓ Avoidance cost approach ✓ Lower value: 20 €$_{2000}$/t CO_2 (based on Kyoto target) ✓ Upper value: 140 €$_{2000}$/t CO_2 (based on 2030 targets, national avoidance costs in transport sector) ✓ RFI for CO_2 emissions of air transport: 2.5	✓ Avoidance cost approach ✓ Central value: 25 €$_{2010}$/t CO_2 ✓ Bandwidth: 7 to 45 €$_{2010}$/t CO_2 ✓ Cost estimates are based on range found in the literature ✓ RFI for CO_2 emissions of air transport: 2 to 4	✓ Based on IMPACT Handbook (avoidance cost approach) ✓ Cost factors from INFRAS/ISI/IER, 2007 for each transport mode base value of 25 €$_{2008}$/t CO_2 (IMPACT value) ✓ RFI for CO_2 emissions of air transport: 1.0	✓ Damage cost approach and sensitivity calculations ✓ CO_2 costs from UBA 2006a ✓ Central value: 70€$_{2005}$/t CO_2, sensitivity calculation with 20 and 280 €$_{2005}$/t CO_2 ✓ RFI for CO_2 emissions of air transport: 2.5
Accident costs	✓ Road accident data from the IRTAD database, the CARE project and EUROSTAT, data for rail from UIC, DESTATIS for age of victims, further cost factors from Ecoplan, INFRAS, 2008 ✓ Including medical costs, production losses and suffering and grief (VSL) ✓ VSL of 1.5 million € (1998, EU-15) ✓ Damage potential (intrinsic risk) perspective and responsibility perspective (for rail/road at level crossings)	✓ Road accident data from the IRTAD database, data for rail from UIC, for air transport from ICAO, further cost factors from Ecoplan (2002) ✓ Including costs of medical care, production losses and suffering and grief (VSL) ✓ VSL of 1.5 million € (1998, EU-15) ✓ Causer perspective (data from Germany)	✓ VSL of 1.5 million € (1998, EU-15) ✓ Responsibility approach would be preferred. Due to lack of data, for allocation of costs within a transport mode (e.g. road), another allocation method has to be	✓ Cost factors from INFRAS/ISI/IER, 2007 for each transport mode	✓ Accident data from DESTATIS, risk value from UNITE, further costs data from Ecoplan (2000) ✓ Including medical costs, production losses, juridical and administration costs, value of statistical life (VSL) ✓ VSL of 1.5 million € (1998, EU-15) ✓ Causer perspective

Annex C Members of the Advisory Board

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- Snejana Markovic-Chénais, UIC
- Gunnar Alexandersson, CER & ASTOC
- Philippe Domergue, SNCF
- Mario Tartaglia, FS
- Wolfgang Rauh, ÖBB
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Glossary

CBA	Cost benefit analysis
CO_2	Carbon dioxide
CT	Combined (freight) transport
DWL	Deadweight loss
EUR	Euro (€)
GDP	Gross Domestic Product
HDV	Heavy duty vehicles (road trucks) above 3.5 ton gross weight
HST	High speed train
IWW	Inland waterways
Lden	Perceived noise level weighted over day, evening, night
LDV	Light duty vehicles (up to 3.5 ton gross weight)
MC	Motorcycle(s), includes also mopeds
mio.	million
NMVOC	Non-methane volatile organic compounds
NO_x	Nitrogen oxide
pkm	Passenger-kilometre
PM	Particulate matter: PM_{10} = particulate matter with a diameter below 10 µm $PM_{2.5}$ = particulate matter with a diameter below 2.5 µm
SO_2	Sulphur dioxide
tkm	Tonne-kilometre
vkm	Vehicle-kilometre
VOT	Value of Time
VSL	Value of statistical life