External Costs of Transport

Accident, Environmental and Congestion Costs in Western Europe

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Overview

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Summary

Aim and methodology

This study is an update and extension of a former UIC study on external effects (1995). It aims at improving the empirical basis of external costs of transport based on the actual state of the art of cost estimation methodologies. The following dimensions are considered:

- Cost categories: Accidents, noise, air pollution (health, material damages, biosphere), climate change risks, other environmental and non-environmental effects and congestion.
- Countries: EUR 17 (EU member states, Switzerland, Norway).
- Base year: Detailed results for 1995 and rough estimate for 2010 (trend development, mainly based on emission trend forecasts of an EUROSTAT project TRENDS).
- Differentiation of transport means:
  - Road transport: Private car, motorcycles, bus, light goods vehicles, heavy goods vehicles,
  - Rail transport: Passenger and freight,
  - Air transport: Passenger and freight,
  - Waterborne transport: Inland water transport (freight).
- Functional and regional differentiation:
  - Urban and interurban passenger traffic,
  - Short and long distance freight traffic,
  - Application for point to point relations (two passenger and freight corridors).

Two study outputs can be distinguished:

- Total and average costs per country and means of transport: National cost accounts for the base year considered reflect the importance of each cost component. The results are mainly of statistical value. National average values can be – at least in some cases – a basis for pricing strategies and for socio-economic evaluation of infrastructure investments.
- Marginal costs per means of transport and traffic situation reflect the additional costs per additional unit of transport. They represent a European average which could be used as basis for the dimensioning of pricing instruments according to the approach of Social Marginal Costs Pricing, as the European Commission proposes in its White Book on 'Fair Payment of Infrastructure Use'.

Throughout the whole report, congestion costs are treated as a separate issue, since their relevance and measurement is quite different from the ones of other costs categories, especially in regard to total costs. Three different approaches were used; they different values from 0.5% to 3.7% of GDP.

The following table presents the costs categories considered and the methodologies used.

Type of effect	Share of total costs (EUR 17 1995 in %)	Cost components	Most important assumptions
Accidents	29%	Additional costs of - medical care - opportunity costs of society - suffer and grief.	- A value of human life of 1.5 million Euro is considered. - Average costs are equal to marginal costs. There is no specific relation between vkm and accident rates assumed. - Insurance payments are considered in order to estimate external cost components.
Noise	7%	Damages (opportunity costs of land value) and human health.	- The valuation approach is based on a willingness to pay for silent space above 55 dB(A). - Average costs are estimated by a top-down approach based on ECMT data. - Marginal costs are estimated by a modelling approach.
Air pollution	25%	Damages (opportunity costs) of - human health - material - biosphere.	- The results are based on a new and consistent data basis for emissions for all countries (TRENDS/Eurostat). - Health costs are based on a WHO study estimating health costs for France, Austria and Switzerland. - Building damages, crop losses and forest damages are based on results of Swiss expert studies. - Marginal costs are computed by the ExternE model. In order to be compatible with the top-down approach for total and average costs, building damages are adjusted.
Climate change	23%	Damages (opportunity costs) of global warming.	- The data basis is TRENDS. - A unit cost value of 135 Euro per tonne of CO_2 is considered. - Marginal costs are assumed to be equal to average variable costs. - The unit costs of air transport are doubled in order to consider the specific risks of emissions in higher altitudes.
Nature and landscape	3%	Additional costs to repair damages, compensation costs.	- A repair cost is used, estimating the desealing costs for different types of infrastructure. - A reference level (unspoilt nature) of 1950 is assumed. - The effects are not relevant for social marginal costs, since these costs are infrastructure related.
Separation in urban areas	1%	Time losses of pedestrians.	According to the methodology used in Germany (EWS), time losses are estimated based on random samples of different type of cities.
Space scarcity in urban areas	1%	Space compen-sation for bicycles.	- According to the methodology used in Germany (EWS), time losses are estimated based on random samples of different types of cities. - The effects are not relevant for social marginal costs, since these costs are infrastructure related.
Additional costs from up- and downstream processes	11%	Additional environ-mental costs (air pollution, climate change and risks)	- Based on the energy consumption, additional costs for precombustion, production and maintenance of rolling stock and infrastructure is estimated. - For nuclear risks, a shadow price of 0.035 Euro per kWh is assumed, based on willingness-to-pay studies for risk aversion.
Congestion	not taken into account for %.	External additional time and operating costs.	- Use of a traffic model to compute marginal and average costs. - Time values are derived from EU research projects (PETS). Three approaches: - Net welfare loss for road transport facing an optimal congestion tax, - Revenues of an optimal tax, - Time losses relative to a better level of service.

Table S-1: Overview of external costs being considered and of the most important methodological assumptions.

Total and average costs

Accident and environmental costs 1995

The following figures present the results for total and average costs for 1995. Total external costs (excluding congestion) amount to 530 billion Euro for 1995, being 7.8% of the total GDP in EUR 17. Accidents are the most important cost category with 29% of total cost. Air pollution and climate change costs amount to 48%. Whereas the costs for nature and landscape and the urban effects considered are of minor importance, upstream effects (11%) are quite significant, due especially to the fact that they are strongly related to air pollution and climate change. The most important mode is road transport, causing 92% of total cost, followed by air transport, causing 6% of total external costs. Railways (2%) and waterways (0.5%) are of minor importance. Two thirds of the costs are caused by passenger transport and one third by freight transport.

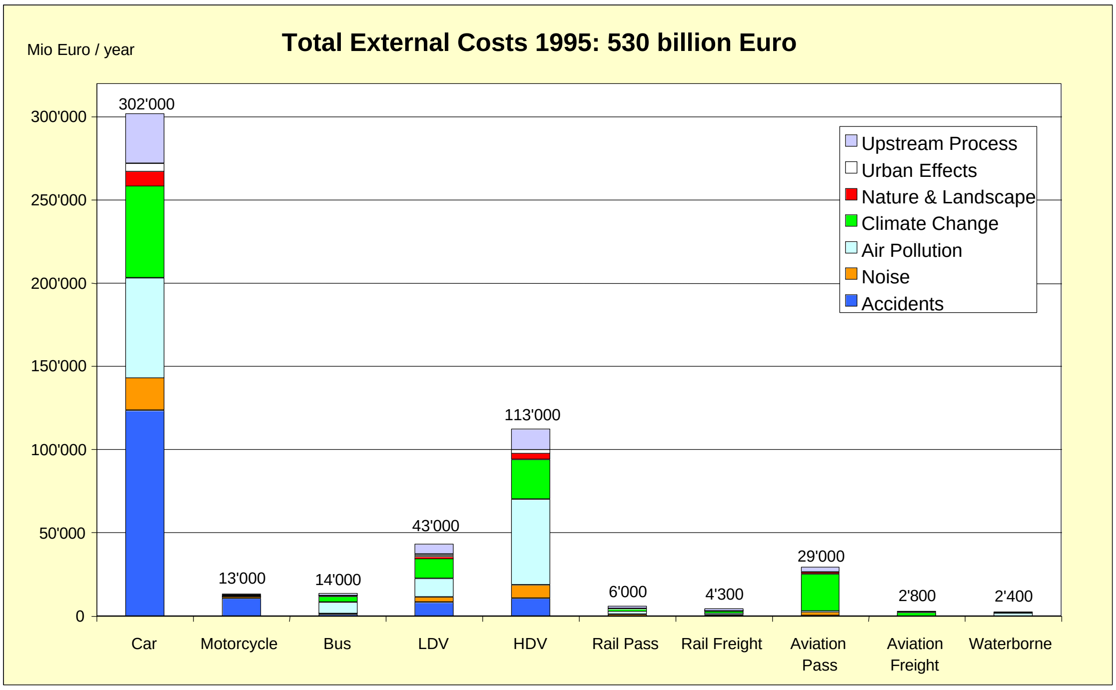

Figure S-1: Total external costs of transport 1995 (EUR 17) by transport means and cost category. Road transport is responsible for 92% of total external costs.

Average costs are expressed in Euro per 1'000 pkm and tkm. Within the **passenger transportation** sector, passenger cars reach 87 Euro. Railway costs amount to 20 Euro, which is 4.4 times lower than costs for the road sector. Most important for the railway sector are the effects on climate change, noise and air pollution. In aviation the predominant effect is climate change.

In the **freight sector**, the average costs of air transport are significantly higher than the costs of all other means of transport. This is due especially to the fact, that freight load (in tonnes) differs from mode to mode. Aeroplanes for example transport high quality freight of low specific weight. The costs for HDV (heavy duty vehicles) amount to 72 Euro per 1'000 tkm, which is 3.8 times higher than the cost for railways.

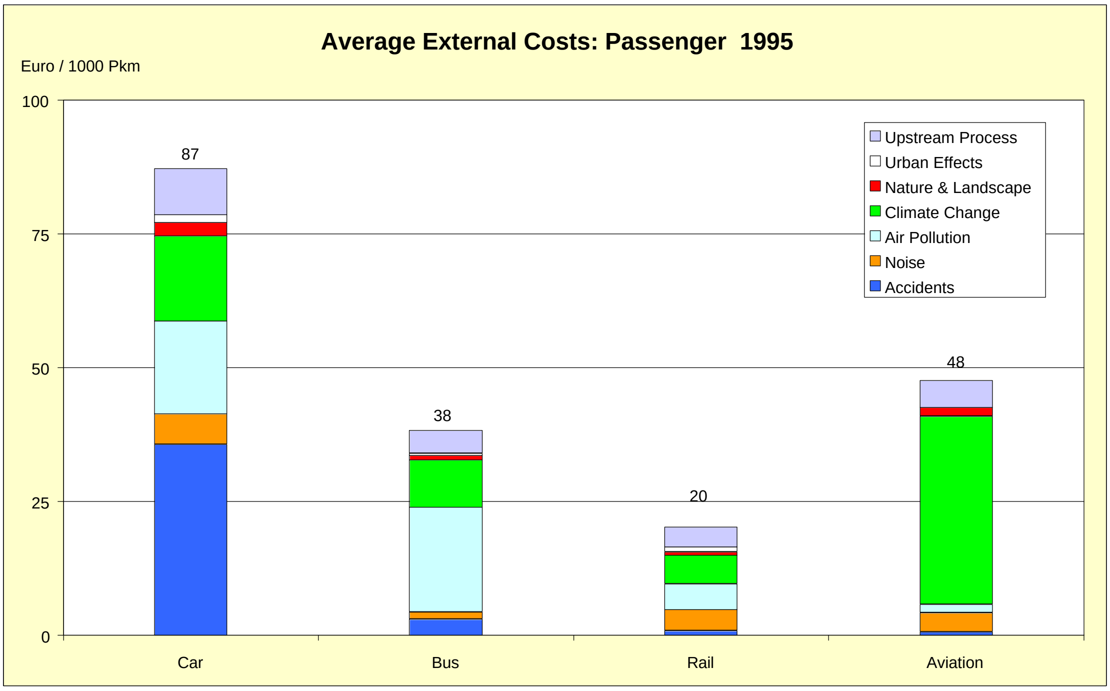

Figure S-2: Average external costs 1995 (EUR 17) by means of transport and cost category: Passenger transport (without congestion costs).

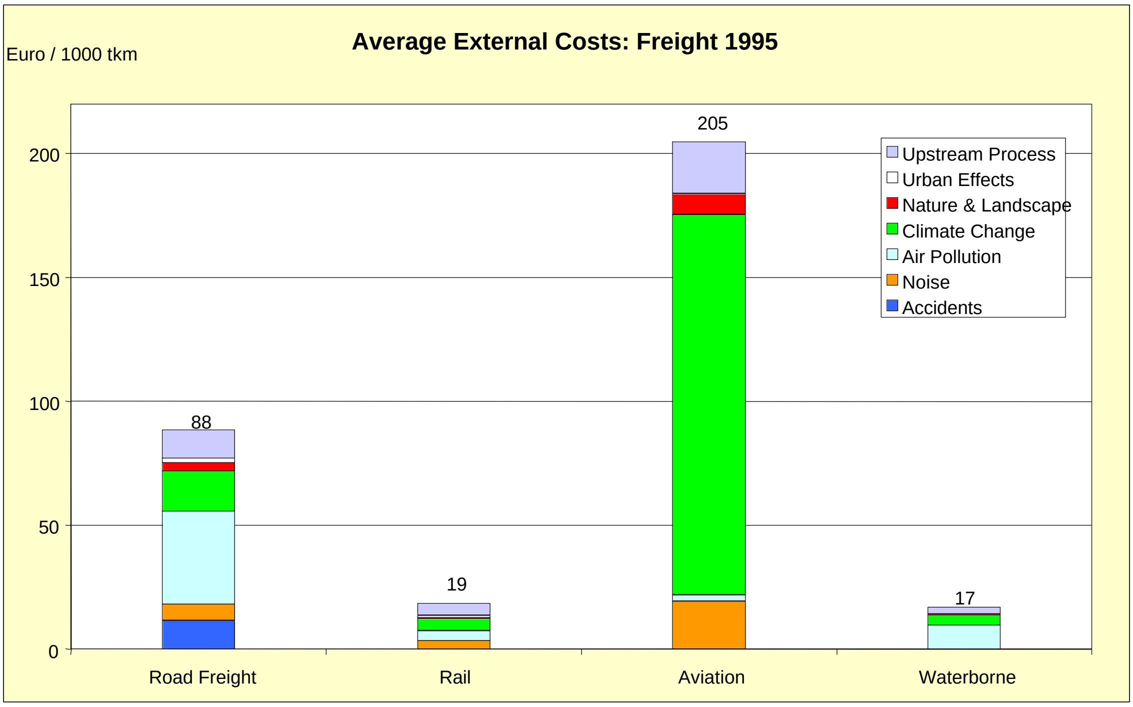

Figure S-3: Average external costs 1995 (EUR 17) by means of transport and cost category: Freight transport (without congestion costs).

The new values are significantly higher than the values estimated for 1991 (IWW/INFRAS 1995). A detailed comparison is difficult, firstly because a new and more consistent database was used. Secondly, additional cost categories were estimated; they amount to 15% of total costs. Thirdly, the values for air pollution (esp. impacts on health) and for climate change risks increased with the new approaches were used.

Trend forecast to 2010

Total costs will increase by 42% between 1995 and 2010. A major factor is transport growth and the increased valuation of environmental damages.[1] The highest growth rates will take place in the aviation and road sectors.

Average costs will also mainly increase. Expected technical improvements will not outweigh the growth in traffic:

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1 The following growth rates of pkm/tkm were considered:
- Road + 26% (cars) +30% (HDV)
- Rail + 26% (passenger) + 0% (freight)
- Air +108% (passenger and freight)
- Waterways no change
- GDP (used for the adjustment of unit costs to consider increased valuation): +39%.
- The expected developments of emissions for the road sector are based on TRENDS.

- There will be an increase of 8% in road passenger transport. Due to improved technology, the costs for air pollution will decrease. Road freight costs will increase by 15%. Major increases have to be expected for climate change costs, since energy savings are not proportional to traffic increase.
- Rail costs will decrease by 2% for passenger transport. For freight transport an increase of 14% is expected, mainly due to increased costs of climate change.

Within air transport, average costs will increase by 16% for passengers and 18% for freight. In contrast, external costs for waterborne transport will decrease by 34%.

Marginal costs and comparison with average costs

The following table shows the values (the ranges, respectively) for all cost categories and means of transport in comparison with the average values. The ranges are quite significant, since different vehicle categories and traffic situations are considered.

Marginal Costs (Average Costs)	Road					Rail		Aviation		Water-borne
[Euro per 1000 Pkm/Tkm]	Car	MC	Bus	LDV	HDV	Pass	Freight	Pass	Freight	Freight
Accidents 1)	11-54 (36)	79-360 (250)	1-5 (3.1)	44-163 (100)	2.3-11 (6.8)	0-1 (0.9)	0 (0)	0-1 (0.6)	0 (0)	0 (0)
Noise	0.2-21 (5.7)	0.6-53 (17)	0.1-7.5 (1.3)	5.3-496 (36)	0.6-52 (5.1)	0.2-23 (3.9)	0.1-1.6 (3.5)	2.3-17 (3.6)	17-87 (19)	0 (0)
Air Pollution 2)	5-17 (17)	14 (7.9)	4-25 (20)	28-118 (131)	14-50 (32)	2-24 (4.9)	1-6.8 (4)	0.8-2 (1.6)	0.8 (2.6)	4.5 (9.7)
Climate Change	12-25 (16)	9.6 (14)	5.5-11 (8.9)	125-134 (134)	15-18 (15)	4.2-8.9 (5.3)	4.2-5.3 (4.7)	36-42 (35)	117 (154)	4.7 (4.2)
Nature & Landscape	0-1.8 (2.5)	0-1.8 (2)	0-1.3 (0.8)	0-23 (23)	0-8.9 (2.2)	0-0.8 (0.7)	0-0.3 (0.5)	0-2.9 (1.7)	0-8.5 (8.5)	0-0.5 (0.5)
Urban Effects	10.7-11.7 (1.5)	6.7-7.4 (1.1)	3-3.2 (0.5)	75-83 (12)	8-9 (1.3)	0 (0.9)	0 (0.9)	0	0	0
Upstream Process	3.3-6.7 (8.6)	2.7-5.4 (6.0)	2.8-6.5 (4.3)	40-72 (69)	4.2-8.8 (8.7)	1.1-9.8 (3.8)	0.4-3.4 (5)	4.1-4.6 (5)	18-23 (21)	0.6-1.4 (2.6)

1) Average of countries considered.
2) Values for specific traffic situations in Germany, adjusted to European average.

Table S-2: Marginal costs by cost category and means of transport (the ranges reflect different vehicle categories (Petrol, diesel, electricity) and traffic situations (urban-interurban).
The values in brackets denote average values as shown in figures S-2 and S-3.

The ranges of marginal costs are based on different traffic situations. In urban areas for example, marginal costs are considerably higher than for interurban transport. Road passenger transport costs amount to 113 Euro per 1'000 pkm in urban areas and

34 Euro for interurban transport. For HDV, the figures are 91.5 Euro per 1'000 tkm (urban) and 40 Euro (interurban), respectively.

Comparing marginal and average costs, the following general conclusions can be drawn:

- For accidents, figures are based on the assumption that the average of marginal costs is equal to average costs. The figures' range results from differences between countries. Urban transport values for cars are about 4 to 5 times higher than those for motorways and up to 1.5 times higher than those for country roads.
- For noise, average costs are well above marginal costs, since additional costs decline with increases in traffic. However, the important night time noise is not considered within the range of marginal costs. The values at night are more than double daytime values.
- For air pollution, average values are in principle similar to marginal values. Constant dose-response-relations are assumed. However, different cost estimation approaches have been used. Thus, a complete comparison is not possible. There are also considerable differences between different vehicle categories. For example a EURO 3 car in urban areas causes about 4 times lower costs than today's average car. Diesel trains cause 7 to 10 times higher costs than electric trains.
- For climate change, average costs are equal to marginal costs. The ranges result from different vehicle categories. Marginal costs per pkm of urban petrol cars for example are about 30% higher than the costs for interurban traffic. Diesel trains cause up to double the climate change costs of electric trains.
- For nature and landscape, average costs are close to maximum (long run) marginal costs. In the short run however, no marginal costs will occur, since the costs are infrastructure related and thus not relevant for social marginal cost pricing approaches.
- For urban effects, only marginal costs of separation are relevant, being above average because of a progressive increase with the amount of traffic. In addition the average values presented in table S-2 reflect national averages, whereas the marginal costs are related to specific urban traffic situations.
- For upstream effects, short-run marginal costs are only related to precombustion processes such as production, transportation and storage of fuels.[2] Therefore they are lower than average costs which include also vehicle and infrastructure related processes. Thus, average costs are close to long-run marginal costs.

All marginal values reflect existing situations. In order to deduce optimal prices and transport taxes respectively, the reaction of transport users to the price changes has to

2 Note that the emissions of electricity production (mainly for the railways) are considered within the air pollution and climate change costs.

be considered as well. For this reason, general optimisation model applications should be used. Thus optimal prices are usually slightly below the values presented here.[3]

Average costs can be used as approximate values for marginal costs for mean traffic situations.

Congestion costs

Total congestion costs are defined according to economic welfare theory as the costs arising from an inefficient use of the existing infrastructure. Due to the specification of the road traffic congestion and the three different approaches used, congestion costs are treated separately throughout this study.

For the EUR-17 countries, total and average road congestion costs, the revenues expected from their internalisation via road pricing systems and an "engineering" measure of additional time costs have been estimated on the basis of an extended network analysis for the year 1995. Due to the chosen welfare-economic approach, congestion costs by definition only appear for transport modes where single users decide on the use they make of infrastructure. Consequently, rail and air traffic are not affected by this kind of congestion. A comparison of the three congestion-related measures is presented by the following figure.

3 These applications are carried out in ongoing EU-research projects (e.g. TRENEN).

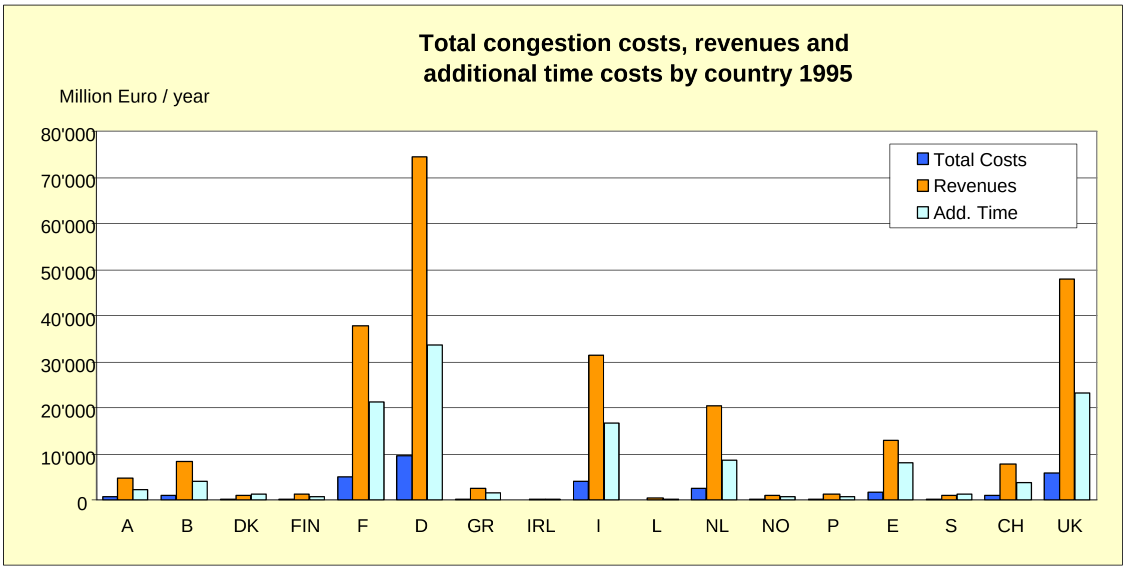

Figure S-4: *Congestion costs: Results by country for 1995 (in billion Euro 1995)*
- Total costs: Reduction of consumer surplus (dead weight loss) for road users compared to optimal congestion pricing-
- Revenues: Revenues from optimal congestion pricing,
- Additional time and operating costs relative to a non congested traffic situation.

On the basis of reduced consumer surplus, the external costs of road traffic congestion are estimated approximately 33.3 billion Euro for 1995, which corresponds to a share of Europe's GDP of 0.5%. Road congestion costs are not equally spread across Europe. As expected, the big industrial countries along the "blue banana" (UK, France, Germany and northern Italy) contribute by far the most to total road congestion costs in the EUR-17 countries.

A rough estimate concludes that 70% to 80% of total congestion costs and revenues in passenger transportation result from urban traffic while the remaining share of costs occur in long-distance travel. In freight transport the share of urban congestion is considerably lower; it is estimated to range between 25% and 45% within the EUR-17 countries.

The forecast of traffic demand to 2010 shows a dramatic increase of total congestion costs of 142% to 80.2 billion Euro p.a. Congestion on the inter-urban road network is estimated to rise of 124%, while on urban roads an increase of 188% is expected. However, these estimates assume that road infrastructure capacity remains constant, which is most likely not true for Europe's major road infrastructure bottlenecks.

The two other approaches show the following results for 1995:

- Revenues from optimal congestion pricing amount to 254 billion Euro (3.7% of GDP).
- Additional time costs amount to 128 billion Euro (1.9% of GDP).

Marginal external congestion costs per vehicle kilometre are defined as the difference between the marginal social costs which a user imposes on the whole system and the private costs perceived by him. They are evaluated on the basis of speed-flow diagrams and are presented by road type as a function of lane occupancy. The following table shows the most important values.

Marginal congestion values (Euro / 1000 km)	Marginal values per vkm SRMC	Charge	Av. DWL	Marginal values per pkm / tkm SRMC	Charge	Av. DWL
Passenger car on motorway						
- relaxed traffic	11	11	0′	6	6	0
- dense traffic	1′980	1′000	78	1′040	529	41
- congestion	2′030	1′480	195	1′070	778	102
Passenger car on rural road						
- relaxed traffic	37	37	0	20	20	0
- dense traffic	1′250	803	2	660	423	1
- congestion	1′950	1′690	28	1′030	888	15
Passenger car on urban road						
- relaxed traffic	26	26	0	19	19	0
- dense traffic	2′710	1′590	60	1′900	1′140	43
- congestion	3′100	2′210	179	2′210	1′580	128

Table S-3: Short-run marginal external costs (SRMC), optimal user charges and average dead-weight-loss (DWL) of road congestion for passenger cars.

Corridor estimates

Our corridor estimates aim to present a set of examples of the magnitude of short-run marginal costs in particular traffic situations to allow a comparison between different passenger and freight travel alternatives. To achieve this goal, four European border-crossing corridors were selected. They constitute two passenger routes (long distance: Paris–Vienna and short distance: Paris–Brussels) and two freight relations (combined Alpine-crossing: Cologne–Milan and uni-modal harbour-hinterland shipments: Rotterdam–Basle). For each corridor three modes (road, rail and a multi-modal alternative) considering corridor-specific rolling material and loading factors, were selected. For the inter-modal transport alternatives (passenger air, combined rail-road freight) all involved transport means are considered (i.e. including terminal or airport access by road).

Following the structure of the report, accident-, environmental- and other transport-external costs on the one hand and marginal external congestion costs and road user charges on the other hand are presented separately in the corridor estimates summarised in table S-3. Since only short-run marginal costs are considered, infrastructure related costs (like nature and landscape, most of the upstream effects) are neglected. The marginal cost calculations are based on a differentiated description of travel routes by road and rail, taking into account local characteristics such as the type of land use, population density, type of infrastructure and traffic conditions. The corridor-wise results are expressed in Euro per pkm/tkm to mark different route lengths and different vehicles used in intermodal transport chains (see fig. S-6 for accident and environment costs).

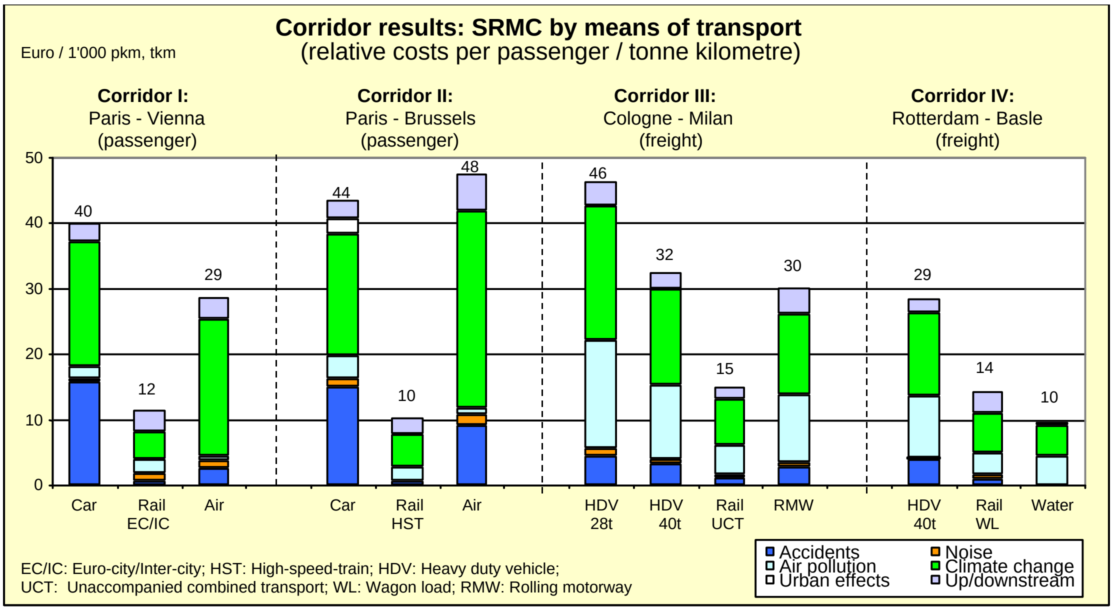

Figure S-5: Corridor results: Accidents and environmental costs for different means of transport

Comparing the corridor results with the average costs in passenger and freight transport (figures S-2 and S-3) the following observations can be made:

- For all uni-modal travel alternatives (passenger and freight) short-run marginal costs are 40–60% below average costs. This is mainly due to three facts:
  (1) the regressive cost function for noise emissions,
  (2) the neglected long-run cost elements and
  (3) the relatively high road safety standards in the countries considered.
- This decrease does not hold for the costs due to the emissions of CO_2, which – in contrast to average costs – dominates all other cost components because CO_2-emissions are not influenced by vehicle technologies nor is the economic valuation sensitive to the type of area.
- Due to the comparatively high external costs of road transportation, the intermodal travel alternatives air (passenger) and rolling motorway services show a rather unfavourable picture compared to unimodal rail transport. The relative external costs calculated are close to those of pure road transport.
- In freight and scheduled passenger transportation, vehicle loading factors may vary significantly and thus the average marginal costs per passenger or tonne kilometre show a wide range of uncertainty. The comparison between different passenger and rail services shows that this effect is more important than the technical standard of the rolling stock used.

The marginal external congestion costs in road and air passenger transport clearly dominate the environmental externalities presented in figure S-6. While congestion costs are about two times higher in the long-distance corridor Paris–Vienna, the short-distance route from Paris to Brussels (corridor II) with its high share of urban roads shows a ratio of 6 for road and 4.7 for air transport.

Uncertainty ranges

The most important sensitivities are the risk value being important for nearly all cost components, the minimal noise level (55 dB(A)), the consideration and procedure of air pollution costs (esp. material damages and biosphere) and the unit costs for climate change. Compared to the previous study (IWW/INFRAS 1995) one can state that the range of uncertainty has decreased, due to more robust data and more in-depth knowledge on several cost components.

Note, however, that the sensitivity ranges vary to both sides. Thus, the cost levels could be higher or lower. Note as well that the sensitivities can outweigh one another. The overall range of uncertainties could even be lower than the uncertainty range for one individual cost component. Thus we can conclude that the primary assumptions chosen in this study represent a 'best guess'. There is no systematic under- or overestimation of the results.

Concluding remarks

Estimations of external costs on a European scale face several challenges. Firstly, a solid and comparable data basis is needed for all countries and all means of transport. Secondly, robust dose response functions and valuation principles for different cost categories are necessary in order to produce defendable results. Although the situation in comparison with previous studies has significantly improved, it is still important to interpret the results in an appropriate manner.

Most important are the relations between different means of transport. In spite of several uncertainties, the relations remain stable and show the level of specific external costs. Within passenger transportation, railways are still the means of transport with the lowest level of external costs. For freight transport rail and waterborne transport are about equal.

The comparison also shows the relevance of different cost categories. Not surprisingly, the better known externalities (accidents, noise) remain rather stable, whereas the risks of air pollution and climate change have led to increased costs. It is important that natural science research in to emission data and cost estimation has improved significantly in these areas during the past few years. Especially for air pollution related health costs and future climatic changes which are rather recent research fields. New risks may possibly be added and integrated in cost estimations in future.

If we consider the trend, total and average costs will increase, despite improved productivity and technology. Although this might be surprising at first sight, there are three main reasons for it. Firstly, the trend of traffic growth will hold and will increase total pollution levels in many areas. Secondly, willingness to pay (for environmental protection) will increase. Willingness to pay will increase with incomes and will lead to higher unit values. Although it is difficult to say what degree this will be the case, the direction is very clear. Thirdly, we have to consider that productivity will increase in future for all transport means, but in different directions. There are some specific effects to consider which might offset the positive impacts. In passenger transportation for example, increased motorization and new forms of (more individual) leisure transport might lead to lower occupancy rates and increasing average costs. In freight transportation, similar effects are possible with increased degrees of globalisation.

In this report average costs and marginal costs are compared. The definition of marginal costs plays a major role in this comparison. Whereas it is very obvious that marginal costs differ from average costs for congestion and noise, because dose response and cost functions are not linear, it is rather difficult to conclude anything like that for other cost components. There are, however, two other elements which became visible making this comparison. Firstly, the marginal cost approach – being mainly a bottom-up approach – is very appropriate to provide differentiated results for different types of vehicles and different traffic situations, in order to make the range of costs visible. Secondly, it is helpful to distinguish between short-term impacts (directly related to the amount of traffic) and long-term impacts (which consider production and life cycles as well). This is especially true for nature and landscape and of up- and downstream processes.

It is also important to read, understand and interpret the results in a ‘top-down manner’. The general statements made above are very robust and should help to provide a sound basis for further cost estimations and for policy implications (especially in the field of pricing). However, it has to be considered that the aggregated results are much more robust than the desegregated results, for example for specific countries or for specific traffic situations, since these values were derived from aggregated results. Thus, the more detailed the results are, the more illustrative they should be considered.

The study has shown the strengths and weaknesses of the estimation of external costs which is useful for future studies. We conclude the following major issues should be treated in more depth:

- **National accounts and marginal costs for different traffic situations**: For these two data sets the purpose of the estimation and the approach employed is quite different. Whereas the former can be used as statistical and strategic information on national level, the latter is directly relevant for pricing issues. The comparability of the approaches employed should be improved. More information is needed on the shape of the cost curves varying with the most important factors of influence.
- **Risk values**: Being one of the most critical assumptions in estimating external costs, the definition of risk values needs a lot of accurate evidence, including political and societal discussions of risk.
- **Air pollution costs**: More research is needed in the field of particulate matter (modelling, relevance of different particulates) for the estimation of health costs.

The other cost elements (especially building damage, damage to the biosphere) have to be improved by new estimations of dose-response relationships.

- **Costs of climate change risks**: In-depth discussions are necessary on the question of the target level to be chosen as this is the main element of cost uncertainties.
- **Congestion**: Although there is enough evidence to estimate marginal congestion costs, the relevance of total (external) congestion costs is still not finally determined.
- **Other external costs**: Upstream effects are in certain cases considered especially for fuel production and for electricity production used by electric trains. Due to lack of scientific data, electricity used for vehicle production by example is not considered. Although their relevance is quite limited compared to the main cost categories, it is important to include them more accurately in future in order to communicate their levels properly.

1. Introduction

1.1. The task

Non-internalisation of external costs in the transport sector is causing wrong market signals and thus leads to significant inefficiencies, expressed as congestion, security problems and significant environmental nuisances. Railway systems are in general the environmentally most adapted transport mean, but are still negatively affected by non-internalisation of external costs. Within the ongoing liberalisation process on an international scale, an internalisation of external costs towards fair and efficient prices between transport means is more essential in order to develop sustainable transport solutions. This policy is recommended by the European Commission within the White Book on 'fair payment of infrastructure use' (EU 1998) In order to implement such a policy, a sound empirical basis of external costs is imperative.

The UIC-study 'External Effects of Transport' (IWW/INFRAS 1995) was the first study presenting external costs for all countries in Western Europe.[4] This very important data basis was used by the EU-Commission preparing the Green Book on 'fair and efficient prices' (EU 1995) and by the working group ECMT preparing their report on internalisation policies (ECMT 1998). The UIC-study was based on the knowledge of the early nineties and presented values for 1991. In the meantime more in-depth knowledge on the estimation of external costs is available (on one hand on European level – for example the EU-research projects ExternE, PETS, QUITS, FISCUS - on the other hand on national level) and besides the quality for transport and environment related data in Europe has improved.

This update study wants to improve the empirical basis of external costs of transport based on the actual state of the art of cost estimation methodologies. The following dimensions will be considered:

- Cost categories: Accidents, noise, air pollution (health, material damages and biosphere), climate change risks, other environmental effects and congestion costs,
- Countries: EUR 17 (EU member states, Switzerland, Norway),
- Cost items: Total and average costs per country, marginal cost per traffic situation,

4 UIC provides as well inputs for the implementation of fair and efficient transport pricing. The most important strategies and instruments are provided in a policy paper (INFRAS 1998e). In order to improve the knowledge on the revenue effects of Social Marginal Cost Pricing, UIC (cofinanced by the European Commission) launched a study, where the TRENEN-models are applied for France, UK and Germany.

- Differentiation of transport means:
  - Road transport: Motorcycles, private car, bus, light goods vehicles, heavy goods vehicles,
  - Rail transport: Passenger and freight,
  - Air transport: Passenger and freight,
  - Waterborne transport: esp. inland water transport,
- Further differentiation:
  - Diesel and petrol (passenger cars), diesel and electric traction (railways)
  - Urban and interurban passenger traffic,
  - Short and long distance freight traffic,
- Base year: Detailed results for 1995 and rough estimate for 2010,
- Application of the results for two point to point relations (Corridor estimates).

Basically the report presents total costs, average costs and marginal costs. Total and average costs are presented per country and transport means, whereas marginal costs are shown for different transport means and traffic situations.

The study is on one hand an update of previous estimates, on the other hand it provides new and upgraded information in comparison to the initial UIC-study. Thus a comparison of old and new values will have many more dimensions than only the different time horizon. Nevertheless we finally will try to explain the main differences based on:
- new traffic situations,
- new traffic and environmental data,
- new unit values or valuation approaches,
- new cost elements considered.

1.2. The procedure

The following Figure 1 gives an overview of the procedure and the input/output of the different work packages leading to the results requested.

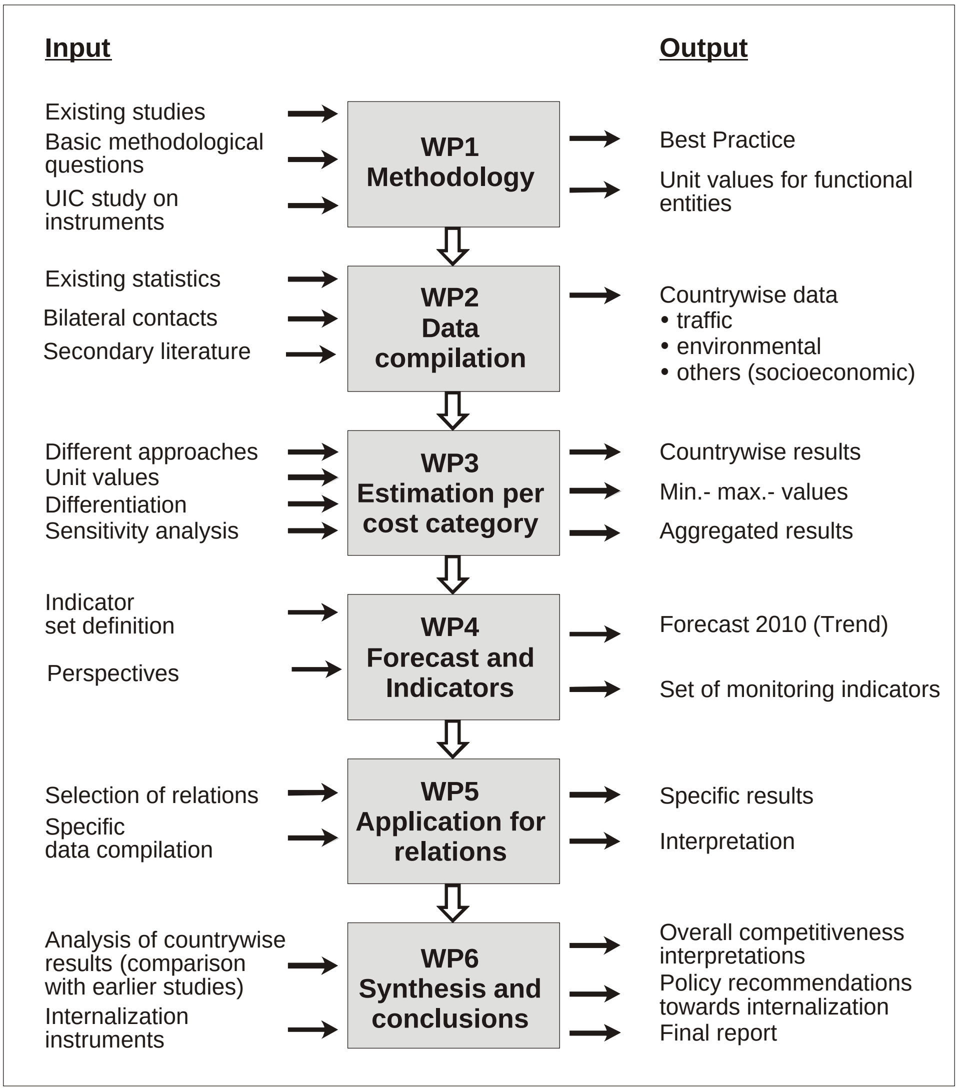

Figure 1: Overview of the work packages (WP)

1.3. Structure of the report

The report presents the methodology chosen and the results per cost category and per transport mean. It is structured as follows:

- Chapter 2 presents firstly the general methodological issues such as the most interesting and sensitive assumptions and the principles for the systems delimitation. Secondly –the procedure and the main assumptions (unit values) for the valuation of each cost component (except congestion) will be shown. Finally the procedure and main assumptions for the forecast 2010 are presented. The methodological background and detailed procedures are shown in the annex.

- Chapter 3 presents the results of total and average cost per country for each cost component (except congestion) for the year 1995 and 2010. Background data and details of the data procedure is shown in the annex.
- Chapter 4 presents the results of marginal cost for each cost component (except congestion) for specific traffic situations.
- Chapter 5 is about congestion costs. These costs are treated separately, since the methodologies and the understanding of the cost for the means of transport considered differs quite significantly from the other cost items. Hence congestion will not be added to the other total and average costs.
- Chapter 6 presents the procedure and the results for the corridors chosen
  - Passenger transport: Paris-Brussels and Paris-Vienna
  - Freight transport: Rotterdam-Basle and Cologne-Milan
  In this chapter, congestion costs are included.
- Chapter 7 finally interprets the results in regard to validity and robustness of data and presents the results of sensitivity analysis.
- Annex 1 presents the most important general input data (socio-economic and transport data per country).
- Annex 2 contains background material and detailed information of the procedure chosen for each cost component.
- Annex 3 finally presents the results (total and average costs) per country.

2. Methodology

2.1. General methodological issues

This chapter outlines the most important methodological aspects. Since all these aspects are discussed in several reports at length, especially in the primary UIC study (IWW/INFRAS 1995) and in related EU research projects (like PETS, TRENEN, ExternE, CAPRI, TRENDS) it is much more a summary focussing some critical aspects which seek for interpretation and decisions on the procedure to be chosen.

2.1.1. Overview of costs considered

The following Table 1 gives an overview of the cost components, which are considered within this update study.

Type of effect	Cost components	Leverage points and variability	Type of Externality
Accidents	Additional costs of - medical care - economic production losses - suffer and grief.	Depending on different factors (partly on vkm).	Partly external (part which is not covered by individual insurance), especially opportunity cost and suffer and grief.
Noise	Damages (opportunity costs of land value) and human health.	Depending on traffic volume and environmental performance.	Fully external.
Air pollution	Damages (opportunity costs) of - human health - material - biosphere.	Depending on vkm, energy consumption and environmental performance.	Fully external.
Climate change	Damages (opportunity costs) of global warming.	Depending on consumption of fossil fuels.	Fully external.
Nature and landscape, water and ground sealing	Additional cost to repair damages, compensation costs.	Fixed costs (separation effects partly depending on traffic volumes).	Fully external.
Separation in urban areas	Time losses of pedestrians.	Depending on traffic volume.	Fully external.
Space scarcity in urban areas	Space compensation for bicycles.	Depending on traffic volume.	Fully external.
Additional costs from up- and downstream processes	Additional environ-mental costs (air pollution, climate change and risks)	Fixed costs (grey energy of infrastructure and rolling stock)	Fully external.
Congestion (treated separately)	External additional time and operating costs.	Depending on traffic amount (number of vehicles).	Separate issue (in relation to other costs): Average costs are internal to the users. Difference between marginal and average costs are external costs.

Table 1: Overview of external costs being considered

In comparison to the 1995 study, several aspects are new being mainly responsible for a change of the results:

- Noise related human health costs (e.g. risks of heart attacks) will increase the valuation of noise costs.
- Human health costs mainly related to the emission of particles and other air pollutants such as NO_2 (risks of asthma and lung cancer) will increase the valuation of air pollution costs. In fact the change to the 1995 study is most significant, since many recent results (epidemiological studies, air pollution modelling, cost estimations) have to be considered.
- Repair and compensation costs for nature and landscape consider the damages (mainly of infrastructure) for all transport means.
- Additional costs occur in urban areas: We have chosen two cost elements which are well known and valuation procedures do exist. Both are related to non-motorised transport. The separation effects (due to infrastructure and traffic volume) increase time cost for pedestrians. The valuation of bicycle lanes represent the scarcity of space for non-motorised transport in urban areas.
- Up- and downstream processes consider the long term aspects in the transport cycle. They occur due to the production and maintenance of infrastructure and rolling stock and the precombustion of energy.
  In the 1995 study the emissions due to electricity production (esp. for the railways) was considered, whereas the precombustion processes of fuel was neglected. Within this study we choose the following distinction:
  - Within the costs of air pollution and climate change, the emissions due to electricity production are considered. Thus the values are comparable with the previous study.
  - Within the costs of up- and downstream processes, additional precombustion processes are considered, such as
    - precombustion of fuels (transport and refinement)[5],
    - production and maintenance of rolling stock,
    - production and maintenance of infrastructure,
    - nuclear risks of electricity production (only for the operation of railway services).

These additional elements will – compared to the 1995 study – increase the values significantly.

Note that some cost elements however are not considered:

- Infrastructure costs are not included, since these costs are only external if revenues are considered as well.[6] Potential infrastructure deficits however depend very

5 The risks for electricity production for the production of vehicles and infrastructure however are not considered.

6 In fact this is true for all external cost. In general however specific transport charges are aimed at covering infrastructure costs.

much on the existing taxation system and the political framework conditions (especially related to the ongoing liberalisation process in the transport sector).

- Other environmental costs are summarised by specific cost components, which firstly are relevant and secondly transparent estimation procedures can be used (see the comments within the respective chapters 2.6/2.7). The estimation procedures can be seen as pilot results, which do not cover the complete range of other environmental disturbances caused by the transport sector.
- External congestion costs consider the overuse of infrastructure in non-scheduled transport. Scarcity costs (which occur for all transport modes) however are not regarded as external. Several studies (e.g. VCÖ 1998) consider total congestion costs, including as well time losses of parking search traffic. We concentrated on the external component of these costs, leading to much lower values (see chapter 5).

2.1.2. Scope of external costs

a) What means "external"?

This update study is focussing on external costs of transport. Previous studies have shown, that it is essential to have a common understanding about the meaning and relation of the term "external". According to the welfare maximisation approach we concentrate ourselves on the **individual point of view**.[7] Hence all costs are seen as external which are not covered by individual traffic users. Hence costs and specific transport charges should be considered and compared for all modes. Transport charges are however only considered for the case of accidents (insurance). It is assumed that the other transport taxes and charges are related mainly to infrastructure costs which are not covered within this study.

b) Total, average and marginal costs

Within the update study, all three types of costs will be estimated. It is important to clarify in advance, how these different results should be interpreted with regard to the internalisation of external costs.

- **Total external costs** refer to the sum of external costs within a special area for a specific time period. It is the sum of individual external cost related to an actual traffic situation. They can be compared between each other, with social costs of transport as a whole (including internal costs), with other social costs in other sectors or with GDP to get an idea about the relevance of each cost component per

7 A typical example are congestion costs: Although these costs are mainly borne by the traffic users as a whole, several costs (e.g. additional time costs – above the average - to the other users) are not covered by individuals and therefore external. The same holds true for accident costs, which are caused between different traffic users (e.g. road transport). From an individual point of view, all those costs are external, which are not covered by individual accident insurance.

transport mean in order to set policy priorities. In addition, a comparison over time is interesting with regard to the development of each cost component.

- **Average external costs** are equal to total costs divided by traffic units and allow the comparison between different transport means. Thus these costs as well are referring to an actual traffic situation within a specific time period. Average costs are interesting for the comparison of the cost performance of different transport means considering today's framework conditions. With regard to road traffic, the ideal indicator is cost by vehicle kilometre. With regard to intermodal comparison, units like passenger and tonne kilometres are appropriate.
  Since infrastructure costs are not covered within this study, average costs are only partially a basis for price signals considering full cost coverage. As a matter of fact, this holds true for accident costs and some other externalities, since dose-response-functions are not very well known. In this cases, average variable costs are a proxy for marginal costs.
- **Marginal external costs** are equal to the additional cost of an additional traffic unit. We have to distinguish between short and long run marginal costs. Short run marginal costs are related to an additional vehicle entering the (existing) system, neglecting (fixed) cost to run the system or additional cost for possible network improvements in the longer run. They can be estimated out of real traffic (and cost) situations, when only variable costs (i.e. costs depending on traffic volume) will be considered. An alternative approach is the estimation of these costs by model simulations. According to the recommendations of the White Paper of the European Commission on 'fair payment of infrastructure use', these costs are a basis for optimal (efficient) pricing of transport.
  Long run marginal costs are considering future system enlargements due to increased traffic volume. Since in the long run, all costs are variable, a possible proxy is – as stated above – the estimation of average costs.[8] We consider this aspect within the marginal cost estimation for some cost elements which are related to infrastructure and thus fixed in the short run (such as nature and landscape depending on the state of existing infrastructure).
  Short run marginal external costs in the optimum are – according to welfare theory – equal to optimal prices for the internalisation of these costs. In order to estimate the level of these costs, traffic reactions due to the introduction of prices have to be considered. Thus, the optimal level of marginal costs is somewhat below the marginal external costs estimated out of real traffic situations.[9]

c) Actual and "optimal" costs

This update study refers to the base year 1995 (incl. a trend forecast for 2010). Thus total and average costs will be based on the traffic situations (traffic amount, loading

8 Note that congestion costs are short run marginal costs. In a long run perspective, future infrastructure costs should be considered in order to get a comprehensive picture.

9 This has to be done by model applications (see for instance TRENEN), which considers as well reactions on other (not transport related) sectors.

factors, modal split etc.) referring to the base year respectively. This situation is different to an 'optimal' situation, where 'optimal' short run oriented prices would be introduced, according to the proposals of the EU-Commission. Within an optimal situation, it is likely that especially loading factors of public transport might improve slightly and specific external costs would decrease.

For the basic estimation of the different cost components, we refer to real traffic situations, estimating the costs in the existing situation.[10] This is as well true for the marginal cost estimation: The results obtained are marginal costs in the existing traffic situation. With this information, optimal prices could be computed by using specific reaction models (e.g. TRENEN). One exception is congestion, which is treated separately within this study (Chapter 5).

d) The scope of congestion

External congestion costs can be regarded as the welfare loss not borne by individual users due to lack of capacity or misallocation of existing volumes (e.g. overuse of infrastructure). It is important to state that this phenomenon might occur as well for scheduled transport like rail and air transport, but it is quite difficult to estimate and does mainly reflect existent inefficiencies of schedule management. We consider scarcity costs of scheduled transport with possible delays not as an externality, since the operators are able to allocate scarce infrastructure by different means to prevent from delays in future schedules.

As mentioned above, congestion is treated separately within this report (chapter 5). This chapter includes these methodological aspects and presents the results of the estimation of total and average costs per country[11] and marginal costs for different traffic situations.

2.1.3. Data basis and country allocation[12]

a) Harmonisation of transport data

In order to base the estimation of countrywise external costs on consistent data, we need comparable figures for transport volumes, emissions etc. Two possibilities are available:

1. Country figures based on official national statistics: Although these are official figures, a comparison between different countries is difficult since the elaboration

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10 Note that within the actual situation, there are some distortions because of non-internalisation of external effects, which is not in favour of those transport means with low external costs like rail and waterway transport.

11 These costs are estimated in three different ways: Additional costs in relation to an acceptable traffic situation, revenues of an (optimal) congestion charge, net welfare losses for car drivers facing an (optimal) congestion charge.

12 See basic data in annex 1.

of these figures usually follows different national methodologies and procedures. Fully harmonised data on European level are being prepared by EUROSTAT, but not yet available.

2. Standardised figures, based on national performance figures like vehicle stock etc. Such figures are produced in related research projects, especially on EU-level. These figures are comparable between countries but do usually not represent national official values. The differences might be significant, although detailed explanations for the deviations might not be available.

We have chosen the second approach since standardised figures allow more easily a comparison of results between different countries.

b) Road transport

Within ongoing research projects (TRENDS 1999) standardised transport volumes and emissions are being estimated for different years. The estimations are based on national motorization (vehicle stock performance), national assumptions of mileage per vehicle and national characteristics (age and emission characteristics of the vehicle stock, national topographic characteristics etc.). This approach allows a consistent and harmonised data basis for each country and enables as well a forecast for 2010, since TRENDS is estimating current emissions and long term perspectives.[13]

c) Rail transport

The traffic data is based on UIC statistics. A very important assumption is related to electricity production and their emission factors, being relevant for air pollution costs and climate risks. For the 1995 estimation, the specific electricity mix of national railways is used. Since detailed results for all countries were not available, we had to base our assumptions on other sources (like information for Germany (DB 1999) and results of a COST-project (Lewis 1997), see annex 2.3.). The electricity mix for the trend forecast 2010 however is standardised and based on the international UCPTE-mix, since electricity markets will be liberalised and national energy mixes might not longer be relevant.

d) Other transport means

For air transport, the national performance of airports and ICAO statistics is considered. Two mileage performance are of interest: For the local effects, so-called LTO-cycle is relevant, which is based on national movements. For global effects, the international mileage has to be considered in order to estimate the emissions. Thus the following specific distances of flights are assumed:

- National relations 300 km
- International relations 1'400 km

For waterways, we used the official EUROSTAT figures. Within these transport means, consistency of data is given, since the input figures are standardised.

13 More detailed information on TRENDS are presented in annex 1.

e) Allocation of cost to countries

Two principles are possible: The causing (nationality) principle, which considers these externalities being caused by traffic users originated from a country, and the suffering (inland) principle which considers these externalities being caused in a country. Basically we will use the territorial principle, since data availability is very limited to estimate the difference. Besides the distinction between these two principles is only partly relevant. It has to be noted however that it was not possible to be consistent for every input data and cost estimation approach. Especially the input figures for road transport are based on the nationality principle, since the figures elaborated are built up on national vehicle stock, whereas the mileage could be anywhere. Thus an important assumption had to be met: **Export and import of mileage (and emissions) are in a balance:** If for example Dutch vehicles cause externalities in Germany, it is assumed that vice versa German vehicles cause the same amount of damage in the Netherlands. It is not possible to prove this assumption consistently. Detailed estimations for Switzerland (having quite a significant part of transiting traffic) for example indicate that this assumption causes minor differences on a national level (INFRAS 1998a).

A specific assumption has to be met for climate risks, since these damages are relevant on a global scale and thus difficult to allocate to specific countries. We considered the following rules:

- Road, rail and waterways: The CO_2-emissions of a country are the basis for the estimations for the world-wide damages and the avoidance costs respectively.
- Air transport: Allocation of CO_2-emissions and other greenhouse gases based on national mileage allocation (see assumptions above) and estimates similar to the other transport means.

2.1.4. Valuation aspects

a) Basic valuation approaches

The different valuation methods have been discussed widely in previous studies. The major rules can be summarised as follows:

- Resource approach: The estimation of damage costs (opportunity costs for the society suffering or repairing these damages/loss of resources) is most appropriate from an economic point of view.
- Prevention approach: The estimation of avoidance costs (in order to avoid damages referring to specific environmental targets) is the second best approach, if damage

costs cannot be estimated properly. This holds especially true for climate change risks.[14]

- 'Optimal' cost levels could be generated, if both approaches are used and marginal damage costs are equal to marginal avoidance costs. Due to the major uncertainties and lack of information, this optimum is very difficult to define and – as already mentioned – not considered in this study.

Within the update study, the **damage cost approach** will be used basically. For climate change effects however, the avoidance cost approach will be used as the main approach, using the damage cost approach for plausibility. We interpret the avoidance cost of climate change as a (standardised) national willingness to pay in order to contribute to world-wide reduction of climate change risks.

b) Critical and sensitive values

Comparing different studies on external cost estimates, nearly all basic (unit) values are quite sensitive for the results (see details in the following chapters). Two basic assumptions are however relevant for different cost categories:

- **Valuation of human life**: Since it is important for the valuation of accident costs, health costs due to air pollution and partly for noise and climate change effects, this value is the most critical assumption throughout the whole study. Looking at the empirical evidence, we can distinguish the human capital approach and the willingness to pay (WTP) for additional risk reduction, based on studies in Scandinavia and UK. CAPRI (based on ExternE) recommends 3.1 million Euro as the value of a statistical life. In comparison the Swiss average value (based on human capital approach) is 1.2 million Euro.
  ► From an economic point of view, the WTP approach is more appropriate. The problem however is the empirical basis to be transferred to all countries. We recommend to use **1.5 million Euro**. We will discuss the details in the subsequent sections (see chapter 2.2. and annex 2.1 respectively).[15]
- **Value of time:** These values are very sensitive for the estimation of the level of congestion costs and additional urban external costs. In comparison to the estimation of human life however, opportunity cost estimates are existing in different studies (especially PETS 1998). There is consensus in using harmonised values. Thus we will use the values recommended on EU-level, see details in chapter 2.2.

In order to consider the range of uncertainties properly, we treat the most sensitive issues in the final chapter on sensitivities (see chapter 7.2).

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14 In the case of climate change. The avoidance cost approach can be seen as the best approach, since it is not possible to estimate the damages properly.

15 This value will be varied in a sensitivity analysis (0.5 million and 3 million Euro).

c) Differentiation between countries

Are time losses or people being killed more expensive in Sweden than in Greece? The differentiation of unit values for different countries is a crucial aspect in a European wide estimation of external costs. Projects like ExternE for example do not differentiate between countries. Looking at the European future with a unit currency (Euro), the distinction will decrease continuously. From our point of view however we think that the opportunity cost of a society depends on its purchase power. Thus, we will consequently translate the values - derived from a representative sample of studies - from one country to another. Therefore we use the **income per capita** as adjustment factor between different countries. It is important however to use the same unit values for all countries in order to allow comparability.

2.1.5. Presentation and aggregation of results

a) Presentation of total, average and marginal values

Total and average costs are presented by country and by transport mean. In addition, average costs refer to specific traffic situations. The same differentiation will be chosen for the presentation of the marginal values, in order to be able to compare marginal and average values. Since the method for the computation of marginal values is mainly based on a bottom up approach (see below), it is possible to present further differentiation. This differentiation is referring to each cost component considering the specific influence factors.

b) Bottom up and top down approaches

Looking at the data situation, national sources are usually better than regional data. In order to estimate total and average costs, it is thus more appropriate to rely on national data sources using a top down approach, where total cost will be allocated to different transport means. This approach has been applied also in the first study. Besides the advantage of better data availability, it allows to present a more or less consistent national average value.

In order to estimate differentiated marginal (and average) values however, a bottom up approach, based on specific and predefined traffic situations, is more appropriate, since this approach is directly relevant for the definition of differentiated pricing schemes. The results can be compared with the top down approach.

The following Table 2 gives an overview of the principle approaches applied in this study.

Type of effect	Total and average cost per country	Average cost differentiation	Marginal cost differentiation
Accidents	Top down, based on national accident figures	Top down, based on national accident figures	Bottom up, based on accident risks.
Noise	Top down, based on noise exposure.	Bottom up, based on noise modelling.	Bottom up, based on noise modelling.
Air pollution	Top down, based on pollution exposure.	Bottom up, based on air pollution modelling.	Bottom up, based on air pollution modelling.
Climate change	Bottom up, based on specific CO2 emissions	Bottom up, based on specific CO2 emissions	Bottom up, based on specific CO2 emissions
Nature and landscape, water and ground sealing	Top down, based on national infrastructure data.	Top down, based on national infrastructure data.	Top down, based on regional infrastructure data.
Separation in urban areas	Bottom up, based on random sample evaluation.	Bottom up, based on random sample evaluation.	Bottom up, based on random sample evaluation.
Space scarcity in urban areas	Bottom up, based on random sample evaluation.	Bottom up, based on random sample evaluation.	Bottom up, based on random sample evaluation.
Additional costs from up- and downstream processes	Top down, based on national emission data.	Top down, based on national emission data.	Top down, based on national emission data.
Congestion	Bottom up, based on network modelling.	Bottom up, based on network modelling.	Bottom up, based on network modelling.

Table 2: Overview of the principal approaches chosen for each cost component.

c) Comparison of average and marginal costs

The comparison has to consider the following elements:

- Identical values due to identical approaches and constant[16] dose-response-functions: This is the case for accident costs, costs for climate change and costs of up- and downstream processes. Although there are several considerations for progressive values, the approaches are simplified (see the remarks in chapter 2.2, 2.5 and 2.8).
- Similar values due to similar methodologies, but different estimation procedures: This is the case for air pollution costs, since total and average costs are estimated by a top down approach and marginal costs are estimated on a marginal cost approach, based on the ExternE-method (see remarks in chapter 2.3).
- Different values due to non-linear dose-response-functions: This is the case for congestion and noise costs, where dose-response-functions are easier to derive. For these two cost components, the difference between average and marginal costs is most relevant.
- Different values due to short and long term considerations: This is the case for the costs related to infrastructure (i.e. nature and landscape, additional costs in urban areas). In the short run, these costs are zero due to the assumption of fixed

16 Not varying with the amount of traffic.

infrastructure. Whereas in the long run, these costs become equal to average costs, considering increased infrastructure due to growing transport volume.

2.1.6. General aspects for the forecast 2010

Several assumptions have to be done for the forecast of the external cost 2010. The main changes will be within the transport volume. For the road transport, the TRENDS-database is used, which provides also a detailed forecast for the mileage of vehicles and emission forecast. For rail passenger transport, an assumption is made that the share of rail transport is constant, that means that the same growth factor as for road passenger is used, for train kilometres and for passenger kilometres. The air traffic volume forecast is based on the ICAO outlook for air transport for 2005 (ICAO 1998). There relatively high annual growth rates for passenger km, for aircraft km and for aircraft movements are used. To produce an outlook for 2010, the rates have been lowered, according to other international studies.

Also some technical aspects and the socio-economic framework will be adapted.

Aspect	**Source**	**Assumption**
Road transport volume	TRENDS	- Car traffic: +26% for EUR17 (countries vary between +13% and +65%) - Freight transport: +30% (between +6% - +59%) - Bus traffic volume: between +50% and +40% - Loading factors: no significant change until 2010
Rail transport volume		- Train-km and passenger-km: +26% (between +13% and +65%) - Freight volume: considered to be stable at 1995 level
Air transport volume	ICAO / other	- Passenger-km: +5% per year - Aircraft km: +4.1% per year - Aircraft movements: +2.3% per year
Waterborne transport volume		No growth of vehicle km and tonne km is assumed.
Emission Factors (all modes)	various	Reduction 1995 – 2010 within the dimensions of TRENDS database for road framework. See annex 2.3 for details.
Unit costs:	PETS	using the change of GDP per capita (see annex)

Table 3: 2010 forecast: Assumptions for the growth between 1995 and 2010 (see also annex 1). The detailed assumptions per each cost component are mentioned in the respective chapters.

2.1.7. General aspects for corridor estimation

The results of the estimation of average and marginal costs will be applied to different corridors (two passenger and two freight corridors). Since differentiated values are used and short term aspects are of major importance for this kind of comparison, short term marginal costs estimation for different transport means and transport chains are used for this comparison.

2.2. Accidents

Table 4 and figure 2 overleaf show the cost components considered and the methodology for calculating total and average external accident costs. Firstly, the cost components per casualty given in table 4 are added in order to estimate social accident costs. External costs are computed by subtracting transfers from liability insurance systems and gratification payments. The resulting external costs per casualty are multiplied with the number of fatalities and injuries. The total external costs are allocated to the modes according to the responsibility for the accident.

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	
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.	

Table 4: External accident cost components

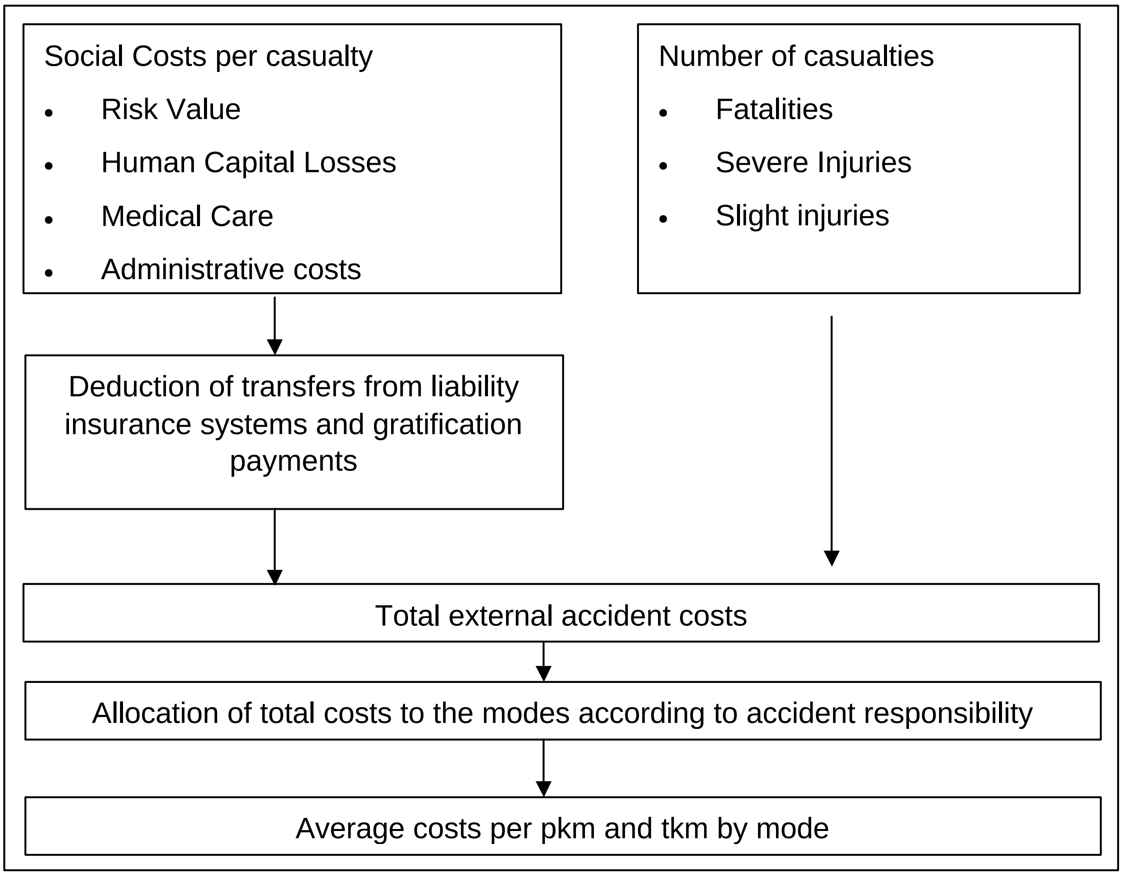

Figure 2: Methodology used for the estimation of accident costs

2.2.1. Risk Value

Accidents are not only the cause of pain and suffering, but often shorten the lifetime of their victims. This clearly is a loss of welfare, which can be regarded as external costs that have to be monetarised. The Risk Value, in some studies as well named 'Human Value', tries to estimate monetary values for pain, grief and suffering of an average transport accident victim.

Often it is argued that at least a share of the Risk Value is internal because the traveller has the choice about his mode of transport. However, it can be replied that accident risks are very small and therefore an adequate risk perception leading to a rational modal choice is very difficult and if not impossible. Thus, this study will regard the entire Risk Value as an external cost.

a) The Risk Value for fatalities

The most common method to assess the Risk Value is the contingent valuation (CV). Persons are questioned how much they would be willing to pay for reducing the probability of a fatality in road traffic. The average willingness to pay (WTP) for reduced mortality risks is divided by the risk reduction being valued. For instance, the Risk Value is 1 million Euro if the average WTP for a risk reduction of 1 in 10,000 is 100 Euro. It is important to mention that the Risk Value is not a measure for the value of a specific individual, especially the person interviewed. Rather it refers to the statistical risks before the damage occurs, i.e. it is not known which individuals will actually be involved, but it can be ascertained to what extent damages are to be expected.

Author	Country, year	EUR 17 Average * (million Euro 1995)	
		Median	Mean
Kidholm 1995	DK 1993	1.7	2.1
Desaigues, Rabl 1995	F 1993	0.9	-
Schwab, Soguel 1996	CH 1994	0.8	2.0
Persson 1998	S 1998	-	2.0
Jones-Lee et al. 1999	UK 1997	0.5	1.8
Average		**1.0**	**2.0**
* weighted with PPP and number of fatalities			

Table 5: Risk Values in recent empirical European CV studies

A number of WTP studies have been conducted in the 1990s to estimate the Risk Value. Table 5 gives an overview of various recent empirical studies based on CV in Europe. Because country values are not comparable due to the different purchasing power in each economy, an EUR 17 average[17] is calculated. The overview shows that the recent studies range between 0.5 and 1.7 million Euro for the median values and between 1.8 and 2.1 million Euro for mean values. The disparities between mean and median values can be explained by the highly right-skewed distribution of individual WTP statements. A small number of people are willing to pay amounts far higher than 50% of the respondents. Because these extremely high bids push the average higher, the researchers often use the median value to estimate the Risk Value. While mean values are an indicator of the average WTP, median values reflect the majority will of the population.

A broader overview of Risk Values and a review of the scientific discussion on CV methods are given in annex 2.1. During the last decade various methodological problems have led to a more cautious approach towards contingent valuations for the evaluation of Risk Values. The 'state of the art' is represented by the latest study of

17 Country values are weighted with the PPP and the number of fatalities. The EUR 17 average reflects the Risk Value of an average fatality in Europe.

Jones-Lee (1999) who found solutions for many of the criticised methodological problems.

The average of the median values stemming from recent empirical studies given in Table 5 amounts to 1 million Euro and for mean values to 2 million Euro. Since it is not clear which of the two values is relevant, this study chooses the average between mean and median which amounts to

1.5 million Euro for the Risk Value of an average fatality in Europe.

This value lies well within the range (median and mean) of Jones-Lee's observations. In a sensitivity analysis Jones-Lee's mean value (0.5 million Euro) is chosen as the lower border. The upper border is represented by 3 million Euro that is used in the ExternE study. Since income elasticity of the WTP is not known, country values are calculated in the same manner as all other external cost components by using the PPP adjusted GDP/capita. The Risk Value for accidents is used as well to estimate health costs for noise and air pollution effects.

b) The Risk Value for injuries

The Risk Value for injuries is estimated as a share of the Risk Value for fatalities[18]. This study will use the ratios established by ECMT (1998), which estimates the Risk Value for severe injuries at 13% and for slight injuries at 1% of the Risk Value of fatalities. Both values are based on a study by O'Reilly et al. (1994) who used a standard gamble methodology to compare the three types of risks without using monetary values. O'Reilly used this approach in order to respond to the above-mentioned criticism on the CV methodology. The latest survey by Jones-Lee (1999) could confirm O'Reilley's results. The ECMT uses as well O'Reilly's standard gamble results, but combines them with an expert ranking, which produces a slightly higher ratio. Accordingly this study will use the following values:

	Fatalities	Reported Injuries	
		Severe Injuries	Slight Injuries
(1000 Euro)	1500	200	15

Table 6: Risk Value per casualty used in this study

18 A list of ratios in several studies is given in annex 2.1.

2.2.2. Human Capital Costs

Accident fatalities of injuries entail some reduction in the future social product of an economy. The production loss can be calculated as:

1. Gross Production Loss = loss in future working time * average future national income/cap
2. Net Production Loss = gross production loss - future consumption.
   In our case, the net production loss is calculated in order to avoid double-counting the lost consumption, which is assumed to be part of the Risk Value

2.2.3. Other external costs

The remaining external costs for medical care, replacement and administration have been researched carefully by Ecoplan (1991) and are used as reference costs in this study. Ecoplan established the social costs and subtracted all costs, which can be regarded as internal, such as transfers from vehicle liability insurances, direct compensation payments, fees and fines paid by the party responsible of the accident. Table 7 only lists the external part of these costs in Switzerland. A detailed description is given in annex 2.1.

Euro 1995	Fatalities	Injuries	
		Severe	Slight
Medical care	3’227	2’525	1’160
Replacement/Reintegration	6’932	453	0
Police, Justice, Administration*	9’839	9’839	5’067
Reported Accidents	**19’997**	**12’814**	**6’225**
Not reported accidents		**2’975**	**1’159**

* registered accidents only
Source: ECOPLAN 1991

Table 7: External medical and administrative costs per casualty in Switzerland

2.2.4. Internalised social costs

More often than not, accident victims receive gratification payments or transfers from the liability insurance of the party responsible. These transfers can be regarded as social costs that have been already internalised and thus have to be subtracted from total external costs. Since no country data are available, the transfer payments are based on the Ecoplan (1991) findings for Switzerland that are adjusted to EU country values.

Euro 1995	Fatalities	Injuries	
		Severe	Slight
Direct payments	34’337	2’655	891
Transfer payments	49’531	2’639	886
Gratification Payments	691	18	6
Total	84’558	5’312	1’783
Source: ECOPLAN 1991			

Table 8: Transfer payments per casualty in Switzerland

2.2.5. Some methodological issues

- **Data Source**:
  The International Road Traffic and Accident Database (IRTAD), which delivers a harmonised data set on road accidents in Europe, is used as the main database. The term 'hospitalised' defined by IRTAD for "non-fatal accident victims admitted to hospital as patients" (IRTAD 1998, Special Report, p. 33) is used as the data for severe injuries. Unreported casualties are estimated according to IRTAD assessments, given in annex 2.1. No Risk Value is attributed to the latter accidents.
- **Attribution of accidents to the road modes:**
  The total number of accidents are distributed to transport modes according to the responsibility of the parties involved. Accordingly the number of road accidents has to be reduced by the accidents caused by non-motorised transport. Since no data are available on the responsibility in all the observed countries, German national accident risks (per vehicle km) are extrapolated on the remaining countries.
- **Rail Accidents:**
  Since annual rail accidents vary considerably, the number of casualties is estimated by calculating the average of the years 1991-1997. An analysis of these accidents at railway level crossings in Germany (Seehafer 1999, p. 32) reveals that 97% of the accidents are caused by road users. Therefore these accidents are regarded to be the entire responsibility of the road participants.
- **Occupational accidents:**
  Accidents involving railway and airline personnel are occupational accidents and thus considered to be internal. Consequently the costs of rail and airfreight accidents can be regarded as internal.
- **Air accidents:**
  Unfortunately no data were available on the number of casualties of air transport. Therefore, the number of fatalities were estimated using average fatality rates given by the ICAO. External costs for injuries could not be included.

- **A Risk Value for relatives and friends**
  is not included due to theoretical deliberations given in annex 2.1.

2.2.6. Forecast of accident costs in 2010

When forecasting accident costs in 2010 the following factors are taken into account:

- Increase of WTP (Risk Value) according to the expected increase of per capita GDP.
- Expected increase in transport volume.
- Change of accident rates (casualties per vehicle kilometre) according to the development in the last decade. With the help of regression analysis, equations are estimated for four country groups in Europe. Future accident rates are calculated by extrapolation.

2.2.7. Estimation of marginal accident costs

The knowledge on marginal accident costs is quite poor. Existing studies are piecemeal, are often not comparable or are containing methodological problems. Often strong assumption have to be made. For example, Jansson (in PETS 1998) relies often on elasticities that are based on the British and Swedish road investment computer programmes. The author states that there is "a huge uncertainty due to the limited number of observations" (p. 52). Studies on marginal costs of railways and airlines are completely missing. Therefore this analysis is focussing on road transport only.

Marginal accident costs are these costs induced by an additional vehicle using the road network, which might cause positive or negative effects. It is possible (1) that drivers are disturbed by the growing traffic and thus the number of accidents increases more than proportional. On the other hand it is conceivable (2) that average speed slows down with increasing traffic and thus the number of accidents increases slower than traffic volumes. A third possibility (3) is a shift from severe to slight accidents with slower traffic speeds on congested roads.

The decreasing accident rates in Europe seem to imply that marginal accident costs are shrinking. However, it must be taken into consideration, that during the last decade new technologies, such as non-blocking brakes and airbags were introduced that had strong effects on transport safety. Therefore, the effects of improved safety have to separated from the impacts of transport volume change in order to estimate marginal costs. Annex 2.1.9 lists seven studies[19], that have been conducted in Europe on the effects of traffic flow on accident rates.

The authors distinguish between accidents on motorways, country roads and urban roads. Unfortunately the studies are not easy to compare. Therefore, in a first step accident rates for low, medium and high traffic flows are compared. The studies show very diverging results for low and high traffic flows. Only for medium traffic flows the rates are comparable. In a second step the severity of the accidents is analysed. Unfortunately there are only two studies giving details on the number of casualties per accident (Taubmann, Krebs/Klöckner). For these studies costs per accident have been calculated using the external accident cost figures for Germany.

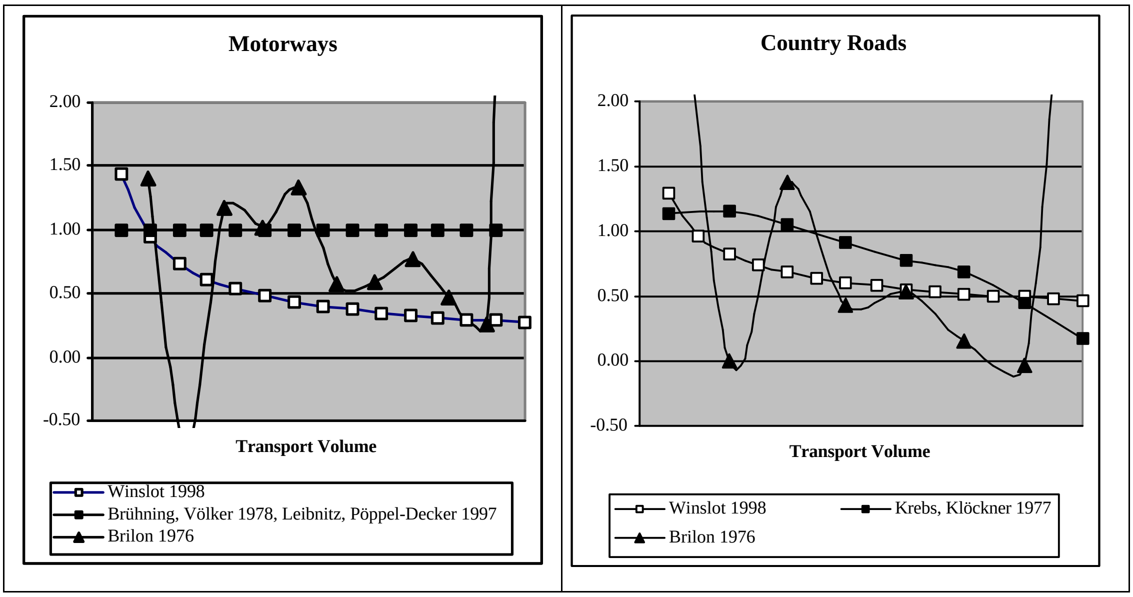

Figure 3: Ratio of marginal and average accident costs

A third step combines the first two steps and estimates the ratio of marginal and average accident costs. Figure 3 gives an impression about the curves for the ratios on motorways and country roads and annex 2.1.9 lists the results of the analysis. Large inconsistencies occur at the extremes and therefore no conclusion can be made for low and high traffic flows. For medium traffic situations in urban conurbation's two studies indicate that marginal costs equal average costs. Marginal accident costs on motorways and country roads seem to be lower than average costs. This implies that an additional vehicle probably reduces speed and thus accident probabilities and severities. The high standard deviation of the results for motorways indicates that even for medium traffic flows the results are still not very consistent.

19 Motorways: Brilon (1976), Brühning, Völker (1978), Leibnitz, Pöppel-Decker (1997), Winslot (1998).
Country Roads: Brilon (1976), Krebs, Klöckner (1977), Winslot (1998)
Urban Roads: Taubmann (1987), Dickerston (1998)

Unfortunately the studies do not give many hints on how the costs can be differentiated between the road modes. Therefore the modal split of the average accident rates is used. In absence of any scientific research on marginal accident costs of railways and airlines, it is proposed to use average costs estimates. No distinction can be made between urban and rural rail transport.

2.3. Noise

Transport noise not only imposes undesired social disturbances, but also influences the individual well being which can entail physical and psychological health damages. Hearing defects can be caused by noise levels above 85 dB(A), while lower levels (above 60 dB(A)) may cause nervous stress reactions, such as change of heart beat frequency, increase of blood pressure and hormonal changes (Planco 1995, p. 117). Noise exposure increases the risk of cardiovascular diseases (heart and blood circulation). Therefore this study includes the external costs for health risks due to noise exposure in addition to the WTP for noise reduction. Figure 4 gives an overview of the method used for the estimation of external noise costs.

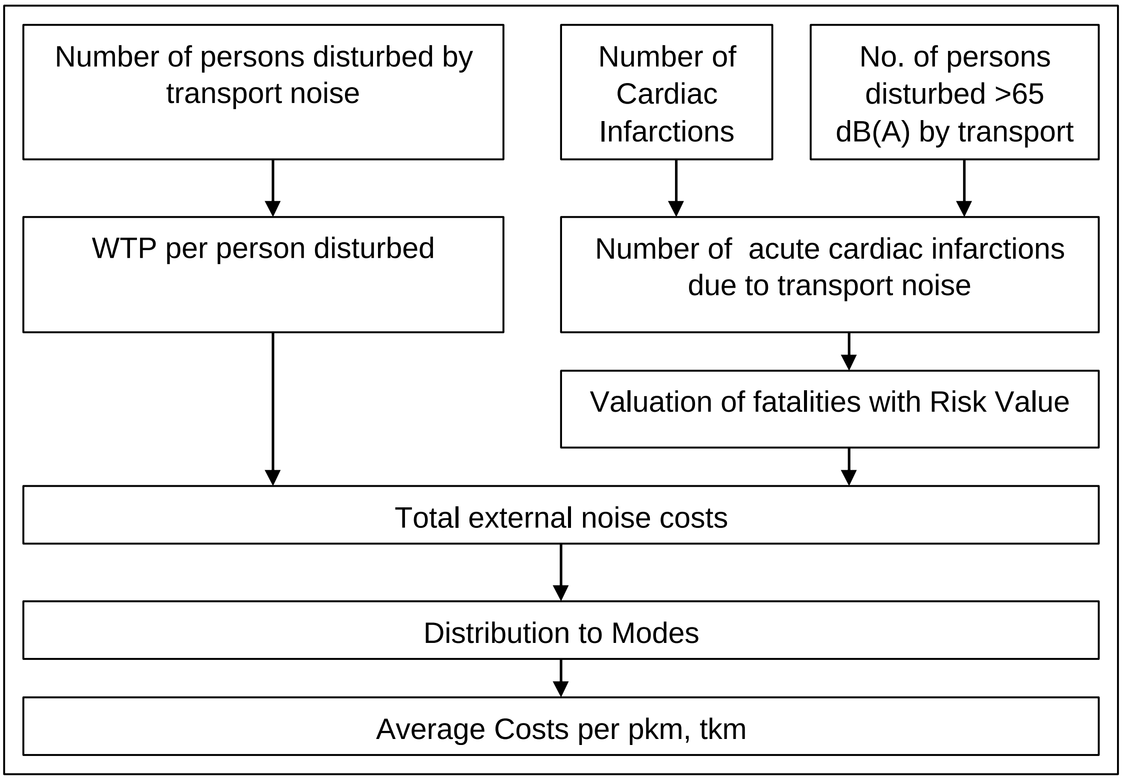

Figure 4: Methodology used for the estimation of external noise costs

The best available data set on the number of persons exposed to transport noise is provided by ECMT (1998), which based their estimations on INFRAS/IWW (1995) and the OECD Environmental Data Compendium (1993). Unfortunately more recent and comparable noise data in Europe cannot be found. In the last decade two opposing trends in Europe can be identified: A growth in transport volume and increase in noise abatement measures. In this study it will be assumed that both trends compensated one another. The Health Report for Germany (1997) corroborates this assumption. In Germany about every fifth person is heavily disturbed by road noise. This share has not significantly changed in the last 10 years.

2.3.1. Estimation of WTP for noise reduction

Figure 5 gives an overview of the values in empirical studies on the costs of transport noise in Europe[20]. Since absolute values cannot be compared, the data are set in relation to the per capita income. Most of the analysed equations have a linear form and a remarkable small variation of their gradients. The incremental increase of WTP per dB(A) amounts to 0.11% of per capita income. Thus, the crucial difference of the investigations are not the marginal costs per dB(A) increase, but the target levels assumed, i.e. the point where the straight line crosses the x-axis. Official target levels for sensitive areas, given in annex 2.2, might help to identify a European consensus on which noise level is considered not disturbing. Not surprising, southern European countries have higher levels than the north. The European mean for day and night[21] can be estimated at 50 dB(A). However, this study will apply a cautious approach using 55 dB(A). Since this approach is favouring railways, a sensitivity calculation for a target level of 50 dB(A) is included in the sensitivity analysis given in chapter 7.2.

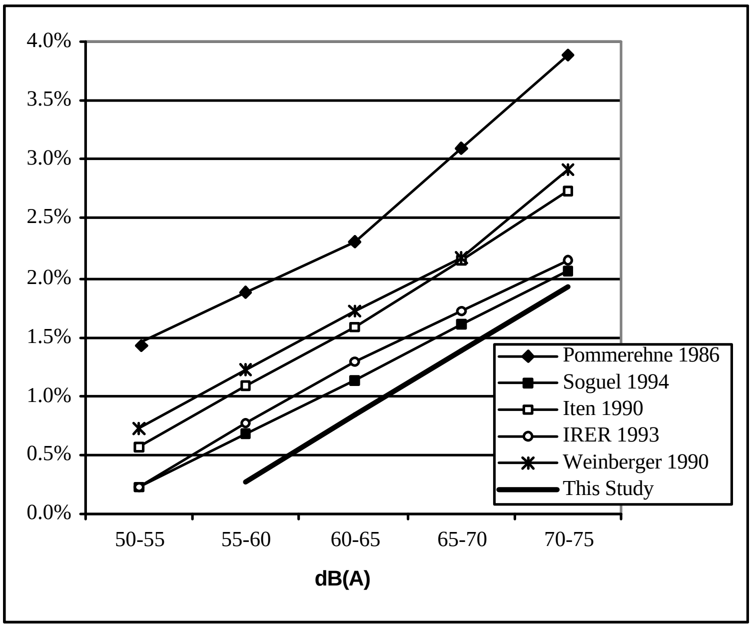

Figure 5: WTP as a share of per capita income

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20 Compare as well annex 2.2.

21 Due to the longer duration, daytime noise is weighted with the factor two.

Given the above assumptions, the WTP for the noise level NL in the reference country Germany calculates as follows:

$$WTP_{NL} = 18.89 * NL - 1039$$

Accordingly the following values with reference to Germany will be used and extrapolated on the other European countries:

dB(A)	55-60	60-65	65-70	70-75	>75
Road, Air	47	142	236	331	425
Rail	0	47	142	236	331

Table 9: Reference values for Germany per person affected in Euro per reduced dB(A)

The reference noise costs per exposed person and year are differentiated by transport mode. In line with the legislation on noise impact in a number of European countries[22] and referring to various scientific reports[23], an adjustment of 5 dB(A) is applied for railway noise by 'shifting' the noise costs by one class. Background for the legislation is a different perception of railway noise compared to road noise.

2.3.2. Health risks

A number of studies have recently been carried out to research the nexus between transport noise and health. Maschke et al. (1997) reviewed studies about the effects of night-time traffic noise on public health. The authors conclude that noise during night-times causes stress and thus increases the risk of gastro-intestinal (stomach, bowels) and cardio-vascular (heart and blood circulation) diseases.

Two studies give empirical evidence about the increase of mortality due to transport noise: Babisch et al. (1993) researched the effects of transport noise (65-70 dB(A)) using two representative samples of 4860 men in Caerphilly and Speedwell (UK). The study revealed that the risk of cardiac infarctions increases by 20% if persons are exposed to outdoor transport noise above 65 dB(A). In another study Babisch et al. (1994) questioned 645 male patients in Berlin hospitals, who had suffered from heart attacks and compared the results with a representative sample of 3390 men. The research confirmed the results from the previous study in the UK for transport noise in the 70-75 dB(A) bracket and revealed increasing risks for transport noise above 75 dB(A). The results of the studies are listed in the following table:

22 E.g. Denmark, France, Germany, the Netherlands, Switzerland.

23 Knall, Schümer, 1983; Fields, Walker, 1982; R Grigo, 1992.

Source	Location	65-70 dB(A)	70-75 dB(A)	75-80 dB(A)
Babisch et 1993	Caerphilly, Speedwell	+20%	-	-
Babisch et al. 1994	Berlin	-	+20%	+70%
Values used in this study		+20%	+30%	

Table 10: Increased risk of cardiac infarctions due to transport noise

Ising et al. (1998) conducted a review of studies on health risks due to noise exposure and confirmed that the experimental and epidemiological studies are consistent. The authors concluded that

a reduction of transport noise below 65 dB(A) during day times and 55 dB(A) during night times would decrease cardiac fatalities in Germany by 3 %.

This study uses the international statistic on cardiac infarctions to estimate the number of people deceased due to transport noise exposure. The higher mortality due to noise exposure is estimated by using national mortality rates that will be increased with the factors given in Table 10. The Risk Value concept is used to value the increased mortality. Due to the older age and the small numbers of deceased, production losses can be neglected. No information can be found on external hospital and administrative costs. The costs for health risks can be added to the costs estimated from the WTP statements.

2.3.3. Forecast of noise costs in 2010

The forecast of external noise costs in 2010 takes into account the following issues:

- Change of total population,
- increase of income,
- changes in noise reduction technologies and
- impacts of transport volume changes.

The change of total population in Europe is affecting the population exposed to transport noise. It is assumed that settlement structures are not changing significantly. The increasing income will have its impacts on the WTP to avoid transport noise.

Table 11 lists the assumptions concerning the technical improvements for the Trend Scenario and the implementation of noise regulations in Europe. The table lists noise improvement in dB(A) and the share of the vehicle fleet affected by the improvements. For road transport it is assumed that the renewal of the vehicle fleet until 2010 will allow an entire implementation of the latest EU noise regulation from October 1995. In rail transport no EU noise regulations exist up to date. Therefore it is assumed that Step 1 of UIC noise action plan (1998) is implemented and affecting 75% of the trains in

2010[24]. UIC proposes to endow freight trains with synthetic brake blocks and passenger trains with disk brakes and wheel absorbers. For air transport it is assumed that the share of planes with low noise emission engines comprises half of the vehicle fleet in 2010.

The impact of the expected transport volume increase is modelled using the function about the noise intensity given in the Noise Protection Manual for Germany. The general form of the basic function is:

$$L_{eq} = a + 10 * lg (Q * (1 + b * p)),$$

with L_{eq} the basic equivalent noise level, Q the number of vehicles (trains) per hour and p the share of freight transport; a and b are specific factors for road and rail. The logarithmic form of the function shows the low impact, which a change in the transport volume has on the noise level. The elasticity used in this study averages out to 0.05. This implies that a 10% increase in transport volume will only entail a 0.5% increase in transport noise.

24 A potential scenario with a retrofit share of 100% will be estimated in the sensitivity analysis (chapter 7.2.).

	EU Noise Emission Limits			Improvement 2010		
	before 1988	since 1988	Oct. 1995*	per vehicle	Vehicles affected	Technical Improvement 2010
Directive	81/334/EWG	84/424/EWG	92/97/EWG			
	dB(A)	dB(A)	dB(A)	dB(A)	%	
Car	80	77	74	3.0	100%	1996 EU noise emission limits entirely implemented
MC	83	79	74	5.2	75%	
Bus	82	80	78	2.0	100%	
LGV	81	78	76	2.0	100%	
HGV	87	83	79	4.0	100%	
Railway	UIC Rail Noise Action Plan		Improvement per train 2010		Trains affected	Technical Improvement 2010
Rail Passenger	93		7.0		75%	Step 1 UIC Proposal 75% implemented
Rail Freight	95		10.5		75%	
Air			Improvement per aircraft 2010		Low noise engines	Technical Improvement 2010
Air Passenger	-	-	5.0		50%	50% low noise emission aircrafts
Air Freight	-	-	5.0		50%	
* MC: 97/24/EG since June 17, 1999						

Table 11: Assumptions for noise reduction in 2010 in the Trend Scenario

2.3.4. Marginal noise costs

Noise is an extremely local phenomenon and thus the investigation of the effects caused by a single vehicle requires the in-depth consideration of the physical characteristics of noise. One of the most decisive characteristics of traffic noise concerning marginal costs is the interdependency between the number of sound sources, the emitted sound energy, its spatial dispersion and its perception by the human ear. On the exposure side the number of affected inhabitants and their sensitivity towards noise disturbance, determined by the type of land use and the time of day, is of great importance. Due to this great amount of influencing parameters the application of sophisticated emission-dispersion models to particular scenarios of traffic situations and settlement structures is required in order to be able to present concrete values of marginal noise costs.

Scenarios for road and rail noise emissions
The scenarios selected refer to three decisive characteristics, which are:

- three different types of land use (rural, suburban and urban),
- two time periods (day, night) and
- two traffic conditions (relaxed, dense).

The type of land use in combination with the time period determines the target level of accepted noise exposure. The type of land use further determines the settlement style and density, which finally results in the number of inhabitants exposed to noise and their average distance to the noise source.

The parameters chosen for the six constellations of area type and daytime and the results received are summarised in the table below:

Land use	Rural		Suburban		Urban	
Time zone	Day	Night	Day	Night	Day	Night
Target level in dB(A)	50	40	60	50	70	60
Distance to road / rail	100 m		20 m		10 m	
Settlement density	*10%*		*50%*		*80%*	
Inhabitants per kilometre in built-up areas	*500*		*500*		*2000*	
Affected inhabitants per kilometre road/rail track	50		250		3000	

Table 12: Physical parameters for the estimation of marginal noise costs

For each type of area an appropriate type of road and rail infrastructure is selected, which is motorway/high speed track for rural areas, a rural road/regional train line for suburban areas and an urban main road/light rail track in terms of urban areas. Respectively the traffic load of each infrastructure (low/high) is selected. The traffic mix in road transport denotes the share of heavy traffic and in rail transport refers to the share of wagons with disk breaks. Specific additives refer to the reflections of road traffic in built-up areas and to the bonus for rail traffic if no marshalling-yards are present.

Transport mode	Road			Rail		
Area	Rural	Suburban	Urban	Rural	Suburban	Urban
Road/rail track class	131	221	521	HS	RT	LR
Traffic volume - low	2’400	1’200	800	60	60	20
Traffic volume - high	6’800	4’800	2’650	30	30	5
Average speed	130	80	40	250	160	80
Traffic mix (HDV, disc breaks)	15%	10%	5%	100%	50%	20%
Specific additives (dB(A))			+3.2	-5.0	-5.0	-5.0

Table 13: Traffic parameters to estimate marginal noise costs

In road transport the noise emission model proposed by the EWS road investment manual is used. Concerning rail transport a similar model is presented in the German handbook on environmental acceptability analyses (HdUVP). The marginal noise costs per vehicle then are defined as the derivation of the respective total noise cost function by traffic volume times the specific emission factor per vehicle type.

Marginal noise costs in air transport
While in road and rail transport the availability of sophisticated noise emission models allows rather precise predictions, such models are not available for airport noise emissions. Alternatively, on the basis of the available road and railway noise emission models the ratio between marginal and average costs is estimated to be roughly 40%. As a range for the marginal noise costs of air traffic a range between 30% and 60% of average costs are considered.

2.4. Air pollution

2.4.1. Valuation basis

Air pollution causes different costs which are relevant for society. Within this study the following elements are considered:

- Impacts on human health,
- impacts on materials and buildings,
- agricultural crop losses and
- forest damages (only within the sensitivity analysis).

Looking at available studies[25], one can conclude that the validity for the estimation for health costs is quite high and very significant. Compared to that, the impacts and monetary damages on materials and buildings or biosphere are less known. There is only one study available (INFRAS 1992), where building damages were estimated in detail (for Switzerland). Besides there are several studies available, which estimated dose-response-functions for materials. These are used for instance within the ExternE-models. The impacts on crop losses (especially due to high ozone levels) are easier to estimate. Several studies (e.g. Fuhrer 1993) estimated the potential damages for agricultural crops. In comparison to health costs however, the level of damage is very little.

In earlier studies, other impacts (especially acid rain and damages to forests) were considered as well. Recent scientific studies (e.g. BMFT 1993) however are not able to draw concrete conclusions on the impact of transport emissions. Some estimations for Sweden[26] are available, where acid rain, caused by HNO_3 and to some extent also by H_2SO_4, is considered. Some shadow values are available, however not easily to be transferred to other countries, since the situation (mainly coniferous forest) is rather special. For the most important value (NO_x), new values are not available. Thus we decided to treat possible damages to biosphere only as a sensitivity (see chapter 7.2.).

In general two main sources are available, which deduct our valuation procedure chosen.

1. **Top down allocation:** Estimation of health costs, building damages and crop losses based on existing studies and transfer of the unit values to the different countries. The values are based mainly on the following three studies:
   - Health costs (WHO 1999)
   - Building damages (INFRAS 1993, INFRAS/Econcept/Prognos 1996)
   - Crop losses (INFRAS/Econcept/Prognos 1996).

   This approach is top down, based on unit values excerpted from these studies and

25 See details in annex 2.3.

26 Information by Lars Johansson, SJ.

transferred (with several indicators) to other countries. It is used to estimate total and average costs per country.

2. **Bottom up approach:** Use of the ExternE models to estimate values for different transport situations. The ExternE model is a bottom up model considering different type of vehicles and regional situations with different dispersion characteristics. This will be done especially for specific situations in Germany. This approach is used to produce marginal cost values.

These approaches are not fully compatible, since totally different procedures are used. A comparison of the two approaches comes to the conclusion, that health costs and crop losses of different vehicles have similar cost levels, whereas building damages are much lower within the ExternE model. ExternE considers several material damage dose-response-functions, which are however of minor importance. Thus we use the ExternE results (for marginal costs) as a minimum level.

The following chapters describe the main assumptions and procedures used. For further details see annex 2.3.

2.4.2. Procedure to estimate total and average costs

a) Health costs

A study commissioned by WHO and other organisations (WHO 1999) estimates road transport related health costs for three countries. This is the most recent data basis available; it delivers reliable data which can be used for the allocation of health costs to other countries. The following table presents total health costs for the three countries considered in this study.

	Austria Road	**France** Road	**Switzerland** Road
Costs of mortality (million Euro)	2'170	15'866	1'586
Costs of morbidity (million Euro)	722	5'749	630
Total Costs Road (million Euro)	2'892	21'615	2'216
Uncertainty range	1'483 – 4'357	11'150 – 32'520	1'117 – 3'357
Costs per capita (Euro)	**359**	**371**	**313**
% of total health costs (incl. other pollutants)	43%	56%	53%

Table 14: Health costs due to road traffic-related air pollution in Austria, France and Switzerland 1996 (WHO 1999)

A very important assumption in the WHO-study is the use of the particle exposition as a driving factor for the cost allocation. It is important to mention, that only a part of the particles (PM_{10}) is related to exhaust emissions. Major parts are related to road abrasion, tyre and clutch abrasion as well as re-suspension (for both road and rail transport). Recent studies (see INFRAS 1999a) indicate that about 80% of road PM_{10} emissions are caused by non-exhaust processes (see Table 15). A reduction of emission factors for the 2010 forecast does not affect the non-exhaust PM_{10} emissions, which will take a bigger share in future. This effect is not important for air and waterways transport.

Mean of Transport	Non-exhaust PM10 [g/vkm] resp. [g/train km]	Mean Percentage of exhaust PM10	Mean Percentage of non-exhaust PM10
Car	0.12	12%	88%
Bus	1.2	37%	63%
LDV	0.21	56%	43%
HDV	1.2	31%	69%
Rail Passenger	2	49%	51%
Rail Freight	2	61%	39%

Table 15: Share of particle emissions due to exhaust and non-exhaust processes
Source: INFRAS (1999a)

Since these emission factors are still rather uncertain in comparison to other emission factors (like NO_x for instance), we decided to transfer and allocate health costs according to a weighted average of NO_x and PM_{10} emissions of each transport mean. Using this weighted mean and a correlation function derived from the WHO study values, PM_{10} exposition was estimated. Exposition values were then used to compute the additional cases of morbidity and mortality according to the WHO baseline increment functions. The cases were monetarised using WHO willingness to pay values (economically corrected using the country adjustment factors) and allocated to the different means of transportation according to their share of total transport NO_x and PM_{10} emissions. Figure 6 displays a step-by-step view of this process, further details can be found in the annex.

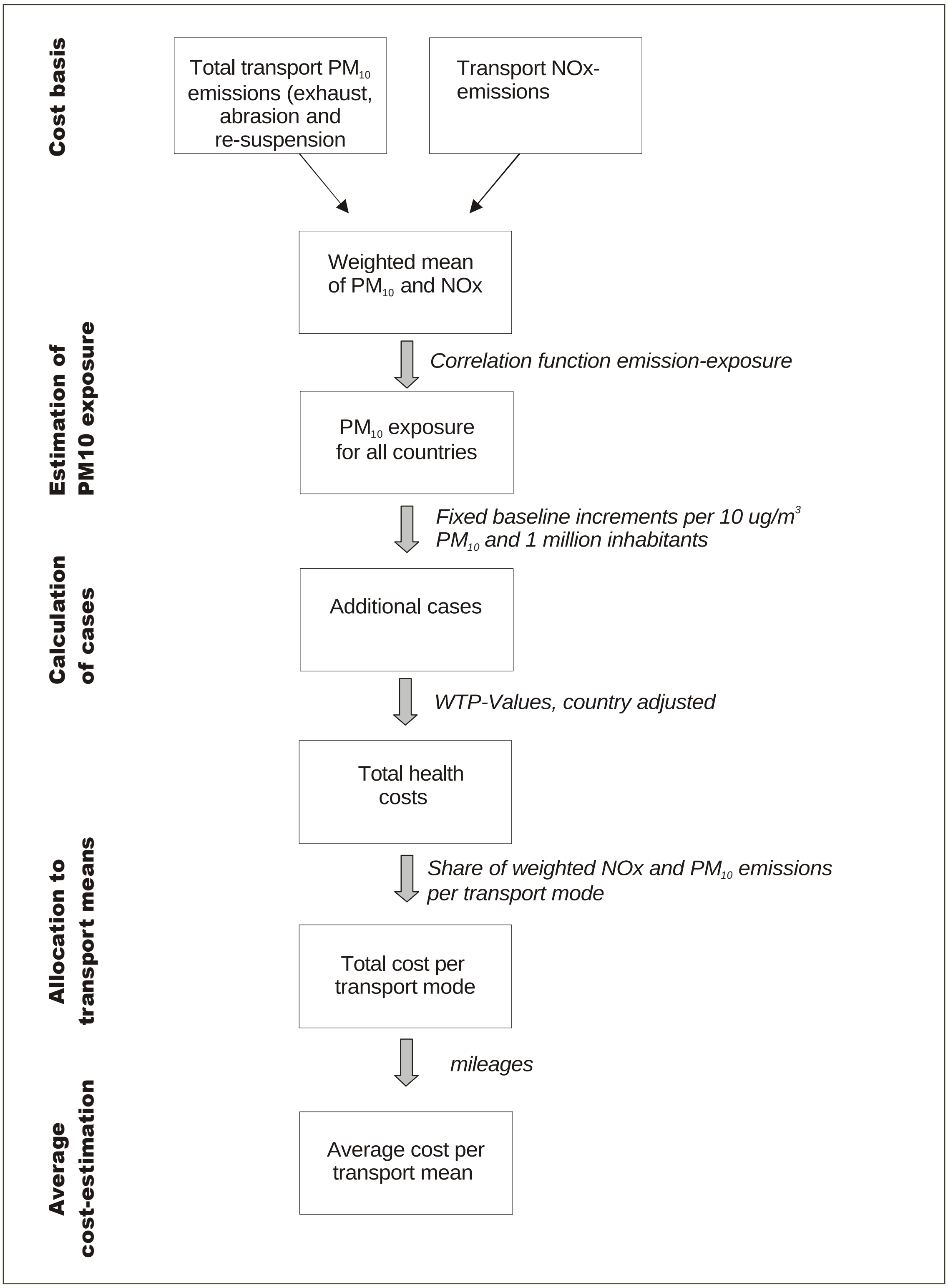

Figure 6: Methodology used for the estimation of health costs

It has to be noted that the results based on the WHO-study are quite high in comparison to previous estimates (ExternE, Auto Oil Programme, estimates of avoidance costs for Sweden). The main reason however is not related to the dose-response-functions used, but to the estimation and modelling of the particulate matter, which is a very sensitive issue, where further research is needed (especially for non-exhaust particles). For the time being however, we can conclude that the WHO-study and the TRENDS-database[27] is presenting the state of the art of cost estimation. Upcoming results from the ExternE programme, estimating as well total costs per country, will enable further steps for plausibilisation. These results though are not yet available.

b) Building damages, crop losses and forest damages

The procedure used for the top down approach for those other damages is based on recent Swiss studies in this field. The following Table 16 presents the results of these Swiss studies.

1993	Damages to buildings	Crop losses	Damages to forests
Road			
Passenger	41%	77%	63%
Freight	59%	23%	34%
Rail			
Passenger	-	-	2%
Freight	-	-	1%
Total [million Euro]	270 – 410	19 – 41	210 – 540

Table 16: Transport related damages to buildings, crop losses and damages to forests. Results for Switzerland: Basic results (for 1993) for the allocation of costs expanded to EUR 17 (INFRAS/Econcept/Prognos 1996). The values for damages to forests are only used for sensitivity analysis.

These basic figures for Switzerland are transferred to other European countries according to the NO_x-emissions, country size, agricultural production, forest area and population. The allocation to different transport means is based on their share of total transport NO_x-emissions. Since the values and dose-response-functions for the estimation of forest damages are very weak and not reliable from today's point of view, we use these values only for sensitivity analysis. They are not included in the baseline estimation.

The following Figure 7 shows the procedure for the allocation of these costs to all transport modes and countries. The most important driving factor are the NO_x-emissions. These emissions can be used as a leading emission component in order to allocate damages to the transport sector. Thus they serve as well as a proxy for other pollutants (like VOC, SO_2). Further details can be found in the annex.

27 TRENDS database is used directly for road transport.

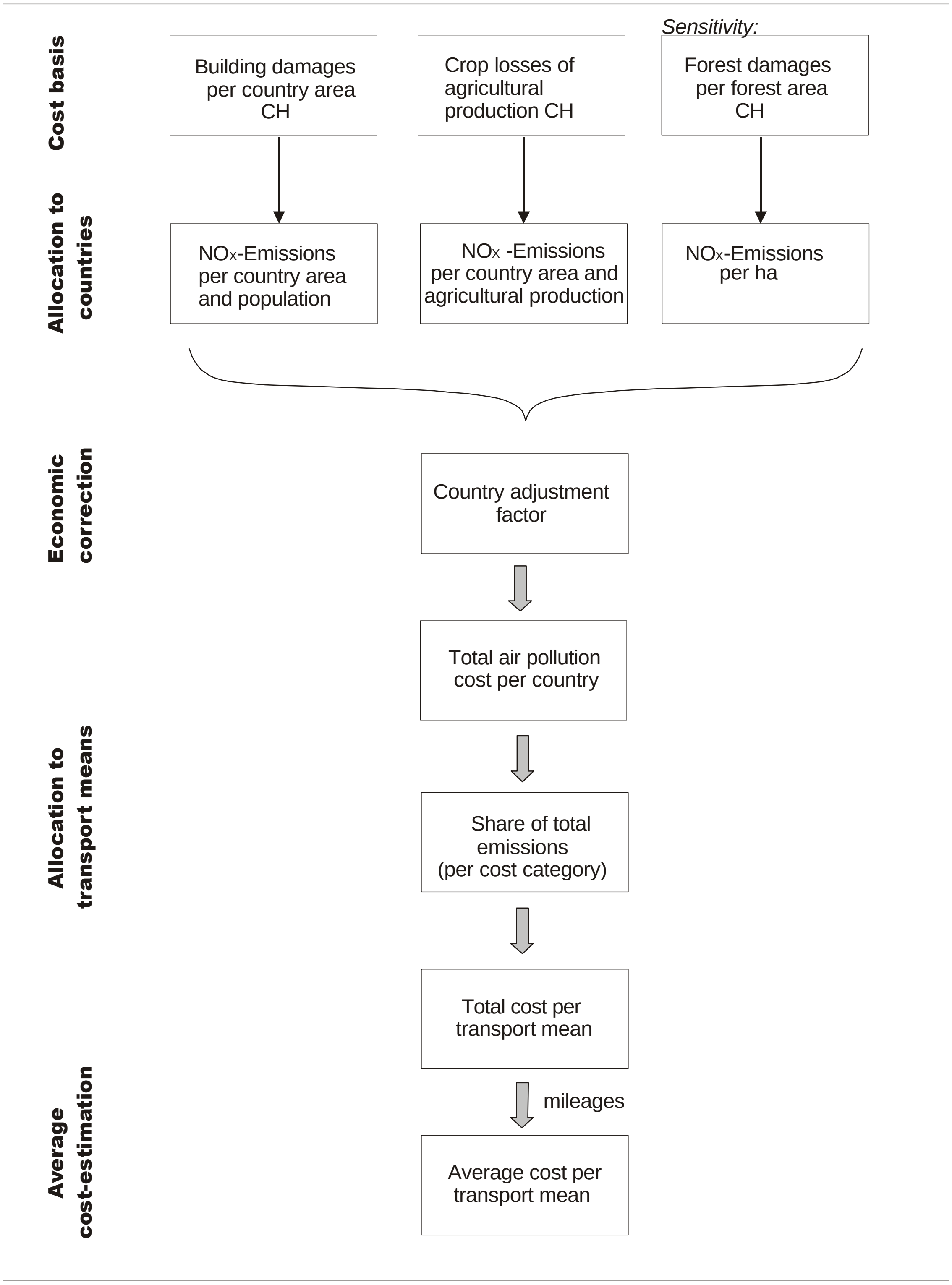

Figure 7: Methodology used for the estimation of building damages, crop losses and damages to forests (as a sensitivity)

c) Electricity production of railway operation

This part of precombustion is important for air pollution and for climate change. Since the mix of plants to produce electricity is different for different countries, this is a very sensitive aspect for the railways. Another important issue is the treatment of nuclear energy compared to fossil fuel powered plants. We based our estimations on the following assumptions:

- Use of the national electricity mix of the railways for the estimation of railway's emissions for the estimations 1995.
- The emissions emitted by fossil powered plants are treated in the same way than other transport related emissions within the top down estimations.[28]
- The use of nuclear power plants is free of emissions. However a shadow factor to consider the risk aspect will be added. This is done within the estimations of up- and downstream effects (see chapter 2.8).

The input data is shown in annex 2.3.4.

d) Forecast 2010

All unit costs (risk value, WTP-values) are scaled according to GDP/capita growth between 1995 and 2010. Population growth was taken into consideration, but not a possible change of building area per person or total agricultural area. Transport emissions were estimated as follows:

- Road: the emissions of the TRENDS-database are used. Included are changes in vehicle stock, specific vehicle use and emission factors, individually for every country. The overall resulting emissions of exhaust PM_{10} for the EUR17 countries are 64% lower than 1995 (cars: -53%, busses: -65%, LDV: -58%, HDV: -70%). Total NO_x emissions are reduced by 63% (cars: -73%, busses: -54%, LDV: -56%, HDV: -55%).
  Additional non-exhaust particle emissions are calculated with unchanged factors for 2010 as 1995.
- Rail: Reduced emission factors of Diesel traction are used for 2010. The reduction of emissions per vkm and the increased energy efficiency is the same as for HDV (TRENDS and other resources, see annex 2.3.4). NO_x emission factors (per GJ) are reduced by 88%, PM_{10} emissions by 62%.
  Emissions due to electricity production are calculated for 2010 with an important and simplifying assumption: for all EUR17 countries, the mix of electricity production is the same, due to expected effects of the liberalisation of the energy markets. Within an internationally free exchange of electricity national mixes will not be relevant anymore. Thus we refer to a UCPTE-mix, considering the average European production. One result of this assumption is that all countries have some amount of nuclear electricity production, and those who had a big nuclear share in

28 Within the ExternE model, there is a differentiation, since they distinguish between local and regional emission components.

1995 calculation produce more CO_2 in 2010. (see annex 2.3 for the estimated electricity production mix for 2010).

- Aviation: Based on a comparison of different aircrafts ("old" and "new"), emission factors for aircrafts in 2010 are estimated. Considering also a productivity growth (growing load factor), the emissions per pkm or tkm are reduced (compared to 1995) by 15% to 40%.
- Waterways: the same reduction of emission factors per tkm is considered as for HDV in road transport (source: TRENDS)

2.4.3. Procedure to estimate marginal costs

The marginal cost estimation is based on the results of the ExternE models developed within EU research programmes (Joule-Thermie). It is an established model being able to estimate air pollution and climate change damages based on the most important dose-response-functions. For the computation of air pollution costs, over 40 dose-response-functions are used. Most important are the functions related to mortality and human health. The functions are based on primary particles ($PM_{2.5}$) and secondary particles (nitrates, sulphates). The relevant dose-response-functions are similar to the ones used within the WHO study. The dispersion modelling however is quite different, since it is a completely different procedure. We will discuss the most important differences in annex 2.3.

Since it is a bottom up approach, modelling specific traffic situations and regional characteristics, it is not yet possible to estimate total cost per country properly. Thus we can use this established approach for the estimation of marginal costs only.

One crucial question is the shape of the dose-response-function for different levels of traffic and air pollution concentration. In general one could expect a progressive shape with rising marginal costs by rising traffic volume. The empirical evidence however does not allow to prove this assumptions. For building damages for example even the opposite could be true. If a specific break even point is reached, a restoration activity is necessary. This point might be reached at a rather moderate emission concentration in urban areas. Thus ExternE uses **constant dose-response-functions** for their modelling. That means: Marginal costs are equal to average variable costs. Since it is a bottom up model, different traffic situations can be estimated more precise. From this point of view, ExternE computes a kind of marginal costs based on constant dose-response-functions.

In order to be able to compare marginal cost and average cost, it is necessary to consider the higher estimates for building damages properly. Thus the results will be presented within a range. The lower values are based directly on the results of the ExternE modelling. The values for Germany are translated to a European average, using the country adjustment factors. The higher values include the estimates for building damages used in the top down approach described above, based on a proportional relation between health costs and building damages.

2.5. Climate change

2.5.1. Valuation basis

The estimation of the costs of climate change – compared to the other costs evaluated within this study – has to face many uncertainties. The damage cost approach is very limited since long term climate change risks (on a global scale) are very difficult to estimate. Although there is a very dense scientific network existing, based on IPCC, reliable damage values cannot be computed properly.

Thus one considers usually also avoidance cost approaches, based on specific reduction aims. Although it is easier and more transparent to estimate these costs to reduce greenhouse gases, several problems have to be faced. First of all the reduction aim has to consider a scientific and a political dimension. How much to reduce within which timeframe? Which country has to reduce how much, especially: what is the role of the Western European countries considered in this study? Secondly the question arises how much the transport sector has to contribute to defined reduction aims. From an economic point of view a least cost approach should be used. That means: The level of contribution depends – compared to other sectors – on the level of marginal avoidance costs in the transport sector. Different studies (e.g. IPCC 1996, Prognos 1992) indicate that the most economically viable measures are usually located in the building sector, whereas the avoidance strategies in the transport sector do not only have a technical dimension, but as well a behavioural one. Behavioural changes (e.g. energy saving driving behaviour, change of modes, reduction of individual mobility) have a high cost-effectiveness, but - since not costs but reduced mobility benefits are relevant – are difficult to quantify.

A second problem is the regional systems delimitation. If we consider a worldwide strategy, the costs of reducing greenhouse gas emissions will be lower in Eastern Europe and in developing countries than in Western Europe. Recent tendencies in the climate response strategy discussion consider this element by allowing emission trading.

And thirdly: Which reduction aim should be considered? We can distinguish scientific aims and political aims based on the Kyoto protocol 1998.

We decided to estimate the costs of climate change based on scientific studies which estimate the costs for developed countries in regard to a scientific reduction aim (reduction of European transport CO_2 emissions of 50% relative to 1990 until 2030, recommended by IPCC). This leads to an average **shadow value for CO_2 of 135 Euro per tonne,** with a range of 70 up to 200 Euro. This value is representing an average value based on available scientific studies. Several countries (like Germany or Sweden) are even proposing higher values (see details of studies in annex 2.4).[29]

Since the reduction of climate change risks requests a global strategy, we do not distinguish between different situations within the countries considered. For all countries and all transport means the same unit cost value (Euro per tonne CO_2 reduced) will be used. This assumption is based on the fact, that specific avoidance costs for the transport sector in different countries are only partly available and not comparable. This assumption contains as well an aspect of justice. All countries are treated the same way, being actors within an international strategy, and the transport sector has to contribute in a similar way as the other sectors do.

2.5.2. Procedure for the cost estimation

The procedure is based on the unit values presented above. According to the methodology chosen and considering the wide range of uncertainty, we assume that **marginal costs do not differ from average costs**. In fact the values used for avoidance costs are based on different studies estimating marginal avoidance costs per country. The standardisation (using the same values per tonne of CO_2 for all countries and transport means) allows this generalised approach. Thus the CO_2 emissions per transport mode (per unit of transport for marginal cost presentation accordingly) are multiplied by the unit costs presented above.[30]

One exception concerns air transport. Since air transport is more critical than other modes (see IPCC 1999) due to the emissions in higher altitudes, a specific factor is used to consider this fact. Thus the CO_2 emissions of air transport are multiplied by a factor 2 (based on different sources, e.g. Schuhmann 1996).

The main assumptions for the forecast 2010 are presented below. Although one could argue that avoidance costs are an average annual value for a future time period

29 The range will be examined within the sensitivity analysis. In addition also other approaches will be considered in order to refer to the political approaches (see chapter 7):

Euro (1995)/t CO_2	Unit costs	Range
Reduction of 8% (acc. to Kyoto decisions for Western Europe up to 2010 referred to 1990).	37	~ 37
Joint Implementation (acc. to Kyoto considering worldwide emission trading).	9	6 – 12
Minimal damage costs (based on ExternE 1999).	28	10.9-92.5

30 In regard to electricity production for the railways, see the section of air pollution in the previous chapter. Here it is important to mention, that marginal cost are not based on national electricity mix, but on a generalised UCPTE mix, since marginal electricity is the same for all railways under liberalised market conditions.

considering an optimal path of avoidance measure, an adjustment of the unit values was considered in the same way as for other cost components (GDP adjustment), since we base our valuation on a trend scenario considering a growth of CO_2 emissions being not on track of the climate strategy envisaged.

Most important assumptions for the forecast of climate change costs:

- Road: TRENDS-database emissions of CO_2 are used. Despite improving energy efficiency of road vehicles, a significant traffic growth leads to slightly higher annual CO_2 emissions. Total EUR17 CO_2 emissions are 11% higher than in 1995 (cars: +2%, busses: +7%, LDV: +28%, HDV: +24%).
- Rail: As for NO_x and PM_{10}, a reduction of CO_2 emissions of Diesel locomotives with the same proportions as for HDV road vehicles is assumed (-9%)
  As mentioned in the forecast of air pollution, we use one single electricity production mix for EUR17 in 2010. This estimated mix contains a nuclear power share of about 35% and a hydro-electric share of 15% (see annex 2.3 for power mix 2010). Consequently 50% of the electricity production is based on fossil sources. Some changes of the climate change cost are due to this fact, others due to traffic growth. The national share between diesel and electric traction is however unchanged.
- Aviation: A growth of energy efficiency (-12% CO_2) per pkm and tkm is assumed, based on higher load factors and new engines.
- Waterways: the same reduction CO_2 emissions per tkm is considered as for HDV in road transport (-9%).

2.6. Nature and landscape

2.6.1. Valuation approach

As mentioned already in chapter 2.1, these effects are mostly related to transport infrastructure and do in general not depend on the level of use.[31] They depend very much on the individual perception of society and are usually difficult to measure.[32] Thus within national estimates of external costs, these costs are usually not considered, firstly because they are fixed costs and mostly irreversible[33], secondly due to lack of detailed information of the perception of individuals.

The determination of the external effects of nature and landscape which includes the pollution of soil and groundwater due to transport is difficult. Up to now, it has not been feasible to quantify them in monetary terms as it has been done for other externalities like accidents, noise, air pollution and climate change. We distinguish two kinds of effects:

a) Effects which are caused by the **provision** of the infrastructure (roads, rail tracks, dams, bridges, airports, etc.):
   - spatial separation effects/barrier effect (also influenced by utilisation of infrastructure),
   - reduction of the quality of landscapes,
   - loss of natural land area (loss of biotopes).

b) Effects which are caused by the **utilisation** of the infrastructure:
   - pollution of soils and surface/groundwater systems,
   - pollution caused by accidents.

From an economic point of view, the valuation of the damages (for instance based on a willingness to pay approach) would be most feasible. A direct valuation of transport related damages is however not available (see Infraconsult 1998). Thus we refer to a more pragmatic but consistent approach. In order to avoid double counting, we summarise all effects with regard to nature within one cost category.

Based on a network classification, we estimate those costs which are necessary to improve existing infrastructure to a level that is neutral (acceptable) from an environmental point of view. Most important is a set of unit costs based on the **repair and compensation costs approach**. In order to consider the different levels of damages, we assume that new infrastructure – due to improved environmental legislation and the use of environmental impact analysis – is less harmful than old infrastructure.

31 Thus they are not relevant for the social marginal cost approach.

32 It is important to state that air pollution and climate change effects will harm nature (biosphere) as well. Those elements however are included in air pollution and climate costs discussed above.

33 In regard to existing infrastructure, these costs are usually not really reparable. Thus the aspects of nature and landscape are usually very important aspects for the evaluation of new projects, e.g. within environmental impact analysis or cost benefit analysis.

The repair cost approach is used as the main approach to estimate the additional costs for the different transport modes. The same approach will be used as well in official estimations for these damages related to transport in Switzerland. It has the advantage to be transparent, further it also considers other environmental costs like groundwater nuisances. However since the approach is based on rather sensitive assumptions, we will compare the results – for reasons of plausibilisation – with a prevention cost and the willingness to pay approach mentioned above. The results of the comparison are shown in annex 2.5.

2.6.2. Procedure for the estimation of total and average cost

a) Steps for the estimation 1995

Figure 8 presents the detailed approach which is trying to determine the costs of the different repair and compensation measures.

Firstly we have to define an initial state of nature and landscape which is regarded to be 'natural' enough and worth aspiring after. The state of nature at the year 1950 is regarded as sustainable by experts (see Ökoskop 1998). In other words, its state at that time corresponds to an acceptable intervention in nature and landscape. Damages since then have to be compensated. This starting point is generally used to calculate the sealed area and additional impaired area (side effects) caused by transport infrastructure. It is applicable especially for road transport. For other modes, some additional assumptions were necessary (see details in annex 2.5).[34]

34 This is especially sensitive for railway infrastructure, since this network was built earlier than the road network (mostly before 1950). For the estimation of total costs, the approach is in favour of the railways. This can be justified within a historical perspective, since the construction of the motorway network (since 1950/1960) caused a significant rise of awareness of damages to nature and landscape. However if we consider these costs for future infrastructure, the infrastructure of different means of transport have to be treated equally.

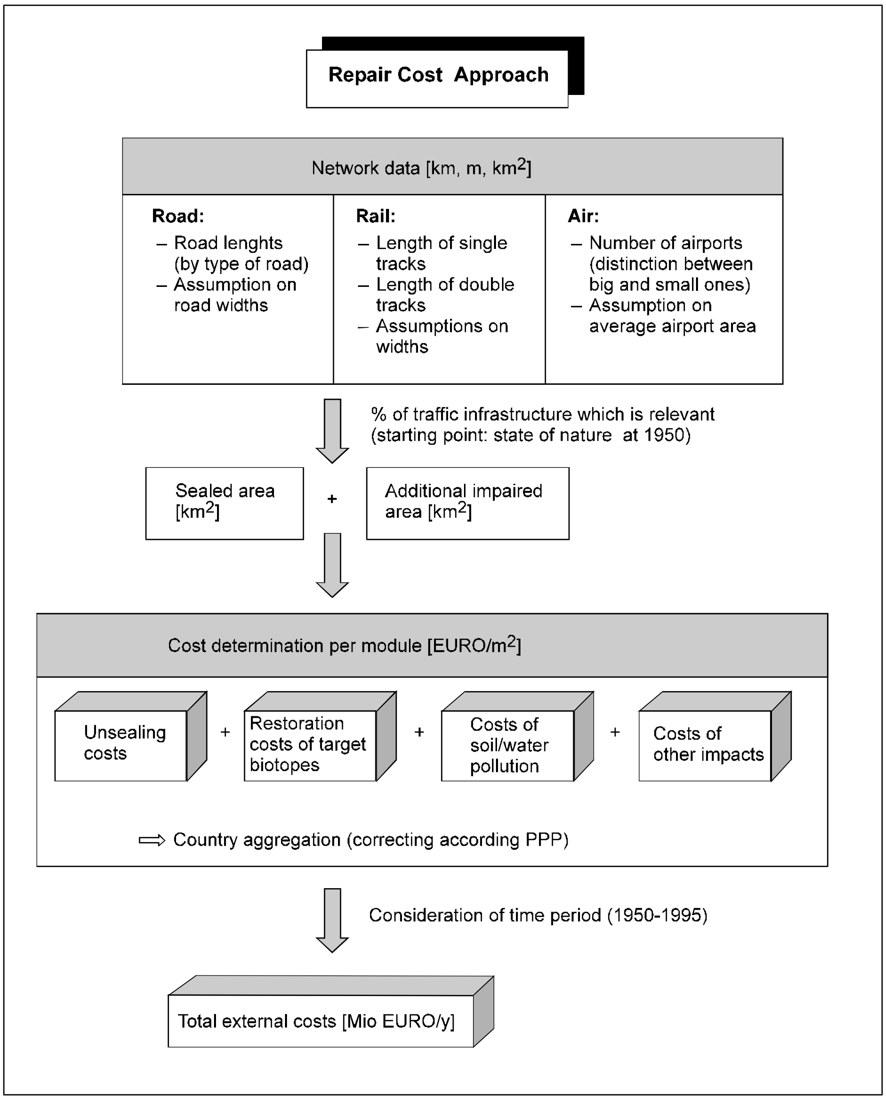

Figure 8: *Methodology of the repair cost approach to value costs for nature and landscape (the approach for waterborne transport is somewhat different, see details in annex 2.5)*

The allocation of the cost per transport mode to the vehicle categories are based on specific assumptions:

- The allocation of road transport is according to PCU:
  - Passenger Car 1
  - Motorcycle 0.5
  - Bus 3
  - LDV 1.5
  - HDV 3.

- The allocation of rail transport is according to train kilometres.[35]
- The allocation of air transport is according to the aeroplanes movements.

b) Assumptions for the forecast 2010
The forecast considers the following developments:

	Road	Rail	Air	Waterways
Infrastructure development	50% of growth rate of road traffic growth (vkm*PCU)	stable	same growth as for road infrastructure	same growth as for road infrastructure
Adjustment of unit values	GDP/cap.	GDP/cap.	GDP/cap.	GDP/cap.

Table 17: Most important assumptions for the forecast of costs of nature and landscape

2.6.3. Procedure for the estimation of marginal costs

Based on the assumption that infrastructure is fixed in the short run, no short run marginal cost will occur in regard to nature and landscape. One exception are specific separation (barrier) effects for fauna, which might slightly depend on traffic volume. Since it was not possible to estimate these costs in detail, we consider this effect to be negligible. That means: Cost for nature and landscape are only relevant in the long run, where marginal costs are near to average costs of road infrastructure, if we assume that future infrastructure construction is likely to grow at the same rate as in the past.

Besides, there is a question if these costs do differ between different traffic situations and regional characteristics, especially between urban and non-urban areas. This depends very much on the concrete case. Since the range of future changes is very complicated, a distinction is very artificial. However we consider long term marginal costs only relevant for non-urban situations. For urban situations, future infrastructure will not cause additional damage to nature and landscape, but will increase scarcity problems. These are considered in the following section.

35 A distinction between electrified and not electrified rail tracks has not been made, although the damages are different. Whereas the pollution of diesel tracks (due to air pollutants) is mainly causing soil and groundwater problems, electrified tracks are causing soil problems (due to abrasion) and visual intrusion due to electric overhead cables.

2.7. Additional costs in urban areas

2.7.1. Valuation approach

Since urban areas face higher specific external costs of transport, it is essential to analyse possible effects more in detail. Usually one can distinguish three major effects, which are of relevance:
- time losses due to separation effects for pedestrians
- scarcity problems (expressed as the loss of space availability for bicycles)
- urban visual intrusion due to transport volume and infrastructure

Since the last element is very difficult to measure and no reliable estimates are available, we will concentrate on the first two issues. These elements are attached to the road sector in urban areas, and, to some account, also to rail transport. It has to be mentioned that the estimation of these elements have a pilot character. The approaches chosen are based on existing methods used (esp. in Germany) and are therefore quite familiar within infrastructure evaluation approaches. We have to note however, that both approaches used are just a proxy for urban traffic damages. The legitimisation of these costs is based on a fairness principle: The road sector is leading to space scarcity in cities, which causes additional cost especially for non-motorised transport.[36]

2.7.2. Separation effects in urban areas

a) Procedure for total and average costs

Based on the methodologies of EWS (1997) we propose a simplified procedure, referring to a cluster approach. The following Figure 9 illustrates the procedure (see as well annex 2.6).

The estimates are based on a pilot survey for Zurich, where the levels and crossings are measured in detail. Also, results of EUROMOS (European Road Mobility Studies) have been used, especially data from Munich, Southampton and Madrid. For these cities, network length is available in details. The results are transferred to other cities, using general indicators like the traffic volume and percentage of urban population. For this purpose, we use the population of cities with 50'000 inhabitants and more.

The estimation of separation effects of urban railway tracks is based on the same methodology. Railway tracks have about the same separation effect as an urban motorway (road type C), pedestrians need to take a longer way and loose therefore time. A detailed analysis of a model town (Zurich) gives a rough database for a specific urban effect. Railway tracks in tunnels and on bridges are not relevant for this effect and are not accounted.

36 Public transport is regarded as neutral for the scarcity approach, since the frequency of the vehicles (light rail) is not that high, that specific additional effects could be noted. Still, railway lines have urban separation effects.

These estimation for several European towns show following average unit costs, which have to be corrected with the country specific adjustment factor.

Road: 50 Euro per (urban) person and year
Rail: 17 Euro per (urban) person and year.

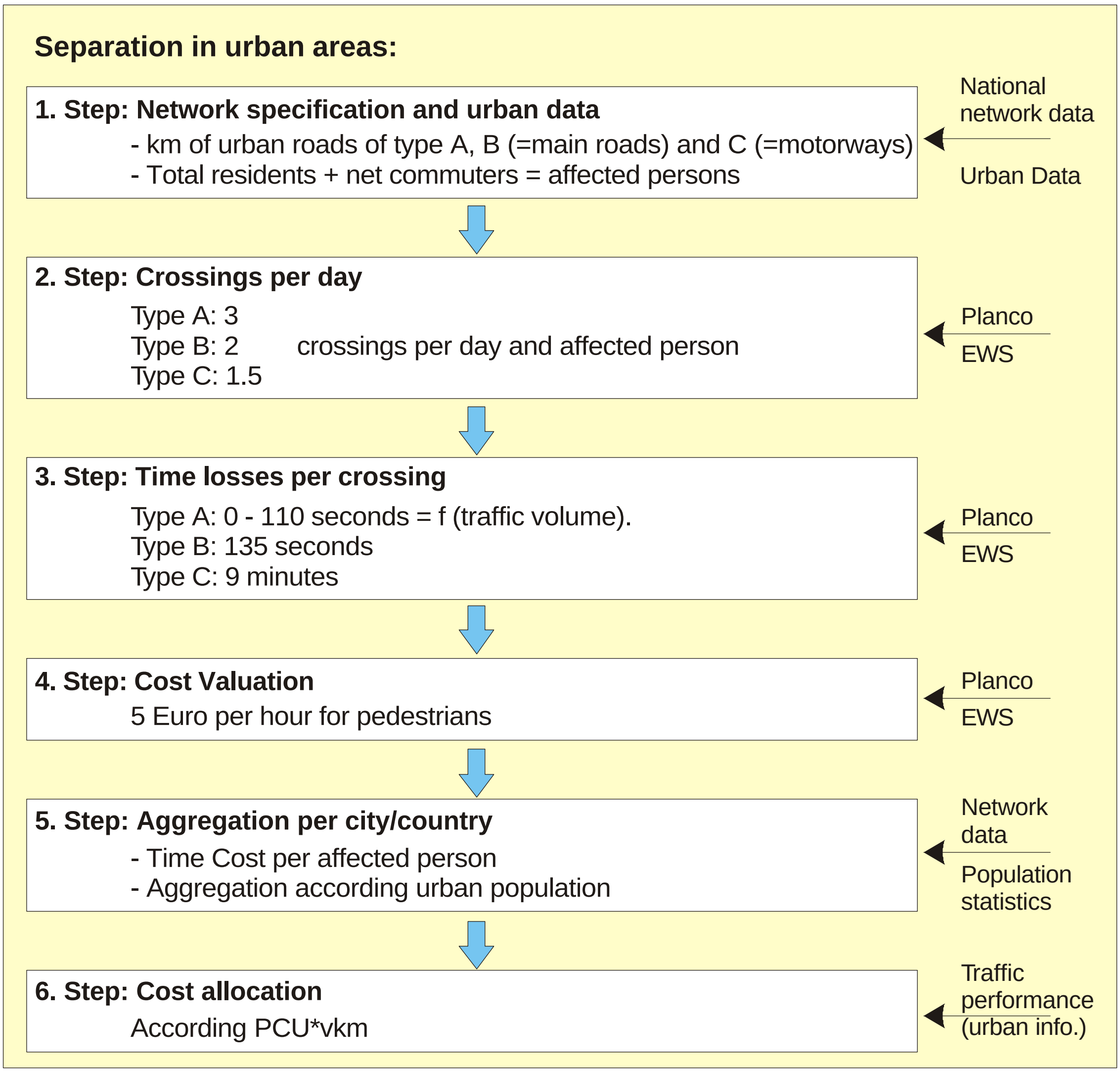

Figure 9: Procedure for the estimation of external costs of separation in urban areas. Railway tracks in urban areas are also taken into account.

b) Assumptions for the forecast 2010

The forecast considers the following development: Unit costs (separation cost per urban resident per year) are upgraded with the growth of GDP per capita.

c) Procedure for marginal costs

Separation costs depend directly on the traffic volume. Thus based on the waiting curve shown in the annex 2.6 we assume that marginal costs are rising due to additional traffic. According to the model, only traffic on roads of type A with a volume between 400 and 800 vehicles per hour can show marginal costs (roads of type B and C have too much traffic that one additional vehicle would cause additional costs). For this traffic situation, marginal separation cost are calculated, using an assumption for percentage of relevant traffic volume and of relevant daily hours.

2.7.3. Space availability for bicycles

Firstly it has to be mentioned, that this approach (like the approach for nature and landscape) is related to the existing (road) infrastructure. It is an indirect proxy of the scarcity aspects in cities. Thus the approach is only relevant for the estimation of total and average costs. Using this approach, there are no short run marginal costs occurring.

a) Procedure for total and average costs

The estimation of space availability for bicycles is used as a proxy for the scarcity of space in urban areas. They can be interpreted as compensation costs for scarce infrastructure for non-motorised transport. The following procedure has been chosen (see as well annex 2.6).

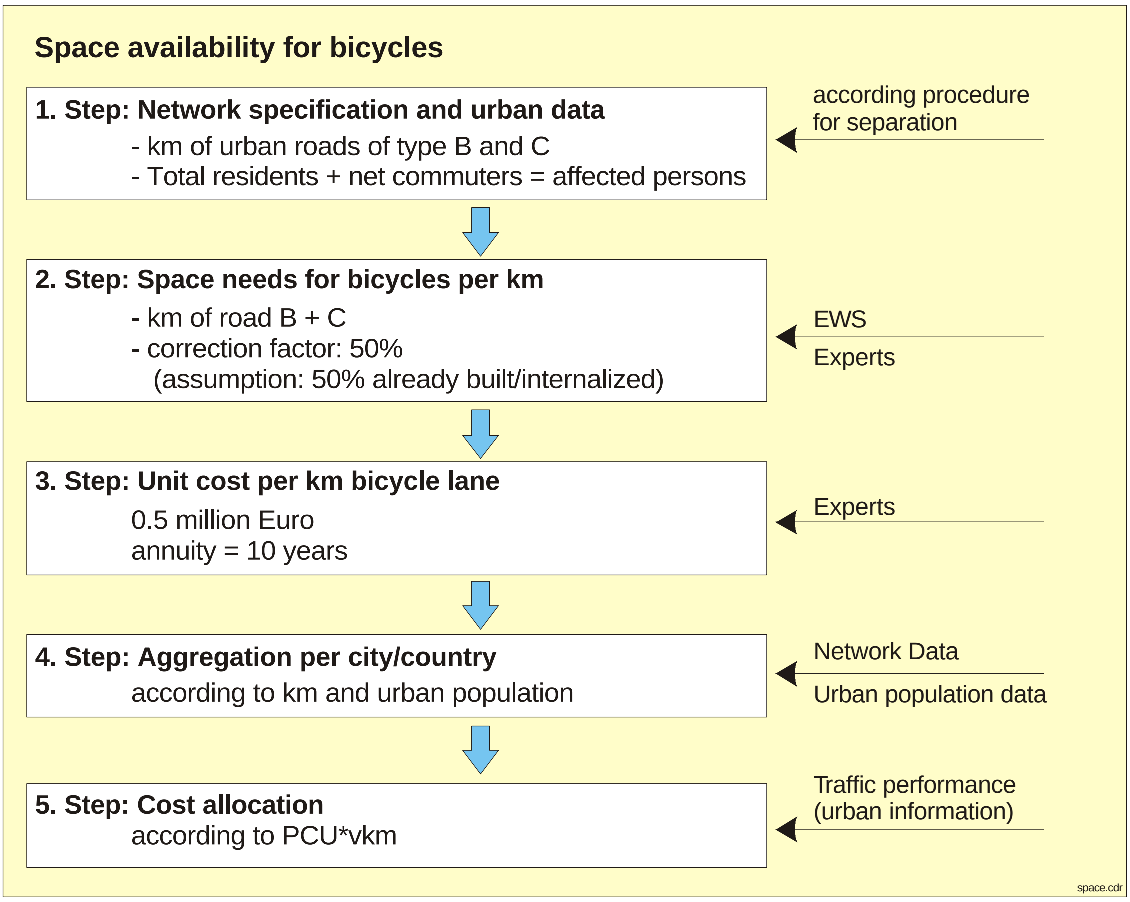

Figure 10: Procedure for the estimation of external costs of missing space availability in urban areas

Most important is the definition of the relevant network. We assume that urban roads with a traffic level of more than 1'000 vehicles per hour have to be considered, in our model road types B and C. For these roads we estimate unit costs per km as a basis for aggregation. According to road experts and to some studies, the average costs of building a bicycle lane are about 0.5 million Euro per km (considering a depreciation rate of 10 years according to expert statements).

Since one can assume, that some cities have already a significant road network, we have to consider a correction factor. Rough estimations (based on observations in Germany and Switzerland) lead to a factor of 50%.

The aggregation to national cost for this urban effect follows the same methodology as for the separation effect. The projection to countrywise total cost is made using an average value per (urban) affected person. This value is between 5 and 21 Euro per person and year for the four model cities. We assume an average unit value of **12 Euro per urban person and year**, which has to be corrected with the country adjustment factor. Again, urban population are assumed to live in cities with more than 50'000 inhabitants.

The cost allocation, as for separation effect, is made with traffic volume using PCU-values (vkm*PCU).

b) Assumptions for the forecast 2010

The forecast of scarcity effects, based on space availability for bicycles, considers the following development: Unit costs (cost per urban resident per year) are upgraded with the growth of GDP per capita.

c) Procedure for marginal costs

The scarcity costs expressed by additional space for bicycle lanes are partly depending on traffic volume. Since we just considered urban main roads which are usually quite crowded, an additional vehicle does not cause additional need for space. That means, in the short run, these costs are close to zero. The argumentation however is similar as within the costs for nature and landscape. In the long run, if capacity is overused, additional space will be needed for new roads and for new bicycle lanes respectively. One could argue however, that a new road leads to a decrease of the existing space problem, leading as well to a decrease of the costs respectively. However there might be a trade off with other space problems in urban areas. Thus – in order to be in line with the approach for nature and landscape – we conclude that long term marginal cost are equal to average costs.[37]

37 Note that average cost are higher than expressed in chapter 3, since the costs estimated are not divided by national vehicle kilometre, but only by these kilometres on urban main roads.

2.8. Up- and downstream processes

2.8.1. Valuation approach

As discussed in chapter 2.1, indirect effects of transport might cause additional external effects. We can distinguish the following:

1. Energy production (precombustion): The production of all type of energy is causing additional nuisances due to extraction, transport, transmission. They depend directly on the amount of energy used. These effects are relevant for all transport means except the railways. Since the emissions of electricity production for railways operation are already considered within air pollution and climate costs, only risk elements (e.g. nuclear risks) are here considered in addition.[38] These costs are also relevant in the short run.
2. Vehicle production and maintenance: The production of vehicles and rolling stock is important in the longer run, considering the life cycles of different transport means. Short run marginal costs are zero. These elements are causing especially additional emissions into the air, having an additional effect for air pollution and climate change costs.
3. Infrastructure construction and maintenance: The same arguments hold true for the infrastructure elements themselves. In the long run, additional emissions have to be considered here as well. They have to be treated similar like the aspects of nature and landscape discussed above, because they are attached to existing infrastructure and thus sunk costs. In contrast to those effects, up- and downstream effects happen especially during the construction phase (e.g. surface renewal).

Although these processes refer to other nuisances already considered within this report (especially air pollution and climate change), it is useful to treat these up- and downstream effects separately, in order to increase transparency. The following effects will be distinguished:

- Upstream effects as a percentage of air pollution costs, based on the amount of indirect effects of related emissions.
- Upstream effects as a percentage of climate change costs, based on the amount of indirect processes of CO_2 emissions.
- Nuclear Power risks for electricity production.

The figures used are based on the eco-inventory of INFRAS (1995b), which analysed the related emissions of all transport processes. The monetary values are based on the values used for air pollution and climate change costs. In addition, specific shadow

38 Nuclear risks for the production of rolling stock and infrastructure are not considered for any transport mean, since the share of electricity of these processes is unknown. This leads to an underestimation of the up- and downstream processes for all transport means, especially for other modes than rail. Street lighting might be one reason.

values based on INFRAS/Econcept/Prognos (1996) are used for the estimation of nuclear power risks.[39]

2.8.2. Procedure for total and average costs

The following Figure 11 and Figure 12 present the approach (details see annex 2.7).

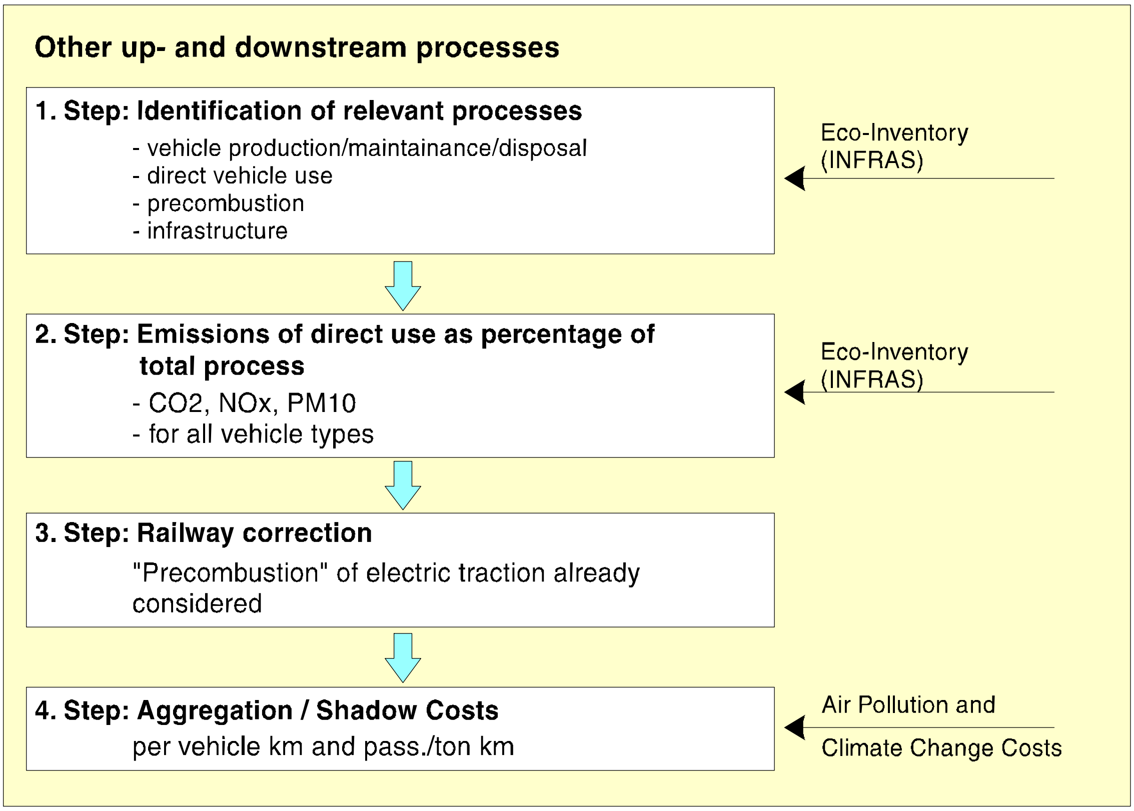

Figure 11: Procedure for the estimation of external costs of other up- and downstream processes

39 The chosen value of 0.035 Euro per kWh corresponds rather good with the CO_2 unit value of 135 Euro per tonne. This is quite plausible since the opportunity cost of not causing nuclear risks is connected with more CO_2 emissions. Detailed information to the basic approach leading to this value is given in annex 2.7.

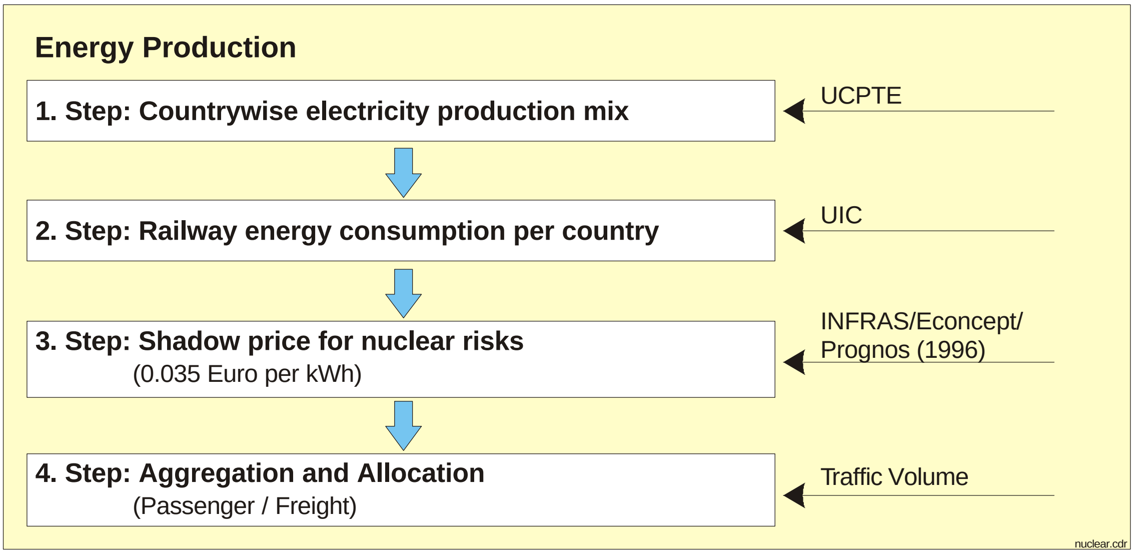

Figure 12: Procedure for the estimation of external costs of nuclear risks

Based on the methodology described in the chapter of air pollution and climate change, specific shadow factors (according to the percentages of indirect emissions) are used in order to estimate external costs. The following table shows the most important relations. Details are mentioned in annex 2.7.

	Air pollution (Percentage of air pollution costs)	Climate change (Percentage of climate change costs)	Nuclear risk (Shadow factor) (Euro per kWh)
Car	20%	32%	
Motorcycle	20%	32%	
Bus	10%	26%	
LDV	22%	30%	
HGV	13%	26%	
Passenger train	32%	30%	0.035
Freight train	67%	35%	0.035
Airplane	24%	13%	
Waterways transport	14%	31%	

Table 18: Used shadow factors for different upstream processes (see annex 2.7)

Assumptions for the forecast 2010
The forecast considers the following developments:

	Road	Rail	Air	Waterways
Air pollution related processes	Percentage of air pollution costs stable	Same electricity production mix for all EUR17 in 2010	like road	like road
CO_2 related processes				
Nuclear risks	-		-	-

Table 19: Most important assumptions for the forecast of upstream effects

2.8.3. Procedure for the estimation of marginal costs

In the long run, all estimated costs are relevant, since production cycles are dependent on the traffic volume. Thus the estimated average costs will serve as a basis for the estimation of long run marginal costs. In the short run however, only additional costs of precombustion are important, since one can expect, that these costs vary directly with the use of energy. Thus short term marginal costs are based on the average costs of precombustion (air pollution, climate change costs and nuclear risks).

3. Total and average costs per country

3.1. Overview

3.1.1. Total and average costs 1995

a) Total costs by cost categories and transport mode

The following figures and tables present the results for total costs 1995. Total external costs (excl. congestion) amount to 530 billion Euro for 1995, being 7.8% of total GDP in EUR 17. These values are significantly higher (almost double) than estimated in the previous IWW/INFRAS study. There are several reasons for that. We will discuss them in chapter 7. Especially air pollution and climate change costs are higher due to the consideration of more impacts and higher unit values. These two cost categories amount to 48% of total costs. Accidents are still the most important cost category with 29% of total cost. Whereas the costs for nature and landscape and the urban effects considered are of minor importance, upstream effects (11%) are quite significant, especially due to the fact that they are related mostly to air pollution and accidents. The most important transport mode is road transport, causing 92% of total cost. This mode is followed by air transport, causing 6% of total cost, whereas railways (2%) and Waterways (0.5%) are of minor importance. Two thirds of the costs are caused by passenger transport, and one third by freight transport.

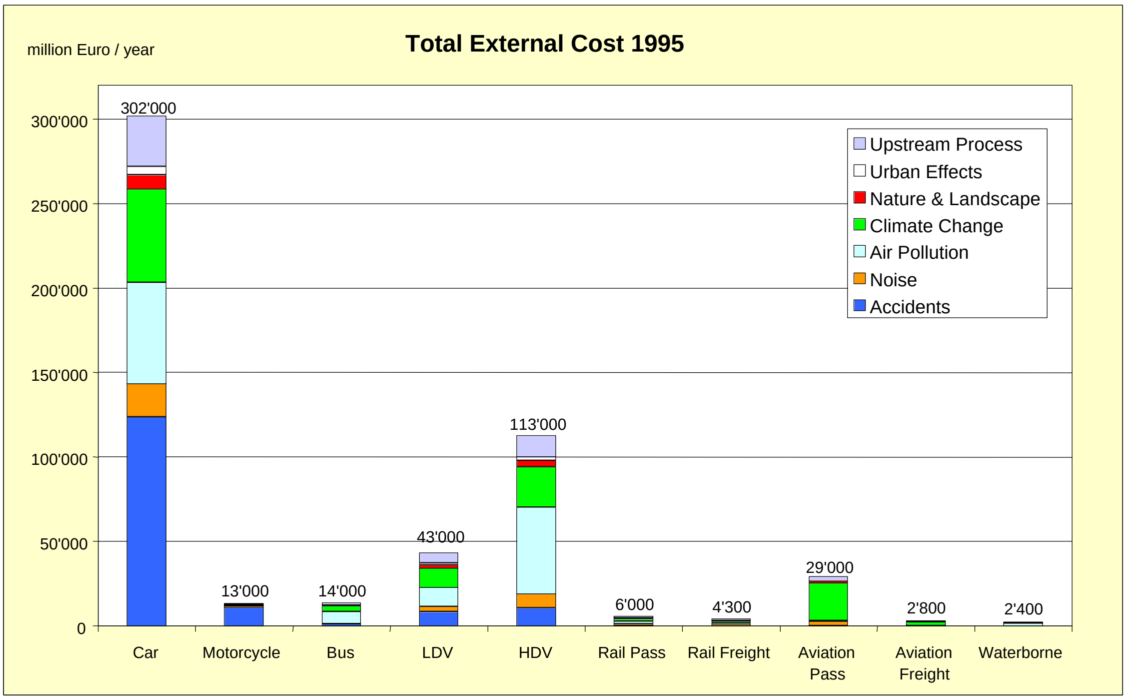

Figure 13: Total external costs 1995 (EUR 17) by transport means and cost category

Total Cost 1995			**Road**							**Rail**		**Aviation**		**Water borne**
[million Euro/year]			Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Accidents	**155'600**	29%	124'000	10'900	1'110	*136'000*	8'520	10'770	*19'290*	248	0	407	0	0
Noise	**36'500**	7%	19'700	738	469	*20'900*	3'050	8'140	*11'200*	1'130	812	2'260	257	0
Air Pollution	**134'300**	25%	59'900	345	7'070	*67'300*	11'200	51'400	*62'600*	1'410	932	495	47	1'490
Climate Change	**121'800**	23%	55'200	600	3'210	*59'000*	11'500	24'000	*35'400*	1'550	1'100	22'200	2'050	485
Nature & Landscape	**16'000**	3%	8'570	88	281	*8'940*	1'960	3'550	*5'510*	190	115	1'040	113	60
Urban Effects	**8'900**	2%	5'040	49	165	*5'250*	1'060	2'100	*3'160*	261	206	0	0	0
Upstream Process	**56'500**	11%	29'800	263	1'550	*31'600*	5'900	12'700	*18'900*	1'210	1'160	3'060	282	353
Total	**529'700**	100%	**302'000**	**13'000**	**13'900**	**329'000**	**43'100**	**113'000**	**156'000**	**6'000**	**4'320**	**29'500**	**2'750**	**2'390**

Table 20: Total external costs 1995 (EUR 17) by transport means and cost category

b) Average cost by cost categories and transport mode

The following figures and tables present average cost in Euro per 1'000 pkm and tkm. In **passenger transport**, motorcycles achieve the highest value with 298 Euro per 1'000 pkm. Passenger cars reach 87 Euro, which is 74% higher than estimated in the previous IWW/INFRAS study. Railway's costs amount to 20 Euro, which is 2 times higher than in the previous study, but still 4.4 times lower than the road sector. Most important are the effects of climate change, noise and air pollution. Within the aviation sector, the predominant effects are climate change costs.

In the **freight sector**, the LDV costs are significantly higher than all other transport means. This is especially due to the fact, that the indicator (tonnes) are not very applicable here, since the freight load is rather different in comparison to other modes. Usually LDV is transporting high quality freight load, with low weight, similar to air transport. The costs for HDV amount to 72 Euro per 1'000 tkm, which is 3.8 times higher than the railways. In comparison to the previous IWW/INFRAS study, road is 51% higher, whereas rail is 2.6 times higher. The reasons are similar to passenger transport (see as well chapter 7).

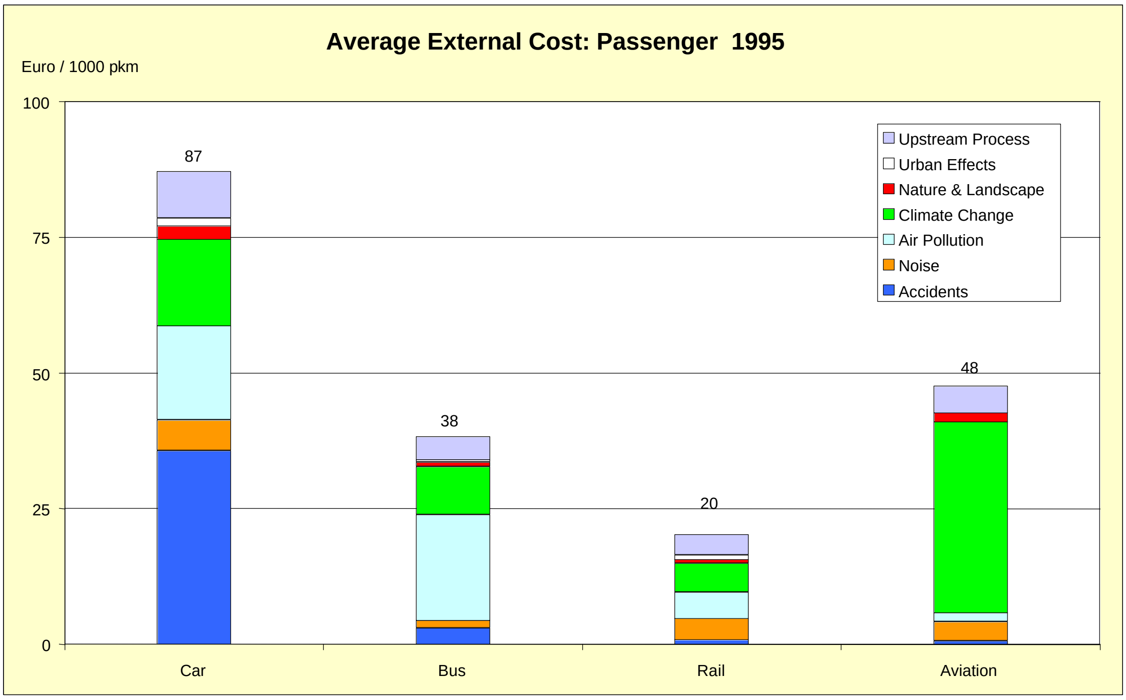

Figure 14: Average external costs 1995 (EUR 17) by transport means and cost category: Passenger transport

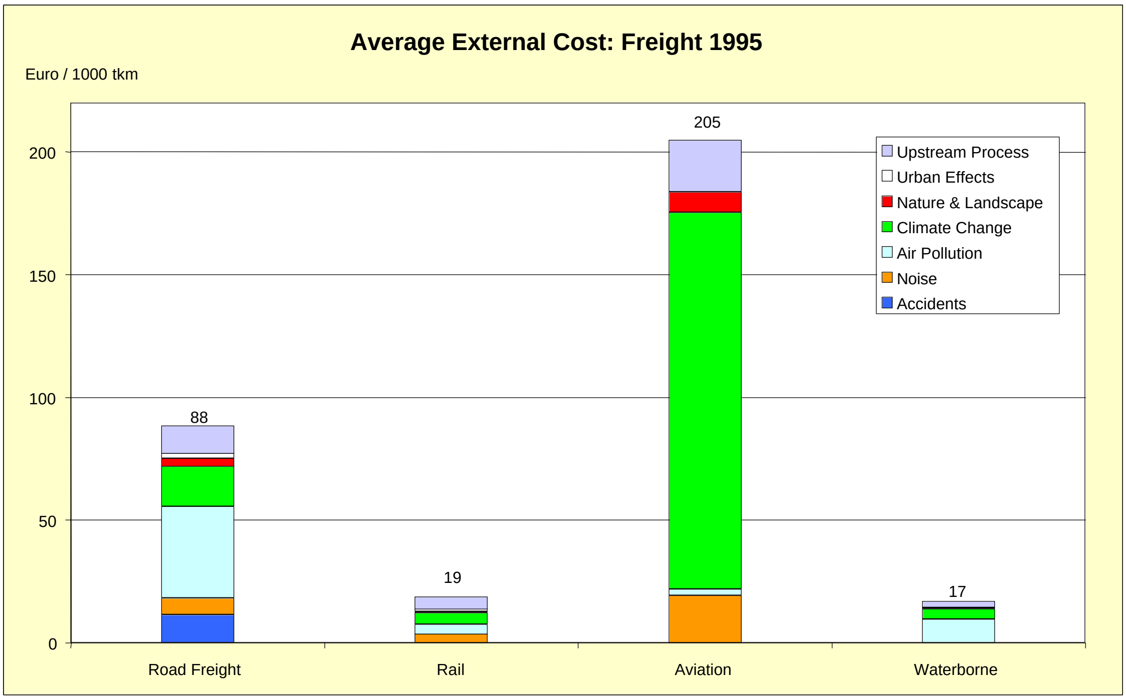

Figure 15: Average external costs 1995 (EUR 17) by transport means and cost category: Freight transport

Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	35.7	250.3	3.1	*35.1*	0.9	0.6	100	6.8	*11.5*	0.0	0.0	0.0
Noise	5.7	17.0	1.3	*5.4*	3.9	3.6	36	5.1	*6.7*	3.5	19.3	0.0
Air Pollution	17.3	7.9	19.6	*17.4*	4.9	1.6	131	32.4	*37.4*	4.0	2.6	9.7
Climate Change	15.9	13.8	8.9	*15.3*	5.3	35.2	134	15.1	*16.2*	4.7	153.5	4.2
Nature & Landscape	2.5	2.0	0.8	*2.3*	0.4	1.7	23	2.2	*3.3*	0.5	8.5	0.5
Urban Effects	1.5	1.1	0.5	*1.4*	0.9	0.0	12	1.3	*1.9*	0.9	0.0	0.0
Upstream Process	8.6	6.0	4.3	*8.5*	3.8	5.0	69	8.7	*11.4*	5.0	20.9	2.6
Total	**87**	**298**	**38**	*85*	**20**	**48**	**505**	**72**	*88*	**19**	**205**	**17**

Table 21: Average external costs 1995 (EUR 17) by transport means and cost category

c) Total and average costs by country

Table 22 presents the allocation to the countries considered. The highest share occurs for Germany with 25% of total costs, followed by France, Italy and UK (with about 15% of costs).

Total Cost 1995		Road							Rail		Aviation		Water-borne
[million Euro / year]		Car	MC	Bus	Pass. Total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Austria	**13'200**	7'980	282	242	8'500	298	3'570	3'880	101	151	520	32	32
Belgium	**19'000**	11'000	285	264	11'600	1'230	4'870	6'110	185	160	706	129	120
Denmark	**8'960**	4'350	90	429	4'860	438	2'560	3'010	242	37	733	81	0
Finland	**5'330**	2'520	185	331	3'030	406	1'210	1'620	63	148	393	30	47
France	**79'400**	42'700	2'060	1'970	46'700	12'200	15'300	27'600	501	512	3'580	395	97
Germany	**132'500**	82'800	4'610	3'140	90'500	4'420	26'600	31'000	1'740	1'960	5'340	607	1'250
Greece	**9'290**	4'500	289	105	4'890	1'480	2'330	3'820	41	7	510	29	0
Ireland	**4'410**	2'450	73	125	2'650	184	951	1'140	40	23	536	28	0
Italy	**78'000**	47'200	1'870	2'200	51'300	5'280	17'500	22'800	972	587	2'180	167	7
Luxemb'g	**1'120**	549	13	34	596	32	371	404	9	13	39	47	7
Netherl.	**22'200**	10'300	353	346	11'000	28	7'910	7'940	321	31	1'760	374	821
Norway	**5'660**	3'150	131	218	3'500	358	1'060	1'420	38	40	636	26	0
Portugal	**10'100**	5'670	489	183	6'340	697	2'200	2'900	102	54	688	36	0
Spain	**43'200**	19'700	425	584	20'700	9'010	9'010	18'100	253	236	3'770	102	0
Sweden	**10'600**	5'820	92	438	6'350	1'160	2'140	3'300	48	112	791	43	0
Switzerl.	**11'700**	7'030	579	291	7'900	539	1'630	2'180	198	109	1'170	121	0
UK	**75'000**	44'200	1'160	2'960	48'300	5'300	13'400	18'800	1'090	140	6'110	504	6
EUR 17	**530'000**	**302'000**	**13'00**	**13'900**	**329'000**	**43'100**	**113'000**	**156'000**	**6'000**	**4'320**	**29'500**	**2'750**	**2'390**

Table 22: Total external costs (EUR 17) 1995 by country

Figure 16, Figure 17 and Table 23 are presenting average cost per country. Like in the previous studies, there are remarkable differences between the countries.

- Within road passenger transport, Germany is highest (28% above average) while Spain and Portugal are lowest (30% below average). Besides the lower national valuations, one explanation factor is the high share of diesel vehicles.
- Within road freight transport, Switzerland is highest (81% above average) and Austria is lowest (51% below average). One explanation factor is the lower weight limit for Switzerland and the high population density.
- Within rail passenger transport, Denmark is highest (149% above average) and Sweden and France is lowest (60% below average). The electricity mix is one important explanation factor.
- Within rail freight transport, Ireland is highest (105% above average) and Sweden is lowest (67% below average). Whereas Ireland has only Diesel traction, Sweden uses green energy sources.

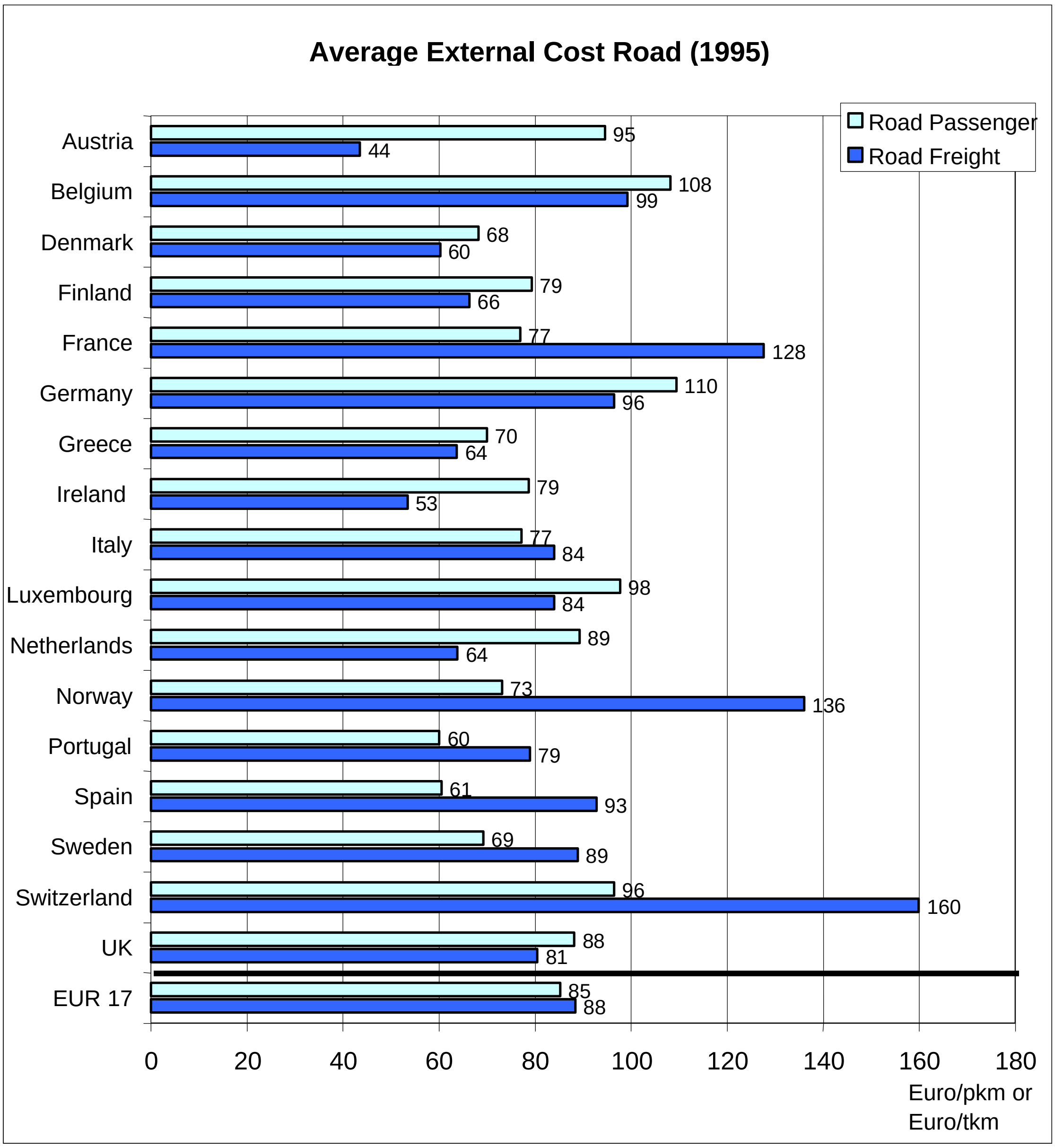

Figure 16: Average external costs 1995 (EUR 17) by country: Road transport

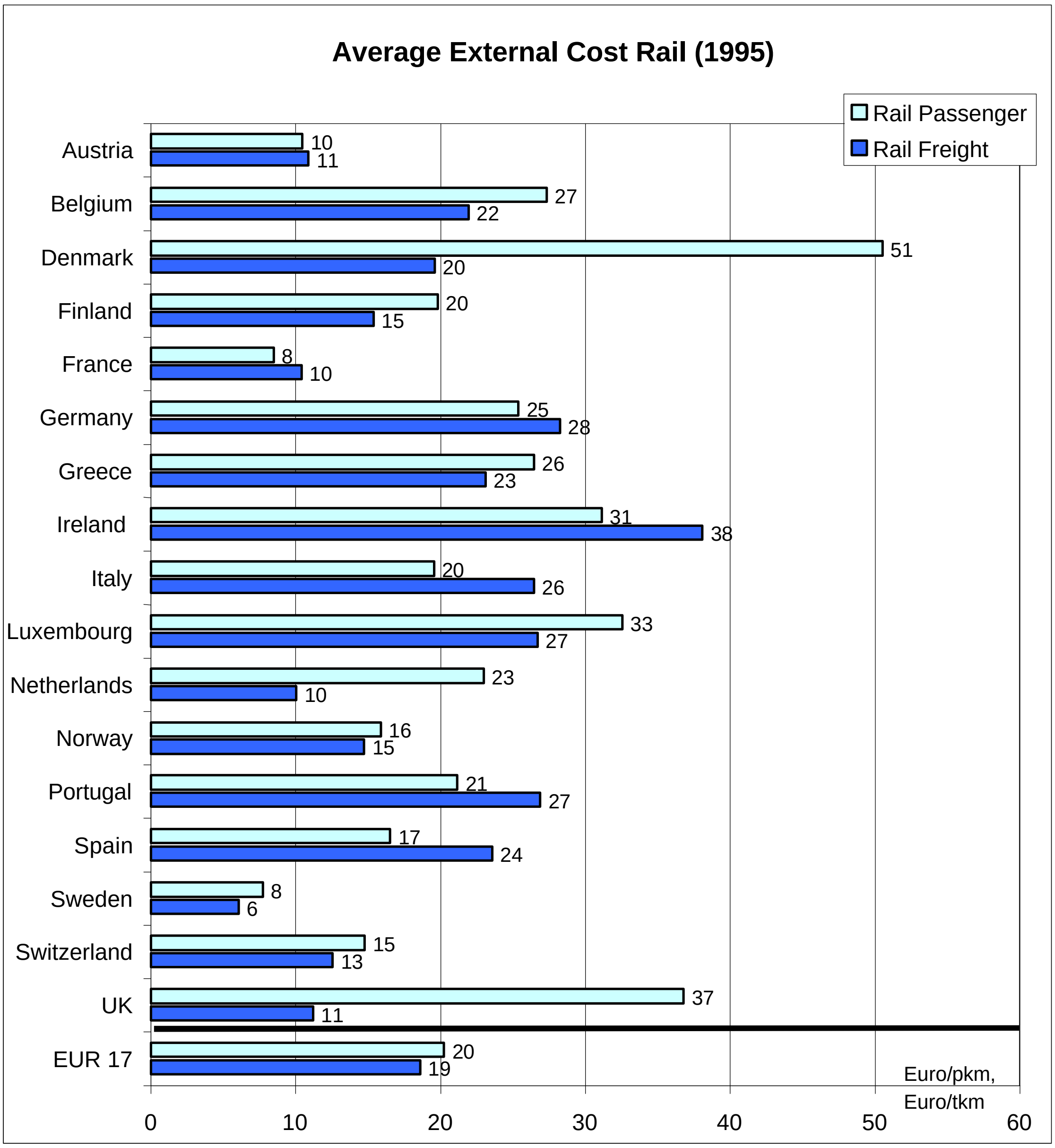

Figure 17: Average external costs 1995 (EUR 17) by country: Rail transport

Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	104	336	19	95	10	46	514	44	44	11	234	15
Belgium	108	310	65	108	27	40	554	87	99	22	208	21
Denmark	75	216	32	68	51	43	500	54	60	20	191	0
Finland	85	205	40	79	20	51	440	57	66	15	238	14
France	78	299	34	77	8	48	529	84	128	10	193	16
Germany	113	360	38	110	25	48	569	88	96	28	199	20
Greece	68	318	38	70	26	49	425	45	64	23	196	0
Ireland	77	254	67	79	31	44	492	50	53	38	215	0
Italy	78	244	38	77	20	52	521	72	84	26	218	70
Luxembourg	102	362	48	98	33	23	581	79	84	27	117	25
Netherlands	92	294	35	89	23	51	536	68	64	10	262	24
Norway	73	181	55	73	16	58	562	115	136	15	199	0
Portugal	61	310	16	60	21	44	468	71	79	27	198	0
Spain	64	217	18	61	17	47	459	59	93	24	167	0
Sweden	72	182	40	69	8	51	405	69	89	6	212	0
Switzerland	96	300	41	96	15	43	643	134	160	13	205	0
UK	88	291	70	88	37	44	509	63	81	11	211	31
EUR 17	**87**	**298**	**38**	**85**	**20**	**48**	**505**	**72**	**88**	**19**	**205**	**17**

Table 23: Average external costs 1995 (EUR 17) by country

3.1.2. Forecast 2010

The following figures and tables present the results for 2010. Total external costs will increase by 42%. A major factor is the increase of the transport volume. The highest growth rates will take place in the aviation sector and in the road.

But also average costs will mainly increase. The increased damages (mainly based on increased valuation of the population, since damages were dynamised by GDP growth). Thus the technical improvements expected cannot outweigh this effect for all transport means:

- There will be an increase of 8% in road passenger transport. Due to improved technology, the costs for air pollution will decrease mainly. Road freight costs will increase by 15%. Major increases have to be expected for climate change costs, since energy savings are not proportional to traffic increase.

- Rail costs will decrease by 2% for passenger transport. For freight transport an increase of 14% has to be expected, mainly due to increased costs of climate change.
- Within air transport, average costs will increase by 16% and 18% respectively. In contrast to that, external costs for waterborne transport will decrease by 34%.

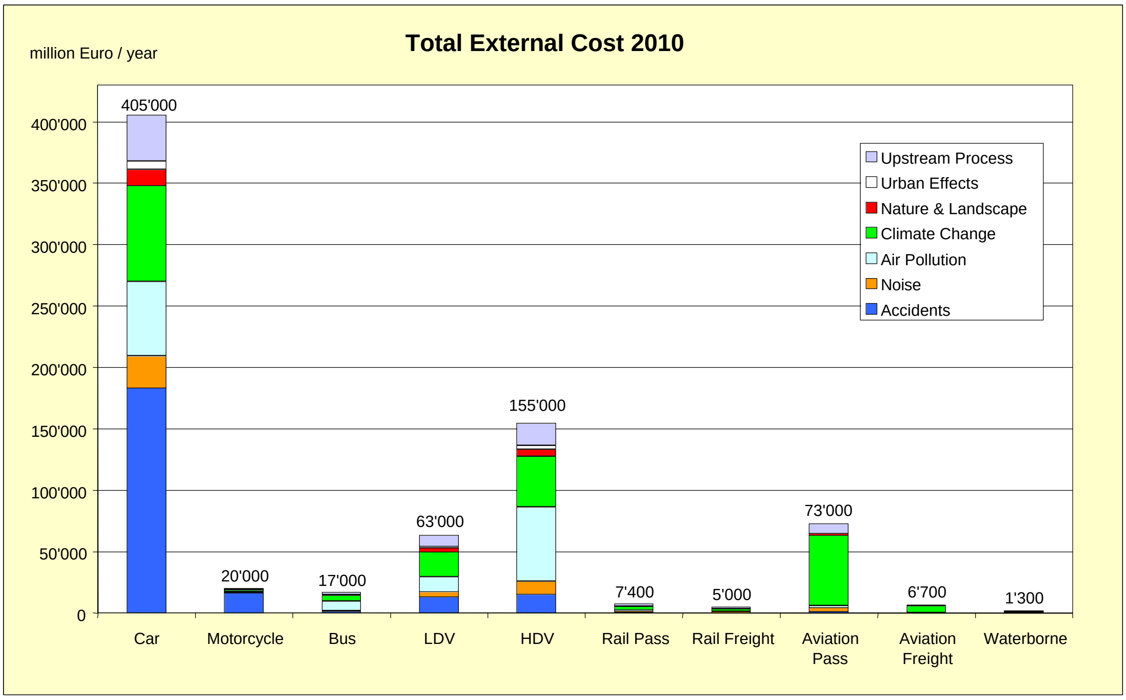

Figure 18: Total external cost 2010 (EUR 17)

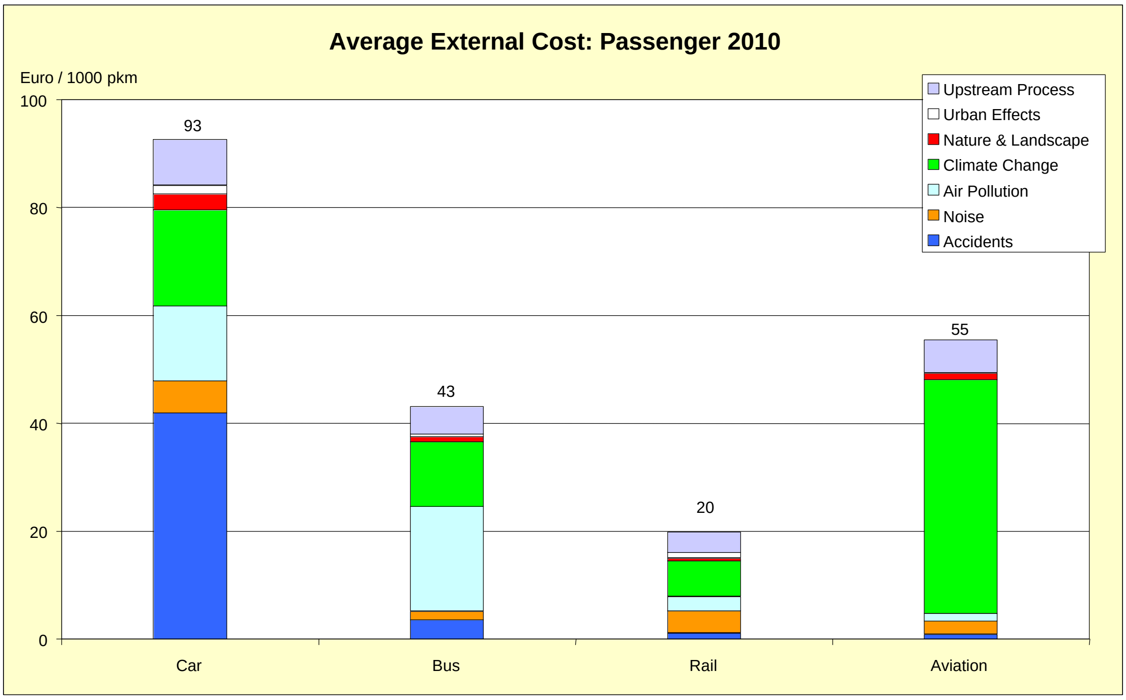

Figure 19: Average external cost for passenger transport 2010 (EUR 17)

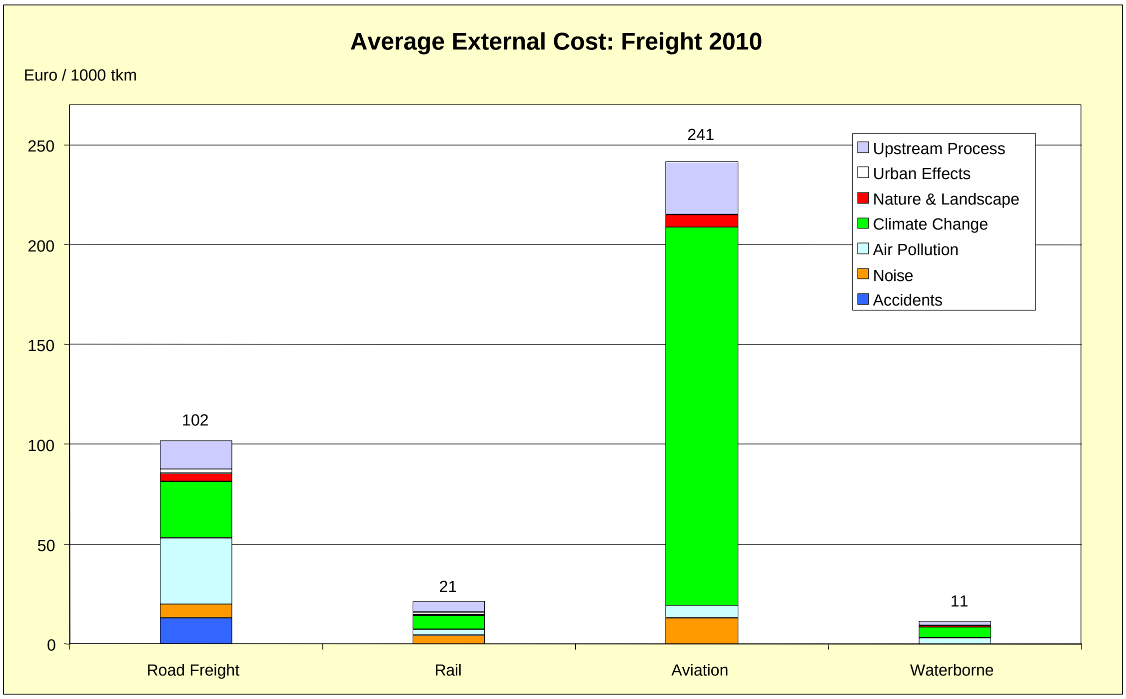

Figure 20: Average external cost for freight transport 2010 (EUR 17)

Forecast 2010: Total Cost		**Road**							**Rail**		**Aviation**		**Water-borne**
[million Euro / year]		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Accidents	**231'000**	183'000	16'200	1'410	*201'000*	13'300	15'200	*28'400*	397	0	1'180	0	0
Noise	**48'700**	26'200	968	634	*27'800*	4'210	10'700	*14'900*	1'480	1'030	3'190	362	0
Air Pollution	**146'000**	60'700	719	7'660	*69'100*	11'900	60'600	*72'500*	980	659	1'870	175	356
Climate Change	**212'000**	77'900	1'050	4'740	*83'700*	20'300	41'300	*61'600*	2'390	1'590	56'900	5'260	616
Nature & Landscape	**25'000**	13'200	137	379	*13'800*	3'250	5'740	*8'980*	190	115	1'650	176	92
Urban Effects	**12'300**	6'910	68	191	*7'170*	1'520	2'980	*4'500*	359	286	0	0	0
Upstream Process	**79'200**	37'300	484	2'000	*39'800*	8'730	18'400	*27'500*	1'580	1'330	7'980	737	239
Total	**754'000**	**405'000**	**19'600**	**17'000**	***442'000***	**63'100**	**155'000**	***218'000***	**7'380**	**5'010**	**72'800**	**6'710**	**1'300**

Table 24: Total external cost 2010 (EUR 17)

Comparison 1995 – 2010:		**Road**							**Rail**		**Aviation**		**Water-borne**
Total Cost		Car	MC	Bus	Pass. Total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Accidents	**48%**	48%	49%	27%	*48%*	56%	41%	*47%*	60%		190%		
Noise	**33%**	33%	31%	35%	*33%*	38%	31%	*33%*	32%	27%	41%	41%	
Air Pollution	**8%**	1%	109%	8%	*3%*	6%	18%	*16%*	-31%	-29%	279%	276%	-76%
Climate Change	**74%**	41%	75%	48%	*42%*	77%	72%	*74%*	54%	44%	156%	156%	27%
Nature & Landscape	**56%**	54%	56%	35%	*54%*	65%	62%	*63%*	0%	0%	58%	56%	52%
Urban Effects	**39%**	37%	37%	16%	*37%*	44%	42%	*42%*	37%	39%			
Upstream Process	**40%**	25%	84%	29%	*26%*	48%	44%	*46%*	30%	15%	161%	161%	-32%
Total	**42.3%**	**34%**	**51%**	**23%**	***34%***	**46%**	**37%**	***40%***	**23%**	**16%**	**147%**	**144%**	**-45%**

Table 25: Total external cost: Changes between 1995 and 2010 in %

Forecast 2010: Average Cost	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	[Euro / 1000 pkm]						[Euro / 1000 tkm]					
Accidents	41.9	295.2	3.6	41.6	1.1	0.9	117.9	7.3	13.0	0.0	0.0	0.0
Noise	6.0	17.6	1.6	5.8	4.1	2.4	37.4	5.2	6.8	4.4	13.0	0.0
Air Pollution	13.9	13.1	19.4	14.3	2.7	1.4	105.7	29.3	33.2	2.8	6.3	3.1
Climate Change	17.8	19.1	12.0	17.3	6.6	43.3	180.2	20.0	28.2	6.8	189.3	5.3
Nature & Landscape	3.0	2.5	1.0	2.9	0.5	1.3	28.8	2.8	4.1	0.5	6.3	0.8
Urban Effects	1.6	1.2	0.5	1.5	1.0	0.0	13.5	1.4	2.1	1.2	0.0	0.0
Upstream Process	8.5	8.8	5.1	8.6	3.9	6.1	77.6	9.7	14.3	5.4	26.5	2.1
Total	**92.7**	**357.6**	**43.1**	**91.9**	**19.9**	**55.4**	**561.0**	**75.7**	**101.7**	**21.3**	**241.5**	**11.2**

Table 26: Average external cost 2010 (EUR 17)

Comparison 1995 – 2010: Average Cost	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
Accidents	17%	18%	17%	19%	33%	39%	18%	8%	13%			
Noise	5%	4%	24%	7%	5%	-32%	5%	1%	2%	27%	-32%	
Air Pollution	-20%	66%	-1%	-18%	-45%	-8%	-19%	-10%	-11%	-29%	139%	-68%
Climate Change	12%	39%	35%	14%	23%	23%	34%	32%	74%	44%	23%	27%
Nature & Landscape	22%	24%	23%	23%	-20%	-24%	25%	24%	25%	0%	-25%	52%
Urban Effects	9%	9%	6%	10%	10%		9%	9%	9%	39%		
Upstream Process	-1%	46%	18%	1%	2%	21%	12%	12%	26%	9%	27%	-21%
Total	**6%**	**20%**	**12%**	**8%**	**-2%**	**16%**	**11%**	**6%**	**15%**	**14%**	**18%**	**-34%**

Table 27: Changes of average external cost between 1995 and 2010 in %

3.2. Results 1995 per cost category

3.2.1. Accidents

Main assumptions:

- The average European Risk Value for fatalities amounts to 1.5 million Euro.
- The Risk Value for severe injuries amounts to 13% and for slight injuries to 1% of the Risk Value for fatalities.
- No additional Risk Value for relatives an friends is included.
- Unreported casualties are adjusted according to IRTAD information.
- Occupational accidents are not included.
- Total costs are allocated to the modes according to the responsibility for the accident.

a) 1995

Most determining for the external accident costs are accident risks, measured in fatalities or injuries per billion vehicle kilometres. Table 28 lists the average casualty rates[40] for road accidents in Europe. Not surprisingly motorcycles have the highest rates, followed by cars. Remarkably trucks and vans have lower accident rates than cars. This might be due to the fact that casualties are attributed to the mode being held responsible for the accident. Professional drivers of trucks and vans most probably cause fewer accidents per kilometre than private drivers of cars.

Casualties per billion vehicle km	**Car**	**MC**	**Bus**	**LDV**	**HDV**
Fatalities	16	76	12	8	13
Severe Injuries	182	927	143	94	91
Slight Injuries	791	1864	817	436	389

Table 28: Average road accident rates per billion vehicle km

Road accident risks in Europe vary considerably. Figure 21 shows the deviation of the risk for injuries and fatalities from the European average. Many Mediterranean countries such as Portugal, Greece and Spain are well above average, while the Scandinavian countries range at the lower end of the scale.

40 Rail and air are not listed, because the data for vehicle km are not comparable.

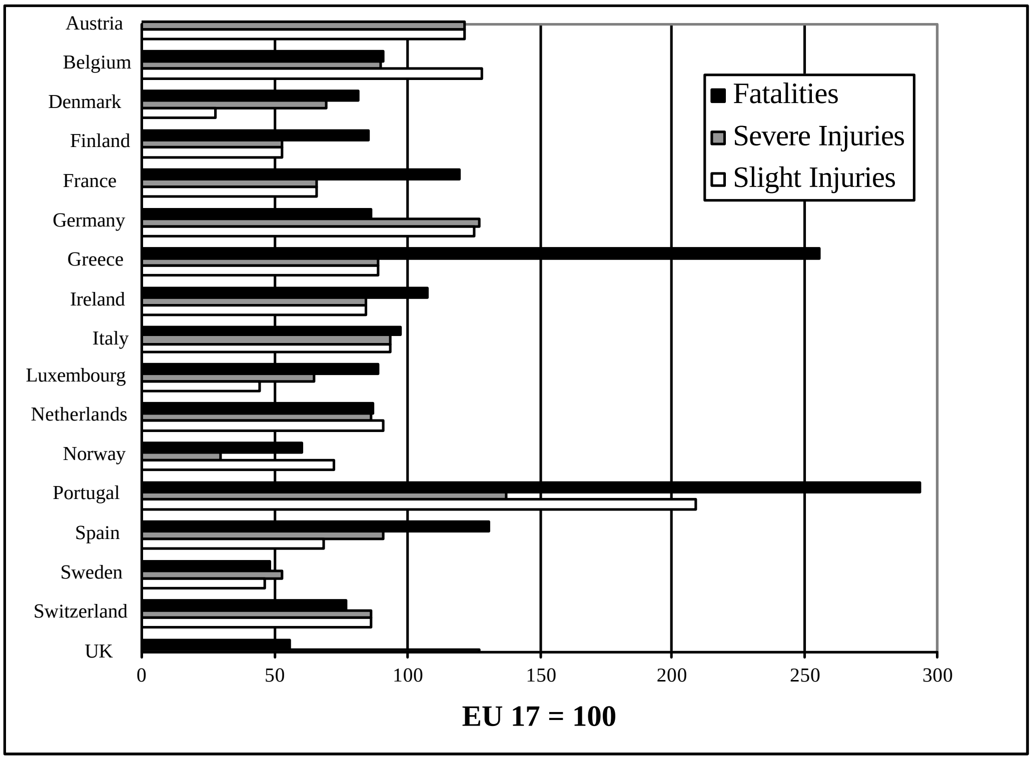

Figure 21: Road accident risks in Europe

In 1995 accident costs in EUR 17 countries comprise 156 billion Euro, which amounts to about 2.3% of Europe's GDP. 43% of the costs are caused by fatalities, 39% by severe injuries and 18% by slight injuries.

Nearly all of the external accident costs are due to road transport, rail and air traffic only comprise 0.5% of total accident costs. However, it has to be mentioned that air accident costs could only be estimated for fatalities, because the data for airborne injuries are not available. As already explained in chapter 2.2., accident costs for air and rail freight transport are regarded as completely internalised. Nearly 80% of external accident costs are caused by cars, followed by 7% for motorcycles, 7% for trucks, 6% for vans and less than one percent for buses.

Accidents: Total Cost 1995 [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Austria	**4'640**	3'880	246	27	4'160	76	384	460	14	-	8	-	-
Belgium	**5'710**	4'710	240	20	4'970	262	465	727	5	-	13	-	-
Denmark	**1'830**	1'470	74	27	1'570	70	165	235	8	-	12	-	-
Finland	**1'080**	770	146	20	934	57	82	139	4	-	5	-	-
France	**23'200**	17'400	1'690	157	19'200	2'280	1'570	3'850	50	-	51	-	-
Germany	**43'400**	35'400	3'900	268	39'500	958	2'760	3'720	58	-	80	-	-
Greece	**3'160**	2'190	257	14	2'460	368	323	691	3	-	4	-	-
Ireland	**1'150**	956	60	10	1'030	33	86	119	1	-	7	-	-
Italy	**23'800**	19'300	1'570	173	21'000	1'060	1'680	2'730	22	-	28	-	-
Luxemb'g	**315**	255	12	3	269	7	35	42	2	-	2	-	-
Netherl.	**4'700**	3'810	294	21	4'130	5	537	542	3	-	24	-	-
Norway	**1'050**	855	96	11	961	39	38	77	4	-	9	-	-
Portugal	**4'450**	3'270	444	31	3'750	217	458	675	21	-	7	-	-
Spain	**11'600**	8'360	363	60	8'780	1'800	991	2'790	4	-	40	-	-
Sweden	**1'960**	1'570	72	22	1'660	157	131	289	2	-	10	-	-
Switzerl.	**3'410**	2'700	470	20	3'190	90	84	174	19	-	25	-	-
UK	**20'200**	16'900	963	227	18'100	1'050	982	2'030	28	-	84	-	-
EUR 17	**156'000**	**124'000**	**10'900**	**1'110**	**136'000**	**8'520**	**10'800**	**19'300**	**248**	**-**	**407**	**-**	**-**

Table 29: Total external accident costs by country 1995

Average costs estimate the relative external costs in Euro per 1000 pkm or tkm. In European passenger transport, motorcycles have the highest average costs (250 Euro), followed by cars (36 Euro) and buses (3 Euro). Travelling by rail or air causes less than 1 Euro/1000 pkm. Regarding freight transport, vans have much higher costs per tonne kilometre (100 Euro) than trucks (7 Euro). This can be explained by the loading capacity, which is by definition far lower for LDVs than for HDVs. On average a van has to drive 19 times longer to produce the same transport volume measured in tonne kilometres.

If average road accident costs are compared on the country level, the differences are smaller than the ones in accident risks. Countries with high accident risks, such as Greece, Portugal and Spain have a relatively low income, which attributes them with a low Risk Value. Countries with low accident risks such as Scandinavia have high incomes and thus high Risk Values. Therefore, countries with medium accident rates and high income, such as Austria, Belgium, Luxembourg and Germany produce the highest average costs per pkm or tkm.

Accident: Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	51	293	2.1	46.1	1.4	0.7	131	4.7	5.6	-	-	-
Belgium	46	262	5.0	46.4	0.8	0.7	118	8.3	12.4	-	-	-
Denmark	25	178	2.0	21.9	1.6	0.7	80	3.5	4.8	-	-	-
Finland	26	163	2.4	24.2	1.3	0.6	61	3.8	6.2	-	-	-
France	32	245	2.7	31.5	0.9	0.7	99	8.5	18.6	-	-	-
Germany	48	305	3.2	47.7	0.8	0.7	124	9.1	11.9	-	-	-
Greece	33	282	5.1	35.2	2.1	0.4	106	6.1	12.3	-	-	-
Ireland	30	209	5.2	30.4	0.7	0.6	88	4.5	6.1	-	-	-
Italy	32	206	3.0	31.5	0.4	0.7	104	6.8	10.7	-	-	-
Luxemb'g	47	315	3.6	43.9	7.1	1.1	127	7.3	8.7	-	-	-
Netherlands	34	245	2.1	33.6	0.2	0.7	97	4.6	4.6	-	-	-
Norway	20	132	2.8	20.0	1.9	0.8	61	4.1	7.8	-	-	-
Portugal	35	281	2.7	35.4	4.3	0.4	146	14.6	20.6	-	-	-
Spain	27	185	1.8	25.6	0.3	0.5	92	6.4	16.0	-	-	-
Sweden	19	142	2.0	18.0	0.3	0.7	55	4.2	8.5	-	-	-
Switzerland	37	244	2.8	38.9	1.4	0.9	107	6.8	13.2	-	-	-
UK	33	241	5.4	32.8	0.9	0.6	101	4.6	9.0	-	-	-
EUR 17	**36**	**250**	**3.1**	**35.1**	**0.9**	**0.6**	**100**	**6.8**	**11.5**	**-**	**-**	**-**

Table 30: Average external accident costs by country 1995

b) 2010

It is amazing to observe how strong fatal road accidents have decreased in Europe in the last two decades. According to IRTAD the number of road fatalities in EUR 17 decreased from 56'972 in 1991 to 48'633 in 1995, which implies a reduction of 15% over the period of 4 years. With the exception of Greece, the European countries registered a strong improvement in traffic safety. This development has to be judged against the background of the increasing transport volume in Europe.

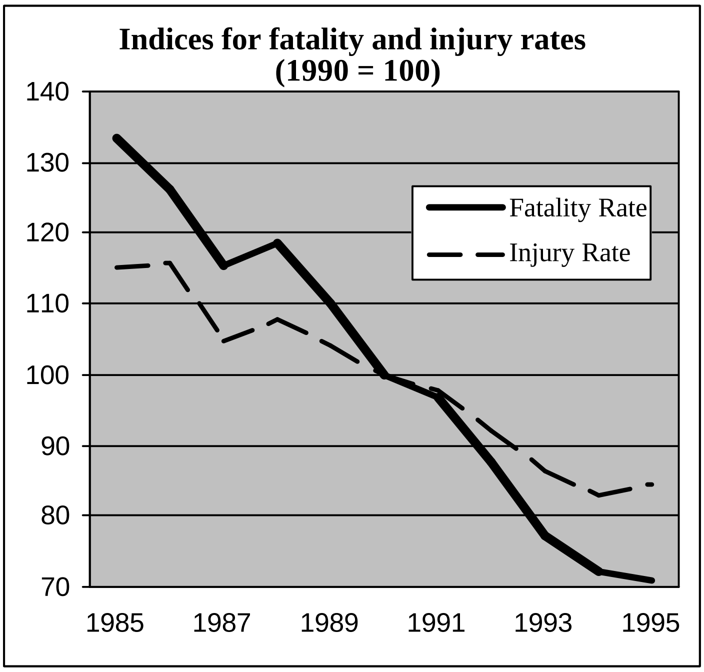

Figure 22: Change of road accident risks per vehicle kilometre in Europe

Figure 22 shows the change of accident risks per vehicle kilometre for EUR 17 countries. From 1985 to 1995 the average injury rate decreased by 27% while the fatality rate shrunk by impressing 47%. The trend shows that road accident severity is decreasing. However, an analysis of the performance on the country level reveals that four country groups exist. In the first group (NL, N and UK), accident rates are very low but the decrease has been stagnating during the last years. The group with the highest accident rates has experienced a strong decline of casualty rates during the recent past. The relevant functions are estimated with a regression analysis, which allows a projection of the rates to 2010. The rates decline between 2% in Sweden and 64% in Portugal.

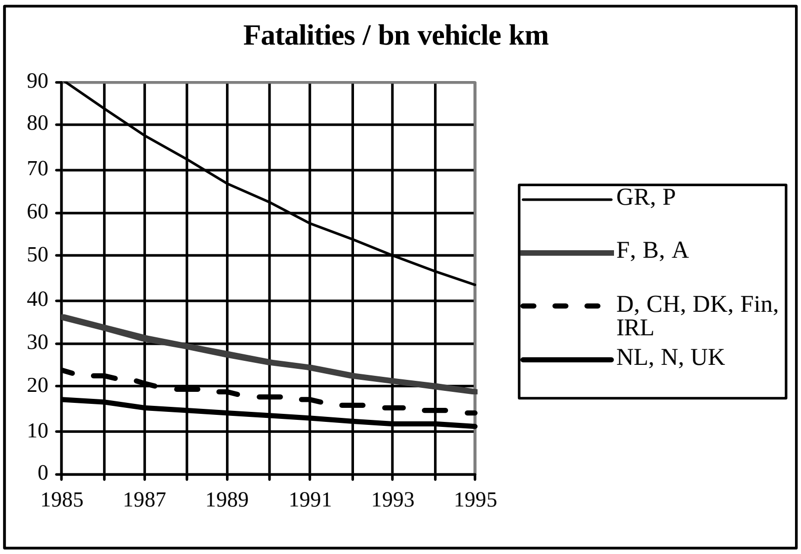

Figure 23: Fatality rates in Europe 1985-1995

A multiplication of the rates with future road transport volumes reveals that until 2010 the number of fatalities in EUR 17 countries will decline by 28%, while injuries shrink with only 6%. Obviously the decreasing accident rates overcompensate for the increasing transport volume. The decreasing accident severity is reflected by the increasing importance of injuries: While in 1995 fatalities comprised 43% of total costs, this value decreases to 29% in 2010.

Euro / 1000 pkm, tkm	Road Passenger	Road Freight	Rail Passenger	Air Passenger
EUR 17	41.6	13.0	1.1	0.9
Change 1995 - 2010	19%	13%	33%	39%

Table 31: Average external accident costs in 2010

Even though the number of casualties is decreasing, the growing wealth, which entails a higher Risk Value (WTP), causes an increase of accident costs by 48%. In 2010 the total accident costs amount to 230 million Euro, which comprises about 2.4% of GDP, compared to 2.3% in 1995. The increase of accidents costs is largely due to the growing transport volume. If average accident costs are compared, most of the modes register an increase lower than the growth of per capita GDP that grows at 39% during this period. For air transport no reduction of fatality rates was assumed and thus average costs increase at the pace of economic growth.

3.2.2. Noise

Main assumptions:

- Linear increase of noise costs with increasing noise volume.
- 55 dB(A) is considered as level of silence (WTP = 0).
- Risk of cardiac infarctions increases by 20% for a noise expose of 65-70dB(A) and by 30% for an exposure higher than 70 dB(A).
- Fatalities due to cardiac infarctions are valued with the Risk Value.

a) 1995

In 1995 the total transport noise costs in the EUR 17 countries amount to 37 billion Euro, which is 0.54% of GDP. Three fifth of these costs comprise the WTP for the reduction of noise nuisance; the remaining share stems from the increased mortality (cardiac infractions) due to noise exposure. This share is far lower for railways, due to the lower noise exposure of the population and due to smaller impacts of railway noise. Road passenger transport comprises 57% and road freight 31% of total costs.

Noise: Total Cost 1995		**Road**							**Rail**		**Aviation**		**Water-borne**
[million Euro / year]		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Austria	**802**	468	12	8	*489*	20	231	*251*	10	10	41	3	-
Belgium	**1'190**	657	15	7	*679*	79	324	*403*	35	22	43	8	-
Denmark	**395**	215	4	10	*229*	23	114	*137*	8	3	16	2	-
Finland	**248**	104	8	7	*120*	17	52	*70*	14	18	25	2	-
France	**7'170**	3'820	153	92	*4'070*	1'150	1'600	*2'740*	42	42	255	24	-
Germany	**10'000**	5'690	265	112	*6'070*	331	2'280	*2'610*	403	325	553	59	-
Greece	**338**	148	7	3	*158*	58	97	*155*	5	1	19	1	-
Ireland	**278**	156	4	4	*164*	12	68	*80*	9	10	16	1	-
Italy	**5'400**	2'850	97	67	*3'010*	343	1'220	*1'560*	307	208	290	19	-
Luxemb'g	**43**	23	0	1	*24*	1	14	*16*	0	0	1	1	-
Netherl.	**1'440**	462	15	7	*484*	1	322	*323*	34	9	487	105	-
Norway	**320**	225	11	7	*244*	23	48	*71*	0	0	5	0	-
Portugal	**474**	221	13	5	*240*	33	143	*176*	18	12	27	1	-
Spain	**2'430**	1'040	18	20	*1'070*	506	573	*1'080*	76	60	141	4	-
Sweden	**328**	179	3	7	*189*	39	74	*113*	8	9	8	0	-
Switzerl.	**980**	576	42	11	*629*	42	88	*130*	105	67	43	5	-
UK	**4'680**	2'870	70	100	*3'040*	373	896	*1'270*	50	16	286	22	-
EUR 17	**36'500**	**19'700**	**738**	**469**	***20'900***	**3'050**	**8'140**	***11'200***	**1'130**	**812**	**2'260**	**257**	**-**

Table 32: Total external noise costs by country 1995

The average noise costs are listed in Table 33. The noise costs that a car in Europe produces, amounts 5.7 Euro/1000 pkm. Passenger railways have lower costs (3.9 Euro/1000 pkm). The most favourable means of transport are buses, while – no surprise - motorcycles cause the strongest noise damage. Air transport is not really comparable, because long distance transports reduce the strong effects caused by take off and landing of short distance flights.

In freight transport noise costs are set in relation to tonne kilometres. Railways have the lowest average costs (3.5 Euro/1000 tkm) followed by heavy-duty vehicles (5.1), while the specific costs of light duty vehicles are far higher (36). This can be explained by the loading capacity, which is by definition far lower for LDV than for HDV. Again a comparison with air transport is problematic. But even not taking into account the distortions by long distance flights, planes are far more unfavourable for goods transport than trucks and trains.

Variations of the country values can be explained by the different exposure levels and by variations of per capita income, which affect the WTP. The extreme values for air transport in the Netherlands are caused by very high exposure levels of the population: the OECD (1993a) estimates that 36% of the population in the Netherlands are exposed to air traffic noise of more than 55 dB(A).

Noise: Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	6.1	14.8	0.7	5.4	1.0	3.6	34.4	2.8	3.0	0.7	18.5	-
Belgium	6.4	15.8	1.8	6.3	5.2	2.5	35.7	5.8	6.9	3.0	13.0	-
Denmark	3.7	10.2	0.8	3.2	1.7	0.9	26.3	2.4	2.8	1.7	4.2	-
Finland	3.5	9.2	0.9	3.1	4.5	3.3	18.9	2.4	3.1	1.9	13.3	-
France	7.0	22.2	1.6	6.7	0.7	3.4	49.8	8.7	13.2	0.9	11.9	-
Germany	7.8	20.7	1.3	7.3	5.9	4.9	42.6	7.5	8.4	4.7	19.3	-
Greece	2.2	7.8	0.9	2.3	2.9	1.8	16.8	1.8	2.8	4.6	6.9	-
Ireland	4.9	14.2	2.2	4.9	7.0	1.3	32.1	3.5	4.1	15.9	6.4	-
Italy	4.7	12.7	1.2	4.5	6.2	6.9	33.9	5.0	6.1	9.4	24.7	-
Luxembourg	4.2	11.3	0.8	3.9	1.6	0.7	25.6	3.0	3.3	0.5	3.5	-
Netherlands	4.1	12.5	0.7	3.9	2.5	14.0	25.7	2.8	2.8	2.9	73.6	-
Norway	5.2	15.5	1.9	5.1	0.1	0.4	35.8	5.1	7.1	0.1	1.2	-
Portugal	2.4	8.1	0.5	2.3	3.7	1.7	22.4	4.6	5.4	6.0	7.9	-
Spain	3.4	9.3	0.6	3.1	4.9	1.8	25.8	3.7	6.2	6.0	6.5	-
Sweden	2.2	6.7	0.6	2.0	1.2	0.5	13.8	2.4	3.3	0.5	1.9	-
Switzerland	7.9	21.8	1.6	7.7	7.9	1.6	50.1	7.2	9.9	7.7	7.8	-
UK	5.7	17.4	2.4	5.5	1.7	2.0	35.8	4.2	5.6	1.3	9.4	-
EUR 17	**5.7**	**17.0**	**1.3**	**5.4**	**3.9**	**3.6**	**35.7**	**5.1**	**6.7**	**3.5**	**19.3**	**-**

Table 33: Average external noise costs by country in 1995 (EUR 17)

b) 2010

Table 34 shows the total external noise costs of transport in Europe in 2010. The amount is one third higher than the costs in 1995. Due to the strong increase in aviation, air transport registers the fastest growth of total costs. Due to the assumed strong improvements, freight trains have a far weaker increase than the growth of GDP per capita, which amounts to 39% for the observed period.

	Road Passenger	Road Freight	Rail Passenger	Rail Freight	Air Passenger	Air Freight	Total
Total costs							
Million Euro	27'800	14'900	1'480	1'030	3'190	362	48'700
Change to 1995	33%	33%	32%	27%	41%	41%	33%
Average costs							
Euro / 1000 pkm, tkm	5.8	6.8	4.1	4.4	2.4	13.0	
Change to 1995	7%	2%	5%	27%	-32%	-32%	

Table 34: Total and average external noise costs 2010

However, this picture changes completely, if average costs are regarded. The increase of costs per pkm or tkm is far below the growth of wealth in Europe. The main reason is the increase of transport volume, which has comparatively low impacts on the total noise level. As described in chapter 2.3.3. the logarithmic form of the noise function entails that a doubling of the transport volume will only bring about a 5% increase of the equivalent noise level. This is the reason why the strongest improvements of average costs can be observed in the mode, which is expected to grow most. While air transport registers far lower average costs in 2010, the stagnating rail freight transport will have significant higher transport costs per tonne kilometre. Even the strong noise improvements assumed for freight trains are more than compensated by this effect.

The average costs of road freight transport do not change significantly compared to 1995, due to the expected increase of transport volume and the assumed improvements.

3.2.3. Air pollution

Main assumptions:

- Consideration of health costs, building damages and crop losses in the main estimations.
- Methodology used: Top down allocation based on expert studies for specific countries (France, Switzerland, Austria).
- Health costs are allocated according to the emissions of PM_{10} and NO_x, the other damages are based on NO_x.
- Data basis: TRENDS which provides comparable emission data for road transport in EUR 17[41].
- Forecast 2010: Use of TRENDS data basis and adjustment of unit costs by GDP growth per capita.

The following tables show total and average air pollution costs by country. Most important are health costs, which amount to 81% of the costs, building damages amount to 18% and crop losses are of minor importance (1%). Of interest is the comparison of average costs:

- Within passenger transport, cars amount to 17.3 Euro/1'000 pkm, which is more than 2.8 times higher than rail transport. The relation has improved, due to the fact, that particles are only of major relevance for diesel cars. Interesting are the very moderate values for aeroplanes. This main reason are the relatively low particle emissions. The air pollutants in higher altitudes are considered in the costs of climate change.
- Within freight transport, HDV is more than 8 times higher than rail. Here the particle emissions of diesel vehicles are predominant.
- The differences between the countries are mainly depending on the vehicle park (age and environmental performance of the park, share of diesel), the vulnerability of population (e.g. share of urban areas) and (for the rail sector) the national electricity mix and the share of diesel rolling stock.

41 Different sources were used for the other sector (see Annex 2.3)
Rail: TRENS, UIC, DB;
Air Transport: ICAO, INFRAS;
Waterborne Transport: UBA.

Air Pollution: Total Cost 1995		**Road**							**Rail**		**Aviation**		**Water-borne**
[million Euro / year]		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Austria	**2'860**	1'170	5.1	109	*1'280*	66	1'450	*1'510*	19	28	7.9	0.5	18
Belgium	**5'570**	2'410	8.8	149	*2'570*	376	2'430	*2'810*	46	41	19.3	3.6	79
Denmark	**2'930**	1'160	3.1	225	*1'390*	130	1'270	*1'400*	106	15	16.8	1.9	-
Finland	**1'430**	586	6.1	151	*743*	110	508	*618*	11	30	5.5	0.3	25
France	**19'000**	7'870	50.8	957	*8'870*	3'180	6'520	*9'710*	128	140	61.7	5.8	57
Germany	**32'600**	15'600	121	1'660	*17'400*	1'260	12'300	*13'500*	392	441	114.6	11.7	777
Greece	**1'760**	578	4.3	40	*622*	287	828	*1'120*	15	3	4.7	0.2	-
Ireland	**980**	456	1.9	58	*516*	47	389	*435*	14	7	7.0	0.4	-
Italy	**21'400**	10'300	51.5	1'170	*11'500*	1'530	8'160	*9'690*	118	73	38.7	2.4	1
Luxemb'g	**383**	122	0.5	21	*144*	12	208	*220*	4	7	1.9	2.4	5
Netherl.	**7'560**	2'510	13.2	204	*2'730*	9	4'210	*4'220*	44	4	27.6	5.7	525
Norway	**1'600**	764	5.6	114	*884*	110	558	*668*	15	16	16.7	0.5	-
Portugal	**1'740**	722	6.1	70	*798*	135	770	*905*	20	14	6.0	0.3	-
Spain	**9'070**	3'180	8.5	245	*3'430*	2'020	3'510	*5'530*	36	36	38.5	1.1	-
Sweden	**2'980**	1'460	3.6	213	*1'680*	290	974	*1'270*	8	17	14.8	0.6	-
Switzerl.	**2'930**	1'570	20.2	169	*1'760*	177	923	*1'100*	23	15	29.0	3.1	-
UK	**19'500**	9'530	34.0	1'520	*11'090*	1'430	6'470	*7'900*	413	46	83.7	6.0	2
EUR 17	**134'000**	**59'900**	**345**	**7'070**	***67'300***	**11'200**	**51'400**	***62'600***	**1'410**	**932**	**495**	**47**	**1'490**

Table 35: Total air pollution cost by country 1995 (EUR 17)

Air Pollution: Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	15.2	6.1	8.7	14.2	1.9	0.7	114	17.6	18.3	2.0	3.4	8.4
Belgium	23.6	9.6	36.6	24.0	6.8	1.1	170	43.3	48.1	5.6	5.8	14.1
Denmark	20.0	7.4	16.5	19.3	22.2	1.0	148	26.6	28.8	8.1	4.4	-
Finland	19.9	6.7	18.3	19.2	3.6	0.7	119	23.8	27.7	3.1	2.4	7.6
France	14.5	7.4	16.4	14.6	2.2	0.8	138	35.4	46.9	2.8	2.9	9.7
Germany	21.2	9.5	19.8	20.9	5.7	1.0	162	40.3	43.3	6.3	3.8	12.1
Greece	8.7	4.7	14.4	8.9	9.5	0.5	83	15.8	19.9	8.7	1.7	-
Ireland	14.4	6.5	31.0	15.3	11.1	0.6	125	20.2	22.2	11.8	3.0	-
Italy	17.1	6.7	20.4	17.2	2.4	0.9	151	33.3	37.9	3.3	3.1	11.0
Luxemb'g	22.8	12.6	29.3	23.4	12.8	1.1	210	43.7	45.7	13.2	6.0	17.1
Netherlands	22.4	11.0	20.5	22.2	3.2	0.8	166	36.2	36.2	1.3	4.0	15.2
Norway	17.6	7.8	28.8	18.4	6.4	1.5	173	59.8	67.1	6.1	3.7	-
Portugal	7.8	3.9	6.1	7.5	4.2	0.4	91	24.6	27.6	7.1	1.8	-
Spain	10.3	4.3	7.4	10.0	2.4	0.5	103	22.6	31.6	3.6	1.8	-
Sweden	18.1	7.1	19.5	18.2	1.3	1.0	102	31.2	37.1	0.9	3.1	-
Switzerland	21.4	10.5	24.0	21.4	1.7	1.1	211	75.1	83.8	1.7	5.2	-
UK	18.9	8.5	36.0	20.1	13.9	0.6	137	30.2	35.2	3.7	2.5	10.9
EUR 17	**17.3**	**7.9**	**19.6**	**17.4**	**4.9**	**1.6**	**131**	**32.4**	**37.4**	**4.0**	**2.6**	**9.7**

Table 36: Average air pollution cost by country 1995 (EUR 17)

Total air pollution cost will increase by 8% between 1995 and 2010, although the fleet performance will improve. A main argument for the increase is the increase in traffic volume, the increase of unit costs (due to increased GDP), compared to a rather moderate decrease of particle emissions due to the fact, that many particles (tyres) depend on mileage. Compared to that, the average costs are decreasing for road passenger cars by 20% and for freight transport by 10% (HDV) and 29% (LDV). Rail transport will decrease significantly due to improved electricity mixes and increased energy efficiency by nearly a factor 2.

3.2.4. Climate change

Main assumptions:

- Methodology based on a avoidance costs approach based on IPCC reduction aims (minus 50% in 2030 in comparison to 1990).
- Uniform unit value of 135 Euro per tonne CO_2 for all transport means.
- Forecast: Adjustment of the unit values with GDP growth.
- TRENDS data basis is used for road emissions 1995 and 2010. For the other transport means specific reductions of CO_2 emissions are made.

The following tables show total and average climate change costs by country. Comparing the average costs, the following comments can be made:

- Within passenger transport, cars amount to 15.9 Euro/1'000 pkm, which is a similar amount as the air pollution costs. These costs are considerably higher than in the previous study, since a higher unit cost value was chosen (135 Euro/tonne CO_2 instead of 50 Euro). The values for rail passenger transport are 50% lower. The highest values result for air passenger transport, where climate change is the predominant effect.
- Within freight transport, the average values for HDV are more than 3 times higher than the values for rail transport. Very high values (more than 10 times higher than HDV) result for air freight transport. Here as well we have to consider, that the indicator (tonnes) is not really comparable, since products of higher value are usually transported by air. Waterborne transport produces as well rather low costs per tonne kilometre, being 11% lower than rail transport.
- The differences between the countries are as well mainly depending on the vehicle park (age and environmental performance of the park, share of diesel) and the national electricity mix (for the rail sector).

Climate Change Total Cost 1995		**Road**							**Rail**		**Aviation**		**Water-borne**
[million Euro / year]		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Austria	**2'930**	1'380	11.2	61	*1'450*	76	901	*977*	29.8	43.7	391	25	9
Belgium	**3'750**	1'767	12.6	52	*1'830*	280	907	*1'190*	38.6	34.6	538	100	23
Denmark	**2'260**	759	5.0	100	*864*	115	565	*681*	67.5	9.7	578	64	-
Finland	**1'460**	543	13.6	94	*650*	114	310	*424*	20.4	53.0	276	21	14
France	**16'900**	7'180	95.7	463	*7'740*	2'990	3'020	*6'000*	66.8	72.7	2'680	299	25
Germany	**27'300**	14'766	194	663	*15'600*	1'020	5'050	*6'070*	481.1	541.2	3'900	452	268
Greece	**2'580**	966	13.1	32	*1'010*	463	683	*1'150*	11.7	2.1	386	21	-
Ireland	**1'230**	456	3.9	33	*493*	49	224	*272*	9.3	4.6	425	22	-
Italy	**16'300**	8'479	89.3	495	*9'060*	1'350	3'780	*5'130*	257.6	159.6	1'540	122	0
Luxemb'g	**222**	81	0.5	6	*87*	6	61	*67*	1.6	2.8	27	34	1
Netherl.	**5'010**	1'850	18.1	66	*1'930*	7	1'550	*1'560*	101.2	9.1	1'040	225	144
Norway	**1'500**	633	9.7	48	*690*	92	221	*313*	9.1	9.8	456	17	-
Portugal	**2'320**	902	17.7	52	*972*	199	524	*723*	25.3	17.7	552	29	-
Spain	**12'700**	4'151	22.0	165	*4'340*	2'760	2'330	*5'090*	81.0	80.0	3'070	83	-
Sweden	**3'130**	1'436	7.7	122	*1'570*	374	530	*904*	9.9	20.7	594	32	-
Switzerl.	**2'640**	1'135	26.1	51	*1'210*	119	290	*409*	6.8	4.3	912	96	-
UK	**19'600**	8'724	60.5	703	*9'490*	1'450	3'020	*4'460*	331.0	36.8	4'850	407	1
EUR 17	**122'000**	**55'200**	**600**	**3'210**	***59'000***	**11'500**	**24'000**	***35'400***	**1'550**	**1'100**	**22'200**	**2'050**	**485**

Table 37: Total climate change costs by country 1995 (EUR 17)

Climate Change: Average Cost 1995	**Average Cost Passenger**						**Average Cost Freight**					
	Road				**Rail**	**Avia-tion**	**Road**			**Rail**	**Avia-tion**	**Water-borne**
	Car	**MC**	**Bus**	**Pass. total**			**LDV**	**HDV**	**Freight total**			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	18.0	13.4	4.9	*16.1*	3.1	34.5	131	11.0	*8.8*	3.1	179	4.2
Belgium	17.3	13.7	12.7	*17.1*	5.7	30.7	126	16.1	*15.0*	4.7	162	4.2
Denmark	13.1	12.1	7.4	*12.0*	14.1	33.9	132	11.8	*12.0*	5.1	152	-
Finland	18.4	15.1	11.4	*16.8*	6.4	35.7	124	14.5	*13.4*	5.5	169	4.2
France	13.2	13.9	8.0	*12.7*	1.1	35.9	129	16.4	*23.3*	1.5	147	4.2
Germany	20.1	15.1	7.9	*18.8*	7.0	34.7	132	16.6	*16.0*	7.8	148	4.2
Greece	14.6	14.4	11.7	*14.4*	7.5	36.9	134	13.0	*16.4*	6.8	146	-
Ireland	14.4	13.7	17.4	*14.6*	7.2	35.0	130	11.7	*9.7*	7.6	172	-
Italy	14.1	11.7	8.6	*13.6*	5.2	36.8	134	15.4	*14.8*	7.2	159	4.2
Luxemb'g	15.0	13.7	8.3	*14.2*	5.5	16.2	113	12.8	*13.2*	5.6	85	4.2
Netherlands	16.5	15.1	6.6	*15.7*	7.2	30.0	133	13.3	*9.6*	2.9	158	4.2
Norway	14.6	13.4	12.1	*14.3*	3.8	41.6	144	23.7	*24.1*	3.6	135	-
Portugal	9.7	11.2	4.5	*9.2*	5.3	35.7	133	16.7	*13.8*	8.8	160	-
Spain	13.5	11.2	5.0	*12.6*	5.3	38.3	141	15.0	*20.0*	8.0	137	-
Sweden	17.8	15.1	11.1	*17.0*	1.6	38.0	131	17.0	*19.1*	1.1	158	-
Switzerland	15.5	13.6	7.3	*14.8*	0.5	33.4	142	23.6	*23.9*	0.5	163	-
UK	17.3	15.1	16.6	*17.2*	11.2	34.5	139	14.1	*16.4*	2.9	171	4.2
EUR 17	**15.9**	**13.8**	**8.9**	***15.3***	**5.3**	**35.2**	**134**	**15.1**	***16.2***	**4.7**	**153**	**4.2**

Table 38: Average climate change costs by country 1995 (EUR 17)

Compared to 2010, total costs are rising by 73%. Average costs of road passenger cars are increasing by 12%. HDV costs are increasing by a bigger amount (32%). Rail transport – as well due to the uniformed electricity mix, increase by 24% (passenger) and 46% (freight).

3.2.5. Nature and landscape

Main assumptions:

- A repair cost approach is used: Costs of desealing are considered for all transport modes. There is no distinction between electric and diesel tracks for the railways since both cause damages, although the detailed effects are different.
- State of 1950 is used as a reference case, especially for road transport. Additional sealings are regarded as external costs.
- Costs are estimated separately for each mode and allocated according PCU to transport means.
- Relevant infrastructure is based on national mileage.
- Forecast 2010: Desealing costs are adjusted by GDP growth rate per capita.

The following tables show total and average costs for nature and landscape by country. Comparing the average costs, the following comments can be made:

- Within passenger transport, cars amount to 2.47 Euro/1'000 pkm, which is 3.6 times higher than rail. One main reason is that road infrastructure has increased significantly between 1950 and today, whereas rail infrastructure remained rather stable.
- Within freight transport, the relation is even more in favour of rail. Rail costs are even lower than waterborne transport, since – as with road transport - the infrastructure for waterborne transport has increased within the last decades.
- The differences between the countries are mainly based on the increase of infrastructure between 1950 and today on the one hand and the loading factors of infrastructure on the other hand. That explains the rather high values for countries like Finland or Norway.

Nature & Landscape		Road							Rail		Aviation		Water-borne
Total Cost 1995 [million Euro / year]		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Austria	**500**	300	2.2	7.2	*310*	17	145	*162*	3	5	18	1	-
Belgium	**490**	279	1.7	4.2	*285*	44	135	*179*	3	3	17	3	-
Denmark	**320**	163	0.9	10.7	*175*	23	85	*108*	4	1	29	4	-
Finland	**347**	159	3.4	14.5	*177*	35	78	*113*	2	6	45	4	-
France	**4'080**	2'080	22.5	67.0	*2'170*	820	847	*1'670*	25	27	167	24	-
Germany	**3'340**	2'040	25.7	54.2	*2'120*	155	801	*956*	34	38	156	22	17
Greece	**306**	117	1.5	2.7	*121*	61	75	*135*	1	0.2	45	3	-
Ireland	**239**	135	1.0	4.8	*141*	14	57	*71*	1	0.7	23	1	-
Italy	**1'390**	797	7.4	25.3	*830*	126	333	*459*	11	7	70	7	5.2
Luxemb'g	**29**	13	0.1	0.4	*13*	1	8	*9*	0	0.3	3	4	-
Netherl.	**514**	253	2.2	5.0	*260*	1	173	*174*	3	0	34	7	35
Norway	**437**	244	3.3	10.7	*258*	32	51	*83*	3	3	85	5	-
Portugal	**187**	86	1.3	2.9	*90*	17	54	*71*	1	0.9	22	1	-
Spain	**1'390**	594	2.8	15.3	*612*	381	322	*703*	6	6	59	2	-
Sweden	**640**	305	1.6	15.3	*322*	88	123	*211*	5	10	82	6	-
Switzerl.	**440**	301	5.9	7.7	*315*	29	45	*74*	6	4	36	4	-
UK	**1'270**	706	4.6	33.1	*744*	121	216	*337*	21	2	152	14	2.6
EUR 17	**16'000**	**8'570**	**87.9**	**281**	***8'940***	**1'960**	**3'550**	***5'510***	**129**	**115**	**1'044**	**113**	**60**

Table 39: Total costs for nature and landscape by country 1995 (EUR 17)

Nature & Landsc. Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	3.9	2.6	0.6	*3.4*	0.4	1.6	29.0	1.8	*2.0*	0.4	8.5	-
Belgium	2.7	1.8	1.0	*2.7*	0.5	0.9	19.9	2.4	*3.1*	0.4	5.0	-
Denmark	2.8	2.1	0.8	*2.4*	0.8	1.7	26.2	1.8	*2.2*	0.3	9.0	-
Finland	5.4	3.8	1.8	*4.6*	0.7	5.8	37.8	3.7	*5.1*	0.6	30.5	-
France	3.8	3.3	1.2	*3.6*	0.4	2.2	35.5	4.6	*8.1*	0.6	11.8	-
Germany	2.8	2.0	0.6	*2.6*	0.5	1.4	20.0	2.6	*3.1*	0.6	7.3	0.3
Greece	1.8	1.7	1.0	*1.7*	0.8	4.3	17.5	1.4	*2.4*	0.8	22.5	-
Ireland	4.3	3.3	2.6	*4.2*	1.1	1.9	36.5	3.0	*3.6*	1.2	10.2	-
Italy	1.3	1.0	0.4	*1.2*	0.2	1.7	12.5	1.4	*1.8*	0.3	8.9	51.8
Luxemb'g	2.3	1.7	0.6	*2.1*	0.6	1.7	18.7	1.6	*1.8*	0.6	9.1	-
Netherlands	2.3	1.8	0.5	*2.1*	0.2	1.0	18.5	1.5	*1.5*	0.1	5.2	1.0
Norway	5.6	4.5	2.7	*5.4*	1.1	7.7	51.0	5.4	*8.4*	1.1	40.6	-
Portugal	0.9	0.8	0.2	*0.9*	0.3	1.4	11.4	1.7	*2.2*	0.5	7.4	-
Spain	1.9	1.4	0.5	*1.8*	0.4	0.7	19.4	2.1	*4.0*	0.6	3.9	-
Sweden	3.8	3.1	1.4	*3.5*	0.8	5.3	30.9	3.9	*6.2*	0.5	27.7	-
Switzerland	4.1	3.1	1.1	*3.8*	0.4	1.3	34.4	3.7	*5.6*	0.4	6.9	-
UK	1.4	1.2	0.8	*1.4*	0.7	1.1	11.6	1.0	*1.5*	0.2	5.7	13.2
EUR 17	**2.5**	**2.0**	**0.8**	**2.3**	**0.4**	**1.7**	**23.0**	**2.2**	**3.3**	**0.5**	**8.5**	**0.5**

Table 40: Average costs for nature and landscape by country 1995 (EUR 17)

Compared to 1995, these costs will increase significantly until 2010, since infrastructure will increase. Total costs will increase by 56%. Nevertheless the situation is different in regard to transport modes. Average values increase for passenger cars by 23%, whereas rail transport faces (due to increased loading factors) a decrease of 16%. HDV average costs increase by 24%, whereas the costs for rail freight transport is decreasing by 15%. A decrease can be noted as well for air transport (around 25%), due to the high traffic increase and improved loading factors.

3.2.6. Additional costs in urban areas

Main assumptions:

- Separation of traffic for pedestrians and costs for bicycle lanes are considered as external costs.
- Separation effects are estimated by additional waiting time for pedestrians dependent on traffic level, based on the German methodology for infrastructure assessment. These costs occur mainly for road transport and on a very minor level for rail transport.
- Bicycle lanes are estimated based on a unit value for every additional kilometre. It is assumed that 50% of the road network has to be equipped with bicycle lanes.
- The estimation is based on specific results for specific cities.
- For the forecast 2010, the unit values are adjusted by GDP growth per capita.

The following tables show total and average costs for urban effects (separation, space availability) by country. Urban effects amount to 8.4 billion Euro. Separation effects are of major importance, with a share of nearly 80%. Looking at average costs, we can state the following aspects:

- Within passenger transport, separation effects have the same level for passenger cars and rail. This is due to the fact, that the detours due to railway lines are bigger, although the absolute amount is much lower. However the space availability for bicycle lanes is only relevant for road transport. They are only locally relevant. The national average values are rather low.
- Within freight transport, the average costs of HDVs are 55% times higher than the costs for freight rail. No costs are occurring for the other transport means.
- The differences between the countries are mainly based on the amount and the share of urban transport. Thus countries like the Netherlands have rather high average costs.

Separation Effects: Total Cost 1995 [million Euro / year]		Road: Car	Road: MC	Road: Bus	Road: Pass. total	Road: LDV	Road: HDV	Road: Freight total	Rail: Pass.	Rail: Freight	Aviation: Pass.	Aviation: Freight	Water-borne: Freight
Austria	**154**	84	0.6	2.0	*87*	5	41	*45*	9.0	13	-	-	-
Belgium	**198**	111	0.7	1.7	*113*	18	54	*71*	6.6	7	-	-	-
Denmark	**150**	83	0.4	5.4	*88*	12	43	*55*	4.8	2	-	-	-
Finland	**104**	52	1.1	4.7	*57*	11	25	*37*	2.6	8	-	-	-
France	**812**	386	4.2	12.5	*403*	152	157	*310*	55.0	45	-	-	-
Germany	**1'930**	1'190	15.0	31.7	*1'240*	91	469	*560*	65.3	65	-	-	-
Greece	**119**	54	0.7	1.2	*56*	28	34	*62*	0.9	0.2	-	-	-
Ireland	**63**	39	0.3	1.4	*41*	4	17	*21*	1.0	0.5	-	-	-
Italy	**1'120**	653	6.0	20.7	*679*	103	273	*376*	45.6	20	-	-	-
Luxemb'g	**8**	4	0.0	0.1	*4*	0	2	*3*	0.4	0.7	-	-	-
Netherl.	**384**	215	1.9	4.2	*221*	1	146	*147*	12.9	3	-	-	-
Norway	**89**	60	0.8	2.6	*63*	8	12	*20*	2.5	2.8	-	-	-
Portugal	**51**	25	0.4	0.8	*26*	5	16	*21*	2.8	1.1	-	-	-
Spain	**784**	346	1.6	8.9	*357*	222	188	*410*	10.2	6	-	-	-
Sweden	**179**	90	0.5	4.5	*95*	26	37	*63*	5.4	16	-	-	-
Switzerl.	**94**	58	1.1	1.5	*60*	6	9	*14*	11.8	7.4	-	-	-
UK	**1'010**	638	4.2	30.0	*672*	109	195	*304*	24.6	10	-	-	-
EUR 17	**7'250**	**4'060**	**40**	**133**	***4'240***	**853**	**1'700**	***2'550***	**261**	**206**	**-**	**-**	**-**

Table 41: Total costs for urban separation effects by country 1995 (EUR 17)

Separation Effects: Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Aviation	Road			Rail	Aviation	Waterborne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	1.1	0.7	0.2	1.0	0.9	-	8.1	0.5	0.5	0.9	-	-
Belgium	1.1	0.7	0.4	1.1	1.0	-	7.9	1.0	1.2	0.9	-	-
Denmark	1.4	1.1	0.4	1.2	1.0	-	13.3	0.9	1.1	1.0	-	-
Finland	1.7	1.2	0.6	1.5	0.8	-	12.2	1.2	1.6	0.8	-	-
France	0.7	0.6	0.2	0.7	0.9	-	6.6	0.9	1.5	0.9	-	-
Germany	1.6	1.2	0.4	1.5	1.0	-	11.7	1.5	1.8	0.9	-	-
Greece	0.8	0.8	0.5	0.8	0.6	-	8.1	0.7	1.1	0.6	-	-
Ireland	1.2	1.0	0.8	1.2	0.8	-	10.7	0.9	1.1	0.8	-	-
Italy	1.1	0.8	0.4	1.0	0.9	-	10.2	1.1	1.5	0.9	-	-
Luxemb'g	0.7	0.5	0.2	0.6	1.5	-	5.7	0.5	0.6	1.4	-	-
Netherlands	1.9	1.6	0.4	1.8	0.9	-	15.7	1.3	1.3	0.9	-	-
Norway	1.4	1.1	0.7	1.3	1.1	-	12.4	1.3	2.0	1.0	-	-
Portugal	0.3	0.2	0.1	0.2	0.6	-	3.3	0.5	0.6	0.6	-	-
Spain	1.1	0.8	0.3	1.0	0.7	-	11.3	1.2	2.3	0.6	-	-
Sweden	1.1	0.9	0.4	1.0	0.9	-	9.1	1.2	1.8	0.8	-	-
Switzerland	0.8	0.6	0.2	0.7	0.9	-	6.6	0.7	1.1	0.9	-	-
UK	1.3	1.0	0.7	1.2	0.8	-	10.5	0.9	1.4	0.8	-	-
EUR 17	**1.2**	**0.9**	**0.4**	**1.1**	**0.9**	**-**	**10.0**	**1.1**	**1.5**	**0.9**	**-**	**-**

Table 42: Average costs for urban separation effects by country 1995 (EUR 17)

Space Availability		Road							Rail		Aviation		Water-borne
Total Cost 1995 [million Euro / year]		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Austria	**32**	20	0.1	0.5	*21*	1	10	*11*	-	-	-	-	-
Belgium	**44**	27	0.2	0.4	*27*	4	13	*17*	-	-	-	-	-
Denmark	**34**	20	0.1	1.3	*21*	3	10	*13*	-	-	-	-	-
Finland	**23**	12	0.3	1.1	*14*	3	6	*9*	-	-	-	-	-
France	**171**	93	1.0	3.0	*97*	37	38	*74*	-	-	-	-	-
Germany	**432**	287	3.6	7.6	*298*	22	113	*134*	-	-	-	-	-
Greece	**28**	13	0.2	0.3	*13*	7	8	*15*	-	-	-	-	-
Ireland	**15**	9	0.1	0.3	*10*	1	4	*5*	-	-	-	-	-
Italy	**253**	157	1.4	5.0	*163*	25	65	*90*	-	-	-	-	-
Luxemb'g	**2**	1	0.0	0.0	*1*	0	1	*1*	-	-	-	-	-
Netherl.	**88**	52	0.5	1.0	*53*	0	35	*35*	-	-	-	-	-
Norway	**20**	14	0.2	0.6	*15*	2	3	*5*	-	-	-	-	-
Portugal	**11**	6	0.1	0.2	*6*	1	4	*5*	-	-	-	-	-
Spain	**184**	83	0.4	2.1	*86*	53	45	*98*	-	-	-	-	-
Sweden	**38**	22	0.1	1.1	*23*	6	9	*15*	-	-	-	-	-
Switzerl.	**18**	14	0.3	0.4	*14*	1	2	*3*	-	-	-	-	-
UK	**234**	153	1.0	7.2	*161*	26	47	*73*	-	-	-	-	-
EUR 17	**1'630**	**975**	**9.5**	**31.9**	***1'020***	**205**	**407**	***612***	**-**	**-**	**-**	**-**	**-**

Table 43: Total costs for urban space availability for bicycles by country 1995 (EUR 17)

Space Availability: Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Aviation	Road			Rail	Aviation	Waterborne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	0.3	0.2	0.0	*0.2*	-	-	1.9	0.1	*0.1*	-	-	-
Belgium	0.3	0.2	0.1	*0.3*	-	-	1.9	0.2	*0.3*	-	-	-
Denmark	0.3	0.3	0.1	*0.3*	-	-	3.2	0.2	*0.3*	-	-	-
Finland	0.4	0.3	0.1	*0.4*	-	-	2.9	0.3	*0.4*	-	-	-
France	0.2	0.1	0.1	*0.2*	-	-	1.6	0.2	*0.4*	-	-	-
Germany	0.4	0.3	0.1	*0.4*	-	-	2.8	0.4	*0.4*	-	-	-
Greece	0.2	0.2	0.1	*0.2*	-	-	1.9	0.2	*0.3*	-	-	-
Ireland	0.3	0.2	0.2	*0.3*	-	-	2.6	0.2	*0.3*	-	-	-
Italy	0.3	0.2	0.1	*0.2*	-	-	2.4	0.3	*0.4*	-	-	-
Luxemb'g	0.2	0.1	0.0	*0.2*	-	-	1.4	0.1	*0.1*	-	-	-
Netherlands	0.5	0.4	0.1	*0.4*	-	-	3.8	0.3	*0.3*	-	-	-
Norway	0.3	0.3	0.2	*0.3*	-	-	3.0	0.3	*0.5*	-	-	-
Portugal	0.1	0.1	0.0	*0.1*	-	-	0.8	0.1	*0.2*	-	-	-
Spain	0.3	0.2	0.1	*0.2*	-	-	2.7	0.3	*0.6*	-	-	-
Sweden	0.3	0.2	0.1	*0.2*	-	-	2.2	0.3	*0.4*	-	-	-
Switzerland	0.2	0.1	0.1	*0.2*	-	-	1.6	0.2	*0.3*	-	-	-
UK	0.3	0.3	0.2	*0.3*	-	-	2.5	0.2	*0.3*	-	-	-
EUR 17	**0.3**	**0.2**	**0.1**	***0.3***	**-**	**-**	**2.4**	**0.3**	***0.4***	**-**	**-**	**-**

Table 44: Average costs for urban space availability for bicycles by country 1995 (EUR 17)

Due to traffic increase, these costs will increase in future. For 2010 an increase of 39% is expected. A major reason is as well the higher valuation of time in future. The increase for both effects is similar. Looking at the different average costs of transport modes, rail separation effects are increasing slightly more than road, because the expected traffic increase is lower.

3.2.7. Up- and downstream processes

Main assumptions:

- For railway operation: Additional nuclear risks are considered. A shadow factor of 0.035 Euro per kWh is considered, based on specific estimations. This value is similar to the shadow value for climate change costs.
- For all transport means additional air pollution and climate change costs are considered based on detailed results of eco-inventories of transport.
- For these effects the same unit costs were used as in the main estimations for air pollution and climate change costs. This holds true for the forecast as well.

The following tables show total and average costs for upstream effects. The three cost elements are aggregated. Most important are upstream processes for climate change costs, mainly based on the use of fossil energy for the construction of vehicles and infrastructure. They amount to 59% of total costs, whereas the air pollution costs amount to 38%. Nuclear power risks have a minor share, but are of special interest for rail transport. They amount to 0.33 billion Euro. Comparing the average costs, we can state the following important results:

- Within passenger transport, upstream effects are higher for passenger cars than passenger rail, whereas the costs for air transport are significantly lower. Nuclear power risks are important for rail and amount to 15 – 20% of average costs, especially for countries like Sweden, Belgium, France and Switzerland.
- Within freight transport, rail has about 60% of the costs of HDV. The share of nuclear power risks is similar as in passenger transport. Whereas the costs for waterborne transport are very low, the high level for air freight transport occurs due to the low loading factors.
- The differences between the countries are mainly based on the amount of mileage and initial air pollution and climate costs. The nuclear power risks are directly based on the railways share of electricity production mix.

Up/Downstream Total Cost 1995		**Road**							**Rail**		**Aviation**		**Water-borne**
[million Euro / year]		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass.	Freight	Pass.	Freight	Freight
Austria	**1'300**	679	4.7	27	*711*	37	416	*454*	17	53	54	3	5.1
Belgium	**2'010**	1'050	5.8	29	*1'090*	167	543	*709*	50	52	76	14	18
Denmark	**1'040**	475	2.2	49	*527*	63	307	*370*	44	7	81	9	-
Finland	**634**	292	5.6	39	*337*	58	145	*203*	8	33	38	3	8
France	**8'140**	3'890	41.1	217	*4'150*	1'600	1'610	*3'203*	134	185	369	41	15
Germany	**13'400**	7'880	86.9	341	*8'310*	583	2'860	*3'440*	302	553	543	63	189
Greece	**1'000**	428	5.1	12	*446*	203	282	*484*	5	0.5	52	3	-
Ireland	**454**	238	1.6	14	*254*	25	107	*132*	4	0.5	58	3	-
Italy	**8'420**	4'790	39.2	247	*5'070*	742	2'010	*2'754*	210	120	212	17	0.3
Luxemb'g	**115**	50	0.3	4	*54*	4	42	*47*	1	2.7	4	5	1.1
Netherl.	**2'500**	1'100	8.5	38	*1'140*	4	934	*939*	123	6	144	31	116
Norway	**646**	357	4.3	24	*385*	52	128	*180*	3	7.6	64	2	-
Portugal	**890**	436	7.0	21	*463*	90	233	*323*	14	8.0	75	4	-
Spain	**4'930**	1'980	8.8	68	*2'050*	1'280	1'050	*2'324*	39	47	416	11	-
Sweden	**1'390**	755	3.2	53	*811*	176	261	*437*	11	39	82	4	-
Switzerl.	**1'170**	679	12.5	31	*722*	75	192	*266*	26	12.2	128	13	-
UK	**8'440**	4'720	26.4	337	*5'080*	749	1'600	*2'349*	223	29	661	55	0.6
EUR 17	**56'500**	**29'800**	**263**	**1'550**	***31'600***	**5'900**	**12'700**	***18'600***	**1'210**	**1'160**	**3'060**	**282**	**353**

Table 45: Total costs of upstream effects by country 1995 (EUR 17)

Up/Down stream: Average Cost 1995	Average Cost Passenger						Average Cost Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Pass. total			LDV	HDV	Freight total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Austria	8.8	5.6	2.2	*8.1*	1.7	4.7	64.6	5.5	*5.3*	3.8	24.6	2.4
Belgium	10.3	6.4	7.0	*10.3*	7.4	4.3	75.1	10.4	*12.3*	7.2	22.8	3.2
Denmark	8.2	5.4	3.6	*7.8*	9.1	4.7	72.1	7.0	*8.2*	3.4	21.2	-
Finland	9.9	6.2	4.8	*9.5*	2.5	4.9	63.4	7.4	*8.8*	3.5	22.9	2.3
France	7.1	6.0	3.7	*7.1*	2.3	4.9	69.2	9.5	*15.8*	3.8	20.1	2.6
Germany	10.7	6.8	4.1	*10.3*	4.4	4.8	75.1	10.1	*11.4*	8.0	20.6	3.0
Greece	6.5	5.6	4.5	*6.5*	3.1	5.0	58.5	5.9	*8.6*	1.7	19.7	-
Ireland	7.6	5.8	7.7	*7.9*	3.2	4.8	66.6	6.1	*6.4*	0.8	23.4	-
Italy	7.9	5.1	4.3	*7.8*	4.2	5.1	73.3	8.9	*10.8*	5.4	21.8	2.8
Luxemb'g	9.4	7.0	5.1	*9.3*	3.6	2.4	79.9	9.4	*10.6*	5.3	12.7	3.6
Netherlands	9.8	7.1	3.8	*9.5*	8.8	4.2	76.4	8.6	*7.5*	1.9	21.8	3.4
Norway	8.2	5.9	6.1	*8.4*	1.5	5.9	81.3	14.7	*19.2*	2.8	18.8	-
Portugal	4.7	4.4	1.8	*4.5*	2.9	4.8	60.2	8.2	*8.6*	4.0	21.5	-
Spain	6.4	4.5	2.0	*6.1*	2.6	5.2	65.0	7.4	*12.1*	4.7	18.5	-
Sweden	9.3	6.3	4.9	*9.3*	1.7	5.3	61.8	9.1	*12.5*	2.1	21.6	-
Switzerland	9.3	6.5	4.3	*9.0*	1.9	4.7	89.1	16.6	*22.1*	1.4	22.8	-
UK	9.3	6.6	8.0	*9.7*	7.5	4.7	71.9	8.1	*11.1*	2.3	23.2	2.8
EUR 17	**8.6**	**6.0**	**4.3**	***8.5***	**3.8**	**5.0**	**69.1**	**8.7**	***11.4***	**5.0**	**20.9**	**2.6**

Table 46: Average costs upstream effects by country 1995 (EUR 17)

Based on the growth of traffic and infrastructure, the costs of upstream effects will grow accordingly. In total, upstream processes will grow by 40% between 1995 and 2010. Most significant is the growth for air pollution and climate change related costs, since the traffic growth will exceed technical improvement and a change in the electricity mix considerably. Average costs will increase significantly less. For passenger transport the increase is below 5%. For freight transport, the increase is around 10%, whereas the growth rate for road exceeds the rate for rail.

4. Marginal costs in different traffic situations

4.1. Overview

4.1.1. General clustering

Marginal costs are presented for different traffic situations.[42] We distinguish different vehicle categories, different traffic situations and transport purposes. The results are expressed in costs per vehicle kilometres (vkm), per passenger kilometres (pkm) and tonne kilometres (tkm) respectively. Within a general clustering average and marginal costs can be compared:

- Distinction between urban and interurban traffic. For aeroplanes we distinguish between short and long distance passenger flights.
- Distinction between different types of vehicles:
  Road: Gasoline and diesel
  Rail: Electricity and diesel traction

This basic clustering is used for all cost components. In order to be more concise, we consider further differentiation which however differs for each cost component, since the influence factors are not always the same. The following table gives an overview.

Transport mean	Vehicle characteristics	Spatial differentiation	Further differentiation
Passenger car	Petrol, diesel	Urban Interurban in densely populated areas Interurban in low densely populated areas	Traffic volume (noise) Different EURO-norms (for air pollution only) Different daytimes (noise)
Motorcycle	Average		-
Bus	Urban bus Interurban bus		-
LDV	Petrol, diesel		-
HDV	3.5 - 7.5 tonnes 32 - 40 tonnes		Traffic volume (noise)
Passenger train	Inter-city diesel Inter-city electric High speed	Urban Interurban in densely populated areas Interurban in low densely populated areas	Different daytimes (noise)
Freight train	Diesel/electric traction	Interurban in densely populated areas Interurban in low densely populated areas	Short and long range
Air transport	Pass. short distance Pass. long distance Freight	-	-
Freight waterborne	-	-	-

Table 47: Clustering for the presentation of marginal costs per means of transport

42 Marginal congestion costs are presented in chapter 5.

The results are presented in costs per additional vkm or per additional transport unit like pkm and tkm. The loading factors used are shown in the following table. They are derived from the estimations of total and average costs.

Transport mean	Passengers per vehicle	Tonnes per vehicle
Passenger car	1.7	-
Urban	1.4	-
Interurban	1.9	-
Motorcycle	1.1	-
Bus	17	-
Urban bus	15	-
Interurban Bus	20	-
LDV	-	0.3
HDV	-	5.6
HDV 3.5 – 7.5 tonnes	-	1.9
HDV 32 – 40 tonnes	-	15
Inter-city train diesel	150	-
Inter-city train electric	248	-
High speed rail	313	-
Freight train short range	-	250
Freight train long range	-	529
Air passenger transport short range	65	-
Air passenger transport long range	90	-
Air freight transport	-	12.7
Freight waterborne	-	1’140

Table 48: Loading factors used for the presentation of costs per transport units for different types of transport. The values are based on total cost estimations (see assumptions in annex 1) and additional sources (ExternE and INFRAS (1997))

The presentation is not differentiated per country, since not the country characteristics, but the traffic situation is most important. They represent an European average. In order to adjust the values to specific countries, we recommend the use of GDP per capita (see table in annex 1).

As mentioned in the methodology chapter, we consider mainly short term marginal cost, representing the additional costs of one additional transport unit entering the system. Costs to build up the system will thus not be considered. Since some cost elements are only relevant in the long run (especially nature and landscape, additional urban effects and up- and downstream effects), we discuss these elements mainly in a qualitative manner, adding figures for long run marginal costs.

4.1.2. Aggregated results

The following table shows the values (the ranges respectively) for all cost categories. The ranges are quite significant, since different vehicle categories and traffic situations are considered.

Marginal Cost	Road					Rail		Aviation		Water-borne
[Euro / 1000 pkm, tkm]	Car	MC	Bus	LDV	HDV	Pass	Freight	Pass	Freight	Freight
Accidents 1)	11-54 (36)	79-360 (250)	1-5 (3.1)	44-163 (100)	2.3-11 (6.8)	0-1 (0.9)	0 (0)	0-1 (0.6)	0 (0)	0 (0)
Noise	0.2-21 (5.7)	0.6-53 (17)	0.1-7.5 (1.3)	5.3-496 (36)	0.6-52 (5.1)	0.2-2.3 (3.9)	0.1-6.3 (3.5)	2.3-17 (3.6)	17-87 (19)	0 (0)
Air Pollution 2)	5-17 (17)	14 (7.9)	4-25 (20)	28-118 (131)	14-50 (32)	2-24 (4.9)	1-6.8 (4)	0.8-2 (1.6)	0.8 (2.6)	4.5 (9.7)
Climate Change	12-25 (16)	9.6 (14)	5.5-11 (8.9)	125-134 (134)	15-18 (15)	4.2-8.9 (5.3)	4.2-5.3 (4.7)	36-42 (35)	117 (154)	4.7 (4.2)
Nature & Landscape	0-1.8 (2.5)	0-1.8 (2)	0-1.3 (0.8)	0-23 (23)	0-8.9 (2.2)	0-0.8 (0.7)	0-0.3 (0.5)	0-2.9 (1.7)	0-8.5 (8.5)	0-0.5 (0.5)
Urban Effects	10.7-11.7 (1.5)	6.7-7.4 (1.1)	3-3.2 (0.5)	75-83 (12)	8-9 (1.3)	0 (0.9)	0 (0.9)	0	0	0
Upstream Process	3.3-6.7 (8.6)	2.7-5.4 (6.0)	2.8-6.5 (4.3)	40-72 (69)	4.2-8.8 (8.7)	1.1-9.8 (3.8)	0.4-3.4 (5)	4.1-4.6 (5)	18-23 (21)	0.6-1.4 (2.6)

1) Average of countries considered

2) Values for specific traffic situations in Germany, adjusted to European average

Table 49: Marginal costs by cost category and transport mean (the ranges reflect different vehicle categories (petrol, diesel, electricity) and traffic situations (urban, interurban).
The values in brackets denote average values as shown in chapter 3.

If we compare average and marginal costs, the following general conclusions can be made:

- For accidents, average costs are in the range of marginal costs. This is plausible since it is assumed that the average of marginal costs are equal to average costs. The range of results stems from differences between countries.
- For noise, average costs are sometimes above marginal costs. This is plausible since costs decline with increased traffic demand. However the important night times are not considered within the range of marginal costs (see detailed tables in the following chapters).
- For air pollution, average values are in principle similar to marginal values. However different cost estimation approaches were used. Thus a comparison is not fully possible (see comment in annex 2.3). There are also huge differences between different vehicle categories.

- For climate change, average costs are equal to marginal costs. The ranges stem from different vehicle categories.
- For nature and landscape and upstream effects, average costs are close to maximum marginal costs. This is plausible since marginal costs are mostly only in the long run relevant.
- For urban effects, marginal costs are higher than average costs. The two values cannot be compared, since average costs refer to national mileage, while marginal costs are referring to specific urban mileage.
- For upstream effects, short run marginal costs are only related to precombustion processes. Therefore they are lower than average costs which include as well vehicle and infrastructure related processes. Thus average costs are close to long run marginal costs.

The following chapters present detailed results per cost category.

4.2. Accidents

Marginal external accident costs are the costs induced by an additional vehicle kilometre. This study distinguishes between accidents on motorways, on country roads and in urban conurbations. The IRTAD database on road accidents was explored to estimate average costs that are the basis for the estimation of marginal costs. Unfortunately the database is often incomplete and therefore a number of estimations had to be made. Table 50 lists the average costs for six selected countries in Europe, where data are (partly) available. Motorways, the safest roads, have far lower costs per vehicle kilometre than country roads, which are followed by roads in urban conurbations.

Euro / 1000 pkm, tkm	**Motorways**					**Country roads**					**Urban roads**				
	Cars	MC	Buses	LDV	HDV	Cars	MC	Buses	LDV	HDV	Cars	MC	Buses	LDV	HDV
Belgium	18	103	2	57	3	25	151	3	54	6	80	453	9	207	14
Denmark	9	63	1	38	1	36	237	3	112	5	29	203	2	92	4
Germany	14	91	1	43	3	56	357	4	138	11	69	429	5	179	12
Netherlands	7	49	0	24	1	38	279	2	106	5	42	302	3	122	6
Portugal	10	82	1	58	4	34	275	3	134	15	54	427	4	225	22
Switzerland	13	85	1	46	2	49	325	4	137	9	52	339	4	153	9

Table 50: Average external accident cost for different traffic situations

There are a number of methodological problems related to the estimation of marginal costs:

- The IRTAD database on road accidents is incomplete and many data have to be estimated.
- The state of the art only allows drawing conclusions about traffic situations with medium traffic flows.
- Marginal costs are split to the road modes by using the same distribution as average accident costs.

Table 51 reflects the uncertainty of the scientific state of the art and thus – as a first estimate - only shows the range of marginal accident costs for medium traffic flows in selected countries. The gap between motorways and country roads has narrowed, while the difference to urban roads has increased.

Euro / 1000 pkm, tkm	Motorways				Country roads				Urban Roads			
	Cars		HDV		Cars		HDV		Cars		HDV	
Estimation	low	high	low	high	low	high	low	high	low	high	low	high
Belgium	7.8	18.8	1.5	3.7	15.1	21.2	3.4	4.7	78.3	83.2	13.8	14.7
Denmark	4.2	10.1	0.6	1.4	21.8	30.6	3.0	4.2	28.3	30.1	3.8	4.0
Germany	6.4	15.3	1.3	3.0	34.0	47.8	6.8	9.6	66.8	71.0	12.1	12.9
Netherlands	3.0	7.3	0.4	1.0	23.4	33.0	3.3	4.7	41.2	43.8	5.4	5.8
Portugal	4.5	10.7	2.0	4.7	20.6	29.0	9.1	12.7	52.6	55.9	21.4	22.8
Switzerland	5.6	13.5	1.1	2.6	29.7	41.7	5.8	8.1	50.4	53.5	9.0	9.6

Table 51: Range of marginal accident costs for medium traffic flows

The methodological analysis shows that the state of the art has not yet found a consensus on the influence traffic flows have on accident rates. One of the major reasons might be that accidents are more influenced by drinking and driving behaviour than by traffic densities. Krebs and Klöckner (1977, p. 85) compare a number of factors influencing transport safety and conclude that traffic density only has minor impacts on safety. Additionally, during the last decades technical safety improvements had far bigger impacts on accident rates than the increasing transport volumes. The numerous studies indicating no nexus between transport flow and accident rates (marginal = average) is an indicator for this. The question raises, if deliberations about marginal cost pricing, stemming from economic theory can be sensibly applied for practical estimations of accident costs.

Therefore, it is recommended to use average costs for different traffic situations (Table 50) rather than marginal cost estimates, which are unreliable and not relevant for peak hour pricing.

4.3. Noise

4.3.1. General Characteristics

The phenomenon of noise is characterised by the logarithmic perception of sound by the human ear. This means, that a doubling of the sound energy only causes a constant increase of the perceived loudness by 3 dB(A). As a result of this characteristic the effect caused by an additional sound generator - and hence its marginal social costs - is the lower the higher the already existing noise level is. This means that the marginal costs of traffic noise are decreasing with increasing traffic load. The interdependency of total, average and marginal noise costs is displayed by the following figure:

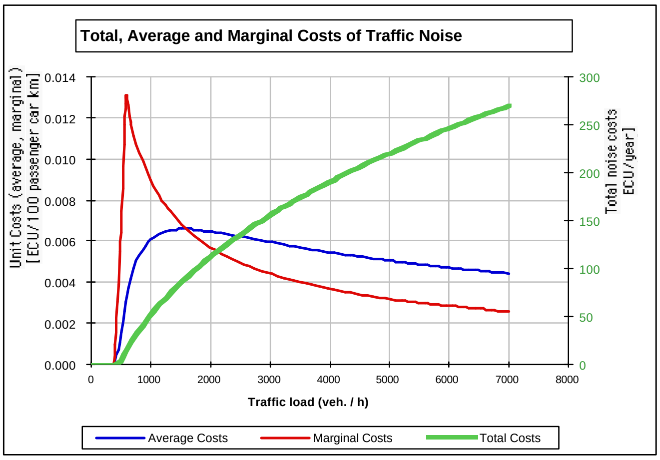

Figure 24: Total average and marginal costs of traffic noise

Following the methodology introduced in section 2.3.4. in the subsequent sections the results of estimating marginal noise costs for characteristic traffic situations are presented for road and rail traffic. For reasons of simplification the marginal cost estimates are averaged across time of day and traffic densities. The magnitude of these influencing variables can be estimated as follows:

- The differences in marginal costs between day and night time stem from different target levels. For a 10 dB(A) reduction in accepted noise emissions e.g. marginal noise costs might increase by a factor of 2.5.
- A doubling in vehicles per hour in road, rail or air transport lets marginal noise costs decrease by approximately 30%.

The average marginal cost values estimated for road, rail and air transport are presented by the following table.

Means of transport	Euro / 1000 vkm		Euro / 1000 pkm	
	Inter-urban	Urban	Inter-urban	Urban
Road				
Passenger car	0.32	29.79	0.17	21.28
Motorcycle	0.63	59.58	0.57	53.19
Bus / coach	1.58	148.94	0.11	7.45
LDV	1.58	148.94	5.28	496.47
HDV	2.92	274.05	0.55	51.71
Rail				
High speed rail	47.93	287.22	0.15	0.92
Traditional rail	58.02	566.33	0.23	2.28
Freight	62.51	837.63	0.12	1.58
Aviation *				
Passenger	207.43	1'084.51	2.30	16.68
Freight	207.43	1'084.51	16.59	86.76
Waterborne				
Freight	0.00	0.00	0.00	0.00

** The columns "inter-urban" and "urban" here denote short- and long distance flights*

Table 52: Marginal noise costs by mode and area 1995

The table allows the following conclusions:

- With the exception of high speed trains rail passenger and goods transport shows the lowest marginal cost values per passenger or tonne kilometre. However, this varies strongly with occupancy rates.
- On the contrary, the noise emissions per passenger or tonne kilometre estimated for air transport exceed the values calculated for the land-based transport modes. However, as the estimation of airport noise emissions is based on average costs the present results need to be regarded with care.
- Waterborne goods transport is assumed not to cause noise pollution.

As noise costs are extremely sensitive to the affected region an in-depth analyses of local conditions is strongly recommended in order to make cost values reliable. The results of the present study just indicate possible ratios between the different transport means.

4.3.2. Road traffic

The table below displays the social marginal noise costs caused by road transport vehicles. The values are presented as Euro per 1000 vehicle, passenger and tonne kilometres for cars, motorcycles, buses, LDVs and HDVs. The results can be interpreted as follows:

- The vehicle-dependent costs in passenger transport are the highest for buses, but regarding the vehicles' load rates motorcycles show by far the highest value being about 10 times above the relative noise emission of a bus passenger. A similar statement can be given for light and heavy duty vehicles.

- Marginal costs in night time are in average 2.2 times the costs during daytime.
- Comparing different traffic conditions to each other it is evident that the marginal costs of an additional sound source in dense traffic conditions is only about 50% of the marginal costs caused under in relaxed traffic conditions.

Scenario			Marginal costs per vehicle kilometre					Marginal costs per pass. / tonne kilometre				
			Euro / 1000 vkm					Euro / 1000 pkm			Euro / 1000 tkm	
Area	Time	Traffic	Car	MC	Bus	LDV	HDV	Car	MC	Bus	LDV	HDV
Rural	Day	Thin	0.25	0.50	1.25	1.25	2.29	0.18	0.45	0.08	4.15	0.43
		Dense	0.13	0.26	0.64	0.64	1.18	0.09	0.23	0.04	2.14	0.22
	Night	Thin	0.59	1.18	2.94	2.94	5.40	0.42	1.07	0.20	9.79	1.02
		Dense	0.30	0.61	1.51	1.51	2.79	0.22	0.55	0.10	5.05	0.53
Suburban	Day	Thin	1.86	3.71	9.28	9.28	17.1	1.33	3.37	0.62	30.9	3.22
		Dense	0.78	1.56	3.89	3.89	7.15	0.56	1.41	0.26	13.0	1.35
	Night	Thin	4.38	8.75	21.9	21.9	40.3	3.13	7.96	1.46	72.9	7.59
		Dense	1.83	3.67	9.17	9.17	16.9	1.31	3.33	0.61	30.6	3.18
Urban	Day	Thin	24.1	48.2	121	121	222	17.2	43.8	8.04	402	41.8
		Dense	11.4	22.7	56.9	56.9	105	8.12	20.7	3.79	190	19.7
	Night	Thin	56.9	114	284	284	523	40.6	103	19.0	948	98.7
		Dense	26.8	53.6	134	134	247	19.2	48.8	8.94	447	46.6

Table 53: Marginal noise costs for road traffic in different traffic situations

4.3.3. Rail traffic

The marginal costs of rail passenger and goods transport in general show a similar picture to the systematic found in road traffic noise. The detailed results are:

- The improved on-board noise reduction measures of modern high speed trains manage to over-compensate the higher noise emissions from air resistance and wheel-rail contact noise due to higher travel speeds. Consequently, the marginal noise costs per train kilometre are estimated by roughly 20% beneath the cost figures calculated for a traditional inter-regional train.
- The 25% higher occupancy rates of high speed trains compared to traditional rail services further underline the above calculation such that the marginal noise costs diverge by 40%.
- In urban areas the noise target level is usually higher than in rural areas and the speeds of trains are lower. Consequently the noise emissions during daytime are likely not to exceed the local target levels and hence the marginal noise costs (especially of the technically advanced high speed trains) are zero.

- Comparing the two rail technologies to individual road passenger transport it can be stated that high speed rail has consequently lower values than passenger cars, while the comparison of usual inter-regional trains and passenger cars does not lead to such a clear picture. Especially on motorways car show slightly lower marginal noise costs per passenger kilometre than the rail system.
- The marginal costs of rail freight transport per tonne kilometre are considerably lower than the marginal noise costs generated by road haulage. The ration between rail and road ranges between 10% and 20% and is at its lower bound within urban areas.

Scenario			Marginal costs per train kilometre Euro / 1000 vkm			Marginal costs per pass. / tonne kilometre Euro / 1000 pkm		Euro / 1000 tkm
Area	Time	Traffic	HST	IRT	FT	HST	IRT	FT
Rural	Day	Thin	34.5	41.8	45.0	0.11	0.17	0.08
		Dense	22.6	27.3	29.4	0.07	0.11	0.06
	Night	Thin	81.4	98.5	106.2	0.26	0.40	0.20
		Dense	53.2	64.4	69.4	0.17	0.26	0.13
Suburban	Day	Thin	231.7	280.4	302.1	0.74	1.13	0.57
		Dense	152.2	184.3	198.5	0.49	0.74	0.37
	Night	Thin	546.4	661.4	712.5	1.75	2.67	1.34
		Dense	359.0	434.5	468.2	1.15	1.75	0.88
Urban	Day	Thin	0.0	0.0	501.5	0.00	0.00	0.95
		Dense	0.0	326.0	410.0	0.00	1.31	0.77
	Night	Thin	693.3	1'170.3	1'471.9	2.22	4.72	2.78
		Dense	455.5	768.9	967.1	1.46	3.10	1.82

HST = High-speed train, IRT = Inter-regional passenger train; FT = Freight train

Table 54: Marginal noise costs for rail traffic in different traffic situations

The values are shown in table 54 are based on calculations for thin daytime traffic through rural and urban areas. The results for high speed rail in urban areas (marginal costs = 0) might seem surprising. The are explained by the new and technically improved vehicle stock and the fact, that in urban areas high speed trains are driving with the same speed than traditional passenger trains. As a consequence, noise targets are not exceeded in the model calculation.

4.3.4. Aviation

Referring to section 2.3.4 the evaluation of aviation noise emissions is based on a more pragmatic approach. While the rather dense networks of the land-based modes road and rail justify the presentation of characteristic example situations, which most likely can be identified all over Europe, the comparably limited number of airports (as the noise emitters of aviation) require a more country-based estimation of marginal noise costs.

Starting from the average costs per flight and taking into account the average distance for a national flight (300 km) and a international flight (1400 km) the average costs per plane-km are received. Assuming average load rates of 150 passengers for an international flight and 80 for a national one the respective average costs per passenger kilometre are calculated. According to the methodological assumptions made in section 2.3.4 a range of marginal costs between 30% and 60% of average costs is given.

The results for domestic and international transport per country are shown in the following table.

Country	Av. costs per movement	Marginal costs low estimate Euro / 1000 pkm		Marginal costs high estimate Euro / 1000 pkm	
	Euro	Domestic	International	Domestic	International
Austria	463	5.8	0.66	11.6	1.32
Belgium	368	4.6	0.53	9.2	1.05
Denmark	139	1.7	0.20	3.5	0.40
Finland	396	5.0	0.57	9.9	1.13
France	486	6.1	0.69	12.1	1.39
Germany	526	6.6	0.75	13.2	1.50
Greece	250	3.1	0.36	6.3	0.71
Ireland	211	2.6	0.30	5.3	0.60
Italy	977	12.2	1.40	24.4	2.79
Luxembourg	61	0.8	0.09	1.5	0.17
Netherlands	3’906	48.8	5.58	97.7	11.16
Norway	51	0.6	0.07	1.3	0.15
Portugal	354	4.4	0.51	8.8	1.01
Spain	303	3.8	0.43	7.6	0.86
Sweden	80	1.0	0.11	2.0	0.23
Switzerland	228	2.9	0.33	5.7	0.65
United Kingdom	654	8.2	0.93	16.3	1.87
Total EUR 17	599	7.5	0.86	15.0	1.71

Table 55: Marginal noise costs for air transport for different traffic situations

The results show extremely high costs in the Netherlands and in Italy. This might be a consequence of airports being located closely to urban areas.

4.4. Air pollution

Table 56 presents the results for the main clustering. The results for road and rail traffic are based on a special model output of ExternE for Germany.[43] In addition to the values presented in the cost categories above, a further differentiation according to vehicle performance is appropriate.

Marginal Air Poll. Cost	per 1000 vkm	per 1000 pkm/tkm
Car Urban	23.5	16.8
Car Interurban	9.7	5.1
Car Petrol	14.1	8.1
Car Diesel	18.5	10.7
MC	15.7	14.0
Bus Urban	379	25.3
Bus Interurban	87.6	4.4
LDV Petrol	8.5	28.4
LDV Diesel	35.6	118.5
HDV Urban	281	50.0
HDV Interurban	80.4	14.3
Pass. Train Urban	1'150	4.6
Pass. Train Interurban	707	2.3
Pass. Train Electric	535	2.2
Pass. Train Diesel	3'600	24.0
Freight Train Electric 1)	535	1.0
Freight Train Diesel 1)	3'600	6.8
Air Pass Short Distance	51.2	0.8
Air Pass Long Distance	91.5	1.0
Air Freight	9.5	0.8
Waterborne	5'080	4.5

1) Long distance

Table 56: Marginal air pollution costs for standard traffic situations

The following tables present a further differentiation for different traffic situations. The “min” values represent directly ExternE results (transformed from German to

43 The values are transformed to European average by using the country adjustment factors (see annex 1). The ExternE approach is shown in annex 2.3.

European values), whereas the "max" values add costs for building damages, based on the top down approach used for the estimation of total and average values.[44]

The values have a considerable spread, mainly based on the vehicle characteristics and the traffic situation. Thus a pre-EURO car in urban areas causes about 30 times more external air pollution costs as a EURO 3 car in rural areas.

The costs for crop losses and material damages (in the ExternE models) are of very minor importance.

Of interest is also the comparison between different transport means: Urban busses might cause higher costs per pkm than clean passenger cars. Electric rail transport is in any case better than the road sector, but railways with diesel traction might cause higher costs than clean road vehicles, especially in urban areas. In comparison, air transport leads – due to their rather low particle emissions – to very low air pollution costs.

Heavy vehicles in freight transport cause somewhat higher costs per vehicle kilometre than light ones. But compared with costs per tkm, a heavy truck causes much lower costs than a light truck or even light duty vehicles. Compared to that, electric freight trains still cause much lower costs.

44 It is assumed that the percentage of these costs is the same for marginal and average values. In Table 56, the max values are shown.

Cost in Euro per 1000 vkm	Marginal Air pollution cost per vkm				
Transport mean	Health	Crop losses	Material	Total min	Total max
Urban Passenger Car					
Petrol (before EURO)	35.3	0.41	0.23	36.0	45.5
Petrol EURO 1	9.6	-	-	9.58	12.1
Petrol EURO 3	8.3	-	-	8.29	10.5
Diesel EURO 1	24.8	-0.09	-	24.8	31.3
Interurban Passenger Car dense					
Petrol (before EURO)	31.6	-1.01	0.46	31.1	39.3
Petrol EURO 1	7.2	-0.18	0.09	7.15	9.04
Petrol EURO 3	4.2	-	-	4.22	5.33
Diesel EURO 1	18.1	-0.27	0.09	17.9	22.6
Interurban Passenger Car rural					
Petrol (before EURO)	8.6	-0.37	0.27	8.52	10.8
Petrol EURO 1	1.3	-0.09	-	1.19	1.51
Petrol EURO 3	1.1	-	-	1.10	1.39
Diesel EURO 1	3.0	-0.18	-	2.84	3.59
Urban Motorcycle	15.0	1.19	-	16.2	19.2
Interurban Motorcycle high	12.4	0.82	0.09	13.3	15.7
Interurban Motorcycle low	10.2	0.92	-	11.1	13.1
Urban Bus	277	-4.17	1.33	274	379
Interurban Bus high	102	-3.02	1.01	99.6	138
Interurban Bus low	28.7	-2.38	0.73	27.0	37.4
Urban Petrol LDV	10.1	-0.09	0.05	10.1	11.2
Interurban Petrol LDV high	12.5	-	0.09	12.6	14.0
Interurban Petrol LDV low	1.7	-	-	1.65	1.84
Urban Diesel LDV	64.6	-	0.09	64.7	72.1
Interurban Diesel LDV high	18.4	-0.09	0.09	18.4	20.5
Interurban Diesel LDV low	6.1	-0.09	-	5.96	6.64
HDV 3.5-7.5 tonnes					
Urban	204	0.41	0.32	205	246
Interurban high	65.7	-1.01	0.46	65.2	78.1
Interurban low	22.8	-0.37	0.27	22.7	27.3
HDV 32-40 tonnes					
Urban	410.4	-4.31	1.47	408	489
Interurban high	128	-3.12	1.10	126	151
Interurban low	33.0	-3.39	0.82	30.4	36.5
Intercity Train diesel					
Urban	4'670	-41.0	18.6	4'650	7'830
Interurban high	1'610	-41.3	20.1	1'590	2'670
Interurban low	382	-40.0	13.7	356	599
High Speed rail	421	-3.9	2.93	420	707
Short Distance Freight Train (diesel)	2'170	-55.6	27.0	2'140	3'600
Long Distance Freight Train (mix)	1'59	-15.1	11.0	1'590	1'830
Short Distance Air Passenger	4.5	0.74	-	5.27	51.2
Long Distance Air Passenger	8.1	1.37	-	9.42	91.5
Air Freight	3.4	2.57	-	5.94	9.50
Waterborne	3'730	230	-	3'960	5'080

Table 57: Marginal air pollution costs for further different traffic situations, expressed in costs per vehicle kilometre (Min: ExternE values)

Cost in Euro per 1000 pkm resp. tkm	Marginal Air pollution cost per transport unit				
Transport mean	Health	Crop losses	Material	Total min	Total max
Urban Passenger Car					
Petrol (before EURO)	25.2	0.3	0.2	25.7	32.5
Petrol EURO 1	6.8	0.0	0.0	6.8	8.6
Petrol EURO 3	5.9	0.0	0.0	5.9	7.5
Diesel EURO 1	17.7	-0.1	0.0	17.7	22.3
Interurban Passenger Car dense					
Petrol (before EURO)	16.6	-0.5	0.2	16.4	20.7
Petrol EURO 1	3.8	-0.1	0.0	3.8	4.8
Petrol EURO 3	2.2	0.0	0.0	2.2	2.8
Diesel EURO 1	9.5	-0.1	0.0	9.4	11.9
Interurban Passenger Car rural					
Petrol (before EURO)	4.5	-0.2	0.1	4.5	5.7
Petrol EURO 1	0.7	0.0	0.0	0.6	0.8
Petrol EURO 3	0.6	0.0	0.0	0.6	0.7
Diesel EURO 1	1.6	-0.1	0.0	1.5	1.9
Urban Motorcycle	15.0	1.2	0.0	16.2	17.1
Interurban Motorcycle high	12.4	0.8	0.1	13.3	14.0
Interurban Motorcycle low	10.2	0.9	0.0	11.1	11.7
Urban Bus	18.5	-0.3	0.1	18.3	25.3
Interurban Bus high	5.1	-0.2	0.1	5.0	6.9
Interurban Bus low	1.9	-0.2	0.0	1.8	1.9
Petrol LDV					
Urban Petrol LDV	33.8	-0.3	0.2	33.6	37.5
Interurban Petrol LDV high	41.6	0.0	0.3	41.9	46.7
Interurban Petrol LDV low	5.5	0.0	0.0	5.5	6.1
Urban Diesel LDV	215	0.0	0.3	216	241
Interurban Diesel LDV high	61.4	-0.3	0.3	61.4	68.5
Interurban Diesel LDV low	20.2	-0.3	0.0	19.9	22.1
HDV 3.5-7.5 tonnes					
Urban	146	0.3	0.2	147	176
Interurban high	46.9	-0.7	0.3	46.5	55.8
Interurban low	16.3	-0.3	0.2	16.2	19.5
HDV 32-40 tonnes					
Urban	27.4	-0.3	0.1	27.2	32.6
Interurban high	8.5	-0.2	0.1	8.4	10.1
Interurban low	2.2	-0.2	0.1	2.0	2.4
Urban Diesel train	31.1	-0.3	0.1	31.0	52.2
Interurban Diesel train high	10.7	-0.3	0.1	10.6	17.8
Interurban Diesel train low	2.5	-0.3	0.1	2.4	4.0
High Speed Rail	1.3	0.0	0.0	1.3	2.3
Short Distance Freight Train (diesel)	8.7	-0.2	0.1	8.6	14.4
Long Distance Freight Train (mix)	3.0	0.0	0.0	3.0	3.5
Short Distance Air Passenger	0.1	0.0	0.0	0.1	0.8
Long Distance Air Passenger	0.1	0.0	0.0	0.1	1.0
Air Freight	0.3	0.2	0.0	0.5	0.7
Waterborne	3.3	0.2	0.0	3.5	4.5

Table 58: Marginal air pollution costs for further different traffic situations, expressed in costs per transport unit (pkm, tkm) (Min: ExternE values)

4.5. Climate change

Table 59 presents the results for the main clustering. In addition to the values presented in the cost categories above, a further differentiation according to vehicle performance is necessary. The results are comparable with the average costs, but differ especially according to the differentiation used. Road transport causes higher marginal costs in urban areas and on highways.

Marginal Climate Cost	per 1000 vkm	per 1000 pkm/tkm
Car Urban	35	24.7
Car Interurban	26	13.6
Car Petrol	31	17.9
Car Diesel	20	11.5
Motorcycle	11	9.6
Bus Urban	162	10.8
Bus Interurban	109	5.5
LDV Petrol	37	125
LDV Diesel	40	134
HDV Urban	85	15.2
HDV Interurban	98	17.5
Pass. Train Urban	1'110	4.5
Pass. Train Interurban	1'510	4.8
Pass. Train Electric	1'050	4.3
Pass. Train Diesel	1'340	8.9
Freight Train Electric	2'200	4.2
Freight Train Diesel	2'790	5.3
Air Pass Short	2'714	41.8
Air Pass Long	3'200	35.6
Air Freight	1'490	117
Waterborne	5'400	4.7

1)long distance

Table 59: Marginal climate change costs for standard traffic situations

The following table presents more differentiated results.

Cost in Euro per 1000 vkm, pkm, tkm		Marginal Climate Change Cost	
Transport mean	**g CO_2 / vkm**	**Marginal Cost / vkm**	**Marginal Cost / pkm, tkm**
Petrol Passenger Car			
Urban	271	37	26.1
Rural	159	21	11.3
Highway	280	38	19.9
Diesel Passenger Car			
Urban	190	26	18.3
Rural	102	14	7.3
Highway	159	21	11.3
Motorcycle	80	11	9.6
Bus			
Urban	1'200	162	10.8
Interurban	811	109	5.5
Petrol LDV			
Urban	347	47	156
Rural	190	26	85.5
Highway	301	41	135
Diesel LDV			
Urban	288	39	130
Rural	239	32	108
Highway	466	63	210
HDV 3.5-7.5 tonnes			
Urban	467	63	45.0
Rural	277	37	26.7
Highway	391	53	37.7
HDV 32-40 tonnes			
Urban	1'600	216	14.4
Rural	991	134	8.9
Highway	997	135	9.0
Intercity train electric	7800	1'050	4.3
Intercity train diesel	9900	1'340	8.9
High Speed rail	11200	1'510	4.8
Short distance freight train (diesel	9'900	1'340	5.4
Long distance alpine Freight train (el.)	25300	3'420	6.5
Short distance Air passenger	20100	2'710	41.8
Long distance Air passenger	23700	3'200	35.6
Air freight	11000	1'490	117
Waterborne	40000	5'400	4.7

Table 60: Marginal climate change costs for further different traffic situations, expressed in costs per vehicle kilometres and costs per passenger resp. tonne kilometres.

4.6. Nature and landscape

Marginal costs for nature and landscape have to be distinguished between short and long run. In the short run, infrastructure is given and an additional vehicle does not cause additional effects. In the long run however, new infrastructure will be necessary leading to additional effects. As mentioned in chapter 2, theses costs might amount to the same level as the average costs. The spatial differentiation shows a zero value for urban transport, since additional infrastructure is causing mainly scarcity problems and does not harm nature. This effect is considered within the urban effect (see next section).

Transport mean	Short run marginal cost	Long run marginal cost	
		Euro per 1'000 vkm	Euro per 1'000 pkm/tkm
Urban Passenger Car	0	0	0
Interurban Passenger Car	0	3.5	1.84
Motorcycle	0	2.0	1.80
Urban Bus	0	0	0
Interurban Bus	0	25.0	1.25
LDV	0	76.7	23.02
HDV 3.5 – 7.5 tonnes	0	12.5	8.90
HDV 32-40 tonnes	0	12.5	0.83
Inter-city Train	0	161	0.81
High Speed Train		161	0.52
Freight Train Long Distance	0	143	0.27
Air Passenger Transport Short Range	0	190	2.92
Air Passenger Transport Long Range	0	190	2.11
Air Freight Transport	0	107	8.45
Freight Waterborne	0	592	0.52

Table 61: Marginal costs for nature and landscape for different traffic situations, expressed in costs per vehicle kilometres and per passenger resp. tonne kilometres

4.7. Additional cost in urban areas

The following tables present marginal costs for separation effects and space availability. Marginal separation costs are rather high, since they refer to a specific situation. It is important to note that these costs only occur for specific traffic situations. According to Figure 38 (see annex 2.6) marginal costs occur between an average vehicle frequency of 400 to 800 vehicles. Lower speed (due to congestion) will decrease marginal costs significantly. Although there are positive average costs for the railways in urban areas, marginal costs are zero, since separation is not dependent from the train frequency. This is true for highways as well.

Transport mean	Euro per 1000 vkm	Euro per 1000 pkm, tkm
Urban Passenger Car	15	10.7
Motorcycle	7.5	6.7
Urban Bus	45	3.0
LDV	22.5	75
HDV	45	8.0
Inter-city Train Passenger	0	0

Table 62: Marginal separation costs for urban transport means (urban main roads)

Marginal space availability costs are in the short run zero, since it is a fixed cost component. In the long run however, they are positive, since additional infrastructure seeks as well for increased space availability for bicycle lanes. They are similar to average costs. In comparison to average costs estimated in chapter 3 however, they are significantly higher, since they only refer to the mileage driven on urban main roads.

Transport mean	Short run marginal cost	Long run marginal cost	
		Euro per 1'000 vkm	Euro per 1'000 pkm resp. tkm
Urban Passenger Car	0	1.33	0.95
Motorcycle	0	0.74	0.66
Urban Bus	0	2.64	0.18
LDV	0	2.27	7.56
HDV	0	5.88	1.05
Inter-city Train	0	0	0

Table 63: Marginal space availability cost for urban transport mean

4.8. Up- and downstream processes

Up- and downstream processes are in general in line with the mileage driven, but with different time horizons. In the short run, only precombustion (production and transport of energy for transport purposes) is directly depending on vehicle kilometres. The following table presents these short run marginal costs, which are slightly below 50% of long run marginal (eq. average) costs. Within rail transport, they are lower for diesel than for electricity driven rolling stock, since the main components of diesel trains are already included in marginal air pollution and climate change costs. For electricity trains, the main short run marginal cost component is the nuclear power risk. Since it is a marginal cost component, the value is equal for different countries, since an additional train is consuming electricity based on an international marginal mix (based on the average UCPTE mix) within a liberalised energy market.

Euro per 1000 vkm, pkm, tkm	Short run marginal cost		Long run marginal cost	
Transport mean	per vkm	per pkm, tkm	per vkm	per pkm, tkm
Passenger Car	5.7	3.28	11.4	6.72
Motorcycle	3.0	2.68	6.1	5.42
Bus	47.3	2.78	111.2	6.54
LDV	12.1	40.25	21.7	72.33
HDV	23.7	4.23	49.5	8.84
Passenger Train Electric	248	1.24	1260	6.32
Passenger Train Diesel	158	1.05	1470	9.80
Freight Train Electric	327	0.62	347	0.66
Freight Train Diesel	106	0.40	888	3.35
Passenger Aeroplane	467	4.06	531	4.62
Freight Aeroplane	223	17.58	288	22.68
Waterborne Transport	638	0.56	1540	1.35

Table 64: Marginal costs for up- and downstream processes for different traffic situations, expressed in costs per vehicle kilometres

5. Congestion costs

5.1. Methodology

Total social congestion costs are an artificial measure of ineffective infrastructure use, which are based on theoretical reflections on marginal social cost functions rather than on the physical measurement of economic or social damages. There is a number of approaches existing. The first category are engineering-type calculations accounting the total user costs below a particular level of road quality. Sensitive figures supporting the interpretation of congestion costs are the revenues from an internalisation charge or the scarcity costs of infrastructure, which describe the production losses of economy due to delays of goods or business trips. As the assessment of secondary economic costs is rather difficult, in this study a carefully defined engineering approach is used to quantify scarcity costs.

Total congestion costs alone are not a very meaningful figure. They describe the benefit in social welfare which could be achieved when infrastructure would be used optimally, but it does not say which effort needs to be made to come to this optimum. An optimal infrastructure use is reached by internalising congestion costs via a Pigou-tax and the collection of this tax in real terms is not for free. Although the transaction costs and not the revenues from an internalisation system denote the costs for optimising traffic behaviour, the latter provides a good basis for estimating the magnitude of transaction costs.

5.1.1. Economic background and overview

In this study, external congestion costs are defined as the dead weight loss according to economic welfare theory. As this definition is non-trivial, a brief introduction to the assumptions and the wording used is given by the subsequent paragraphs.

When the density of traffic is growing, vehicles start to disturb each other, travel speeds are decreasing and consequently time and operating costs of all users within the system are increasing. Individuals only take into account their private cost function and do not consider the additional costs they impose on others in their travel decision. These unconsidered effects are called **marginal external congestion costs** and are determined by the users' private operating costs as a function of traffic density. The sum of (internal) private operating costs a user bears and the external costs he imposes on others is entitled as **marginal social costs** (upper curve in the graph below).

When the marginal external congestion costs are levied on the users, then traffic demand will react by shifts in travel time, routes, modes or by omitting less important trips. As traffic volumes decrease, also the marginal external costs and hence the internalisation charge are declining and respectively a part of the displaced traffic demand will return to its former behavioural pattern. The resulting equilibrium (Q^* in the figure below) is called the **optimal traffic demand** and the respective marginal external costs is the **optimal user charge**.

According to economic welfare theory, the total costs of traffic congestion are defined by the cumulated difference between the marginal social (private plus external) user costs and the willingness of users to pay for a particular level of infrastructure quality of that traffic demand, which is exceeding the optimal level Q^*. This measure (which is depicted by the grey area ABC in the figure below) is entitled as the **dead-weight loss** of infrastructure use, which is considered as the only correct economic definition of congestion. It can be interpreted as the loss in social efficiency because we are not using the existing infrastructure properly.

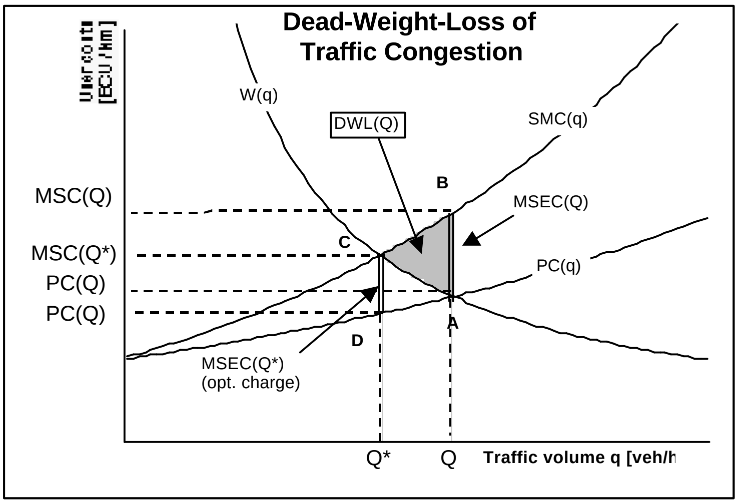

Figure 25: Economic definition of total congestion costs

This welfare-theoretical definition of external congestion costs implies, that those means of transport, where the allocation of infrastructure is planned centrally are free of congestion. This means that congestion costs are only computed for road transport.

As an economic measure of the external costs due to traffic delays embracing all modes, scarcity cost estimates are appropriate. Scarcity costs are the production losses of economy due to the increased binding of material and human resources in transport. To value these effects, detailed delay statistics for rail, air and waterborne passenger and freight traffic by country and travel purpose are required. This quantitative data set should not only contain the delays of single trains or flights, but also the cumulated delay of an average passenger or ton resulting from missed connections. The economic valuation would in particular consider freight and passenger business trips based on the unit values per hour used in the present calculations (see section 5.2).

The transformation of this theoretical approach into a concrete computation of European road congestion costs is briefly discussed below while a detailed elaboration is presented in annex 2.8 of this report.

5.1.2. Time and operating cost functions

a) Speed-flow relationships
The basis for estimating load-depending user cost functions are speed-flow relationships, which express the travel speed as a function of traffic volumes. Actual travel speeds are calculated per segment of the digitised European road network by the application of speed-flow relationships which are used in German investment planning (FGSV 1997). The shape of the speed-flow curves applied is strongly influencing marginal cost functions and consequently the resulting total congestion costs. Two problems are occurring with the speed-flow curves used:

- The transition from free flow to congested traffic is very sharp and lets the marginal social costs grow extremely high in a small range of highest traffic loads. This functional form does not seem unrealistic as it reflects typical contemporary driver's behaviour, but it makes the cost estimates react extremely sensitively.
- When traffic demand is exceeding the road's capacity limit flows remain constant at 20 kph (10 kph) for motorways (other roads). Accordingly, marginal costs become zero under congested road conditions and hence the application of the social welfare theory is no longer possible.

As the calculation of the dead-weight-loss requires monotonously growing user cost functions and secondly as a pricing regime where user charges vanish when the problems get at its worst is nonsense, it was decided to keep the external marginal costs constant when traffic flows exceed the maximum capacity.

b) The value of time
Private operating costs are the sum of the users' time costs and other vehicle operating costs which are depending on traffic conditions. The value of travel time as the most important component of traffic-flow dependent user cost functions is determined according to the following assumptions:

- Time preferences by travel purpose: In passenger transport it is assumed that business travellers have got a much higher valuation of their travel time than private travellers[45]. According to PETS (1998) a European time value of 21.44 Euro per passenger-hour is assumed for business travel, while for private trips according to FISCUS (1999) 25% of this value are considered. In freight transport a value of 37 Euro per shipment and hour for HDV and 20 Euro for LDV is assumed.

45 Private trips include subsume all journeys where the traveller needs to bear total operating costs by himself (commuting, shopping, leisure, etc.), while business trips commonly are financed by the traveller's employer.

- The share of travel purposes per vehicle: It is assumed that 20% of all passenger kilometres in private car travel are due to business purposes. This value results from traffic surveys of cross-channel trips and most probably denotes the upper limit in Europe. Motorcycle and bus mode are both assumed to comprise private trips only.
- Vehicle occupancy factors: the number of people per vehicle in passenger transport is set according to national loading factors. It is not distinguished between travel purposes.
- The modal share: The share of cars, motorcycles, buses, vans and HDV and the respective loading factors is set according to national data derived on the basis of TRENDS (1999) (annex 1).

Considering the specific contribution to road congestion of each type of vehicle as an European average a value of 14.83 Euro per PCU-km in passenger transport and 29.48 Euro per PCU-km in freight transport is estimated. For the total and average cost calculation national values per PCU-km in passenger and freight transport are used.

c) Other operating costs
According to FISCUS (1999) additional vehicle operating costs (fuel consumption, wear and tear, etc.) increase by a factor 2 under congested road conditions and hence are clearly dominated by time costs[46], which grow by a factor five to six. Considering this, operating costs other than time losses are considered only indirectly by keeping the marginal external user costs well above zero, even when traffic speeds have reached a minimum and from a mathematical point of view marginal external costs would vanish.

46 Due to the non-continuous shape of the EWS speed-flow relationships used, the marginal cost functions defined for congested situations are totally artificial. Hence, the rather moderate increase of vehicle operating costs other than time costs are not considered numerically, but are used as an argument to assume marginal external costs to be different from zero even under stop-and-go traffic.

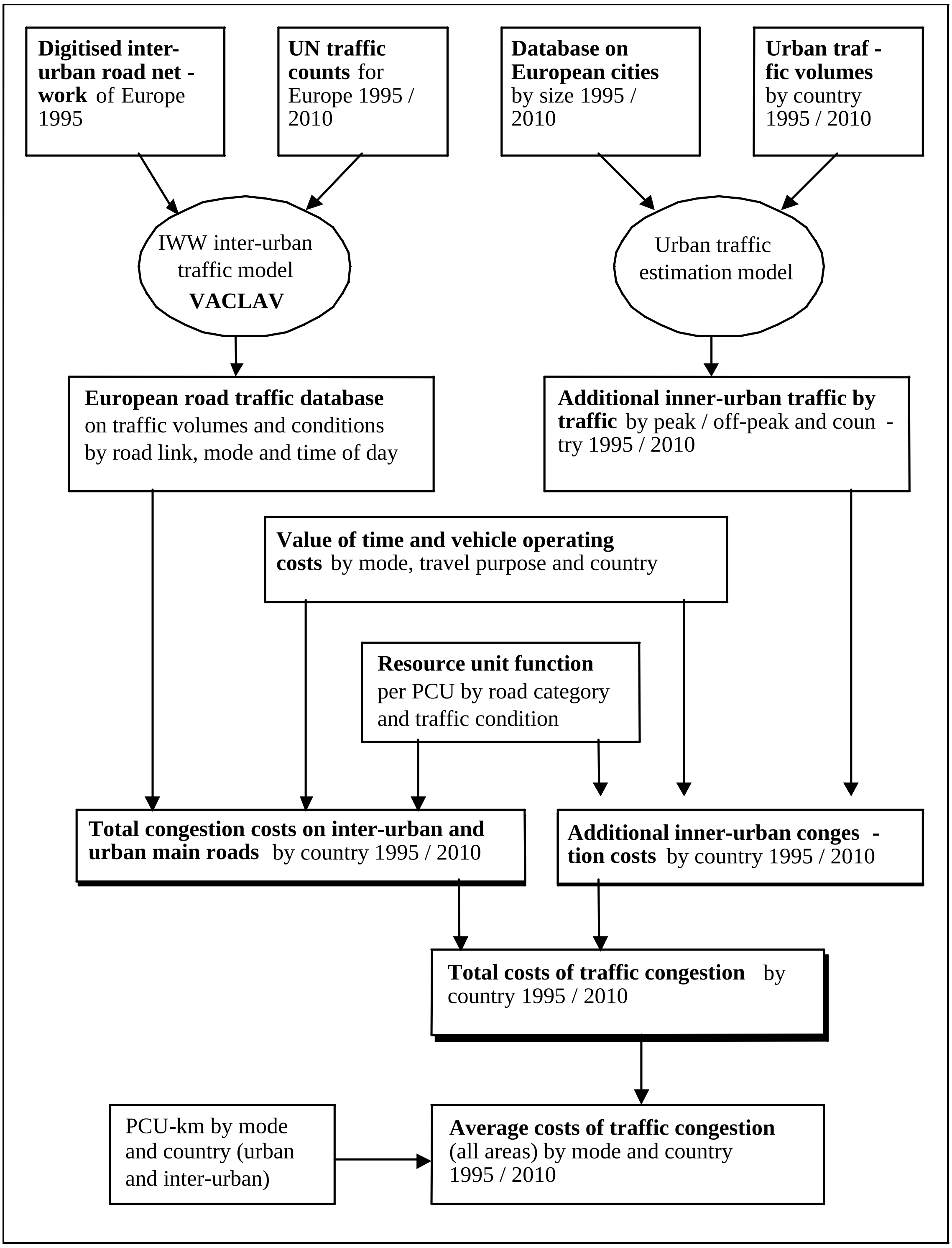

Figure 26: Approach towards total and average congestion costs

5.1.3. Procedure towards total and average costs

The computation of total and average costs of road congestion according to the dead-weight-loss approach is based on a link-wise assessment of the European road network. As only for the non-urban road transport sector detailed, disaggregated information on infrastructure and driving conditions was available, the approach towards total congestion costs needs to be carried out in two steps:

- Inter-urban and urban arterial congestion comprises traffic on motorways, secondary inter-urban roads and major urban access and transit roads. This is modelled by the European traffic model VACLAV developed by IWW.
- Inner-urban congestion refers to the remaining share of road traffic, which is not encoded in the IWW transport networks.

An overview of the computation model is presented by the flow diagram above.

a) Inter-urban and urban arterial congestion

Congestion costs in inter-urban road traffic and on major urban arterioles are computed on the basis of a digitised European road map comprising motorways, primaries and major urban access and transit roads for all western-European countries. The road links are attributed by

- Network information: Length, type of road, number of lanes, gradient and curvature) and
- Traffic data: Volumes of passenger cars and freight vehicles on an average working day.

The traffic data is generated by the IWW inter-urban transport model VACLAV on the basis of UN counting post data for the year 1995. Traffic characteristics (volume, mix) and road network parameters (type, length, curvature, gradient, etc.) provide the basis for calculating Level-of-Service and finally annual congestion costs for each road link. A detailed discussion of the methodology and the underlying database is given in annex 2.8.

Some adjustments are made for the UK and France because the inter-urban network representation of Great Britain in general is very thin compared to the rest of Europe and in France the representation of urban roads is much denser than for other countries.

b) Adjustment of inner-urban congestion

The estimation of traffic volumes and conditions on inner-urban roads which are missing in the IWW road network database are carried out much more roughly. Starting from a database of European cities (OECD 1995) the following assumptions are made:

- Though average travel speeds show a wide range among different cities, the difference of travel speeds between peak and off-peak is almost constant at 70%.

- According to Prud'Homme (1998) the demand elasticity of peak traffic is set to -0.8, while off-peak traffic is assumed to be inelastic (and consequently free of congestion).
- Assuming an average peak hour to include 10% of daily traffic and estimating the number of peak hours for each city by three, 30% of daily traffic is performed under peak conditions.
- It is roughly estimated that 1/3 of (peak) traffic is considered by the network approach and correspondingly 20% of total urban traffic is subject to an adjustment of the above network calculations.
- The total mileage of urban traffic is taken out of TRENDS (1999) for each country.
- The time values per vehicle are set in accordance with inter-urban traffic.

c) Forecast 2010

The forecast of total and average congestion costs until 2010 implies

- The prediction of cost values: According to the general methodology followed by this study the value of time and other operating costs is assumed to grow with the GDP per capita estimated by country (annex 1).
- The growth of traffic demand: The development of traffic demand is taken out of TRENDS (1999) separately for urban and inter-urban passenger and freight traffic. It is assumed that for each country the growth of inter-urban traffic is equally spread over the whole road network and over time segments.
- The development of network capacities: It is assumed that until 2010 no major enlargements of infrastructure capacity is installed.

For a comparison of traffic suffering from congestion 1995 and 2010 the reader is referred to annex 2.8.

5.1.4. Total revenues and additional time costs

An interesting counterpoint to the total congestion costs is the information on the revenues arising from the introduction of a sophisticated road pricing system in Europe. The collected Pigou-tax is estimated as follows:

- In rural traffic the determination of tax proceeds is easily possible by calculating the sum of the marginal social costs at the optimal traffic level Q^* for each road and time segment.
- In inner-urban traffic the estimation is more artificial as detailed speed-flow curves are not available. By the decrease in speed (70%) from peak to off-peak and the assumption that in off-peak traffic conditions are relaxed, Q* and the respective tax revenues are estimated using an urban standard speed-flow diagram.

The quantification of scarcity costs by the engineering-approach is simple, but rather arbitrary. Starting from a selected level of traffic quality the additional user costs are summed up for all road links, time segments and areas (inner-urban / rural). As the reference service level the transition from free flow to beginning disturbance of vehicles is chosen (LOS-C). Extra time costs for LOS D, E and F are calculated by using the cost functions and speed-flow relationships defined above.

5.1.5. Marginal congestion costs and user charges

The estimation of marginal social costs, optimal user charges and the average dead weight loss per traffic unit under different road conditions is the core part of the computation model used for the estimation of total and average congestion costs. The values are calculated using average European time values per type of vehicle. The traffic conditions distinguished are relaxed, dense and congested traffic on motorways, other rural roads and urban roads. For each vehicle category, the marginal social external costs, the optimal congestion charges and the average increase in social welfare resulting from the internalisation of the external congestion costs are presented. The loading rates for determining passenger- and tonne-kilometric figures are set according to the assumptions made in chapter 4.1.

5.2. Results

For the EUR-17 countries total and average road congestion costs of urban and inter-urban traffic, the revenues expected from their internalisation via road pricing systems and an engineering-type measure of scarcity costs have been estimated on the basis of an extended network analysis for the year 1995. Due to the welfare-economic approach chosen, congestion costs by definition only appear for such transport modes, where single users decide on the infrastructure use and consequently rail, air and waterborne traffic is not affected by congestion. A comparison of the three congestion-related measures is presented by the following figure, while the single results are discussed in turn throughout this section.

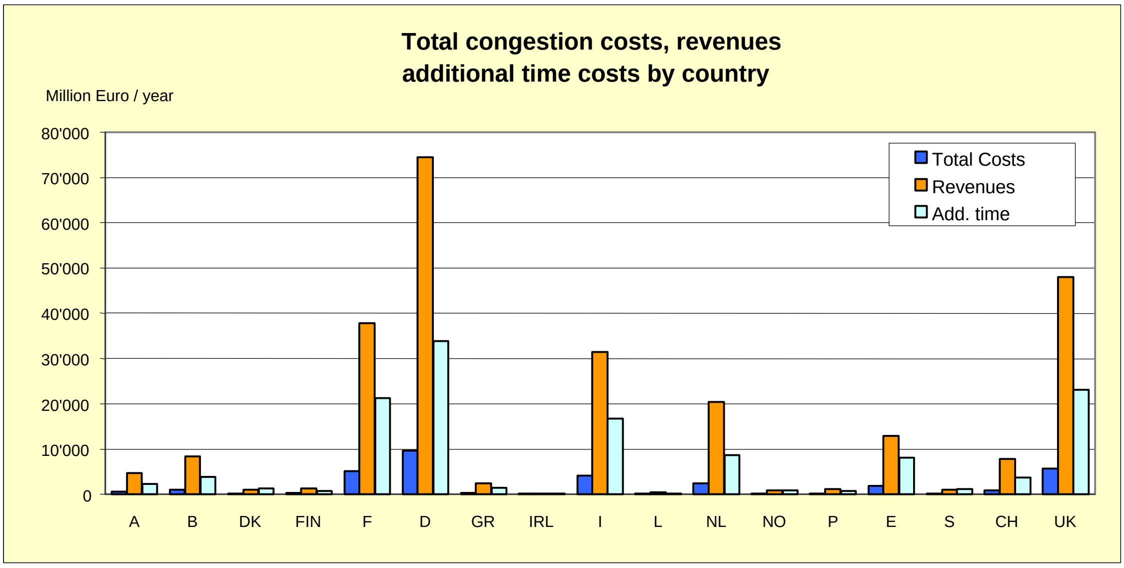

Figure 27: Results by country 1995

Though the approach applied does not allow a direct separation of urban and inter-urban congestion, a rough estimate concludes that 70% to 80% of total congestion costs and revenues in passenger transport are due to agglomeration traffic while the remaining share of costs are occurring in long-distance travel. In freight transport the share of urban congestion is considerably lower; it is estimated to range between 25% and 45% within the EUR-17 countries.

5.2.1. Total and average costs 1995 and 2010

The external costs of road traffic congestion are estimated by approximately 33.3 billion Euro in 1995, which corresponds to a share of Europe's GDP of 0.5%. Road congestion costs are not equally spread across Europe as can be verified in the summary graphic above. As can be expected, the big industrial countries along the "blue banana" (UK, France, Germany and northern Italy) contribute by far the most to the total road congestion costs in the EUR-17 countries. A detailed presentation of country-wise total and average costs by means of transport is given in the two following tables. The results of the costs estimation lead to the following comments:

- The ratio of the total congestion values calculated for Germany, the Benelux countries and Scandinavia seems to meet the current situation rather precisely.
- The total average cost figures should be read with caution because the marginal congestion costs are tremendously differing among different traffic situations (compare the results in section 5.2.2).
- The average costs per passenger and tonne kilometre in some small but highly industrialised countries (in particular in the Benelux countries) the traffic situation is as strained as in Germany or France.

- While the average passenger-kilometric costs for motorcycles in average are 70% of the costs in car transport, due to its much broader range of occupancy rates in bus / coach transport and average passenger causes 10% to 50% of congestion costs compared to the car.

Congestion: Total Cost 1995 [million Euro / year]		Road						
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total
Austria	**658**	367	2.3	45.4	414.7	30.6	213	2447
Belgium	**1'094**	664	3.6	21.8	689.7	101.3	303	404
Denmark	**251**	105	0.3	45.2	150.5	22.1	79	101
Finland	**303**	61	0.8	27.1	88.4	69.8	145	215
France	**5'179**	3'294	29.4	247.2	3'570.8	767.5	841	1'609
Germany	**9'661**	5'384	60.4	301.9	5'746.0	702.4	3'213	3'915
Greece	**306**	249	2.7	7.0	258.4	24.3	24	48
Ireland	**36**	22	0.0	4.9	27.4	3.4	5.6	9
Italy	**4'173**	2'437	17.5	219.7	2'673.9	446.0	1'053	1'499
Luxemb'g	**59**	44	0.2	4.3	48.5	1.0	9.4	10
Netherl.	**2'524**	1'467	12.0	49.8	1'528.9	6.6	989	995
Norway	**166**	99	0.6	16.0	115.2	20.9	29.9	51
Portugal	**161**	106	1.1	15.2	122.4	5.4	32.9	38
Spain	**1'886**	1'096	4.5	63.9	1'164.2	434.9	287	722
Sweden	**248**	103	0.3	36.9	140.2	37.9	69.9	108
Switzerl.	**903**	662	10.9	38.5	711.6	81.0	110	191
UK	**5'711**	3'980	22.9	233.6	4'236.9	577.8	896	1'474
EUR 17	**33'321**	20'139	169.6	1'379	21'690	3'333	8'300	11'633

Table 65: Total congestion costs 1995 (EUR 17)

Congestion Average Cost 1995	Average Cost Passenger (Euro / 1000 pkm)				Average Cost Freight (Euro / 1000 tkm)		
	Car	MC	Bus	Pass. total	LDV	HDV	Freight total
Austria	4.78	2.73	3.64	4.60	52.84	2.59	2.94
Belgium	6.51	3.96	5.36	6.45	45.69	5.38	6.91
Denmark	1.82	0.69	3.32	2.10	25.25	1.64	2.07
Finland	2.05	0.88	3.30	2.29	75.74	6.80	9.66
France	6.06	4.28	4.25	5.86	33.27	4.57	7.77
Germany	7.34	4.72	3.62	6.93	90.56	10.57	12.56
Greece	3.75	2.94	2.56	3.69	7.00	0.45	0.86
Ireland	0.71	0.17	2.65	0.81	9.01	0.29	0.46
Italy	4.05	2.29	3.83	4.01	44.07	4.29	5.87
Luxemb'g	8.18	4.98	6.01	7.91	17.98	1.97	2.16
Netherlands	13.11	9.99	5.01	12.43	125.30	8.48	8.54
Norway	2.27	0.80	4.04	2.40	32.81	3.21	5.10
Portugal	1.15	0.70	1.32	1.16	3.65	1.05	1.17
Spain	3.56	2.28	1.93	3.39	22.17	1.85	4.13
Sweden	1.27	0.59	3.38	1.52	13.27	2.24	3.16
Switzerland	9.05	5.68	5.47	8.66	96.72	8.97	14.57
UK	7.89	5.73	5.52	7.69	55.46	4.18	6.56
EUR 17	5.82	3.90	3.81	5.61	39.05	5.23	6.95

Table 66: Average congestion costs 1995 (EUR 17)

The forecast of traffic demand until 2010 is estimated to result in a dramatic increase of total congestion costs by 142% to 80'170 million Euro p.a. The congestion on the interurban road network are estimated to rise by 124% while on urban roads an increase by 188% is forecasted. These results are very different among countries. The most significant growth is calculated for Portugal and France (both developing by +241%), followed by Ireland (+196%) and Finland (+181%). The lowest increase is estimated for the Netherlands (+85%) and the UK (+95%).

These forecast results are based on the development of total traffic demand as reported in annex 2.8 and assume a constancy of infrastructure capacity until 2010, the results should be regarded with caution. Although a strong tendency for rapidly growing congestion problems can be assumed, the enlargement of road infrastructure, improved traffic control measures and a possibly changing traffic behaviour might calm its growth to some extent.

5.2.2. Tax revenues and additional time costs 1995

Total tax revenues stemming from the internalisation of congestion costs in Europe are estimated to be 254 billion Euro in 1995, from which 26 billion Euro (88.6%) arise from traffic on rural and major urban roads and the remaining 29 billion Euro (11.4%) are due to inner-urban traffic. This means that the charges to be collected in average are 7.6 times higher than the achieved social benefit. The share of road user charges collected from inner-urban traffic also widely differs from country to country (EUR-17 average: 11.4%, maximum (Ireland): 94.1%, minimum (the Netherlands): 4.8%). The total value corresponds to 3.74% of the GDP of the EUR-17 countries.

The ratio of tax revenues to total congestion costs varies among countries and is ranging from a minimum of 3.88 (estimated for Denmark) to a maximum of 8.70 for Switzerland. A tendency can be observed that thinly populated countries will have more modest values, while the sum of tax money which must be raised in order to abolish total congestion costs is considerably high for densely populated countries (e.g. Belgium, the Netherlands, France, Germany).

The extreme discrepancy between tax income from a Pigou-tax and social benefits can be interpreted differently:

- Road transport should be taxed much higher than presently done to internalise external congestion costs.
- The discrepancy indicates that a higher share of the tax income stemming from road transport should be invested in extending road capacity.

A further problem occurs with respect to EU pricing principles: It is evident that in the case of congestion externalities a gap occurs between external costs and prices to internalise external costs. Therefore, second-round effects of pricing are to be expected, which make the political issue of setting the prices right much more complex than can be seen in the simple Pigou-model.

The magnitude of the additional time costs calculated (total: 128 billion Euro) is roughly 50% of the revenues, and hence a factor 4 above total congestion costs. However, it should be noted that the reference traffic level for their computation (LOS-C) has been set in a rather arbitrary way and hence this figure widely varies by the underlying assumptions. The country-wise figures for total costs, revenues and scarcity costs and their shares are presented in the table below.

Congestion costs, revenues and add. time costs 1995	Total Costs and Revenues 1995			Percentage of GDP		
	Dead weight loss	Revenues	Additional time costs	Dead weight loss	Revenues	Additional time costs
Austria	0.66	4.75	2.30	0.37 %	2.66 %	1.29 %
Belgium	1.09	8.39	3.93	0.53 %	4.07 %	1.91 %
Denmark	0.25	0.97	1.26	0.19 %	0.73 %	0.95 %
Finland	0.30	1.37	0.79	0.31 %	1.63 %	0.83 %
France	5.18	37.83	21.21	0.44 %	3.22 %	1.80 %
Germany	9.66	74.44	33.80	0.52 %	4.03 %	1.83 %
Greece	0.31	2.41	1.40	0.35 %	2.76 %	1.60 %
Ireland	0.04	0.17	0.23	0.08 %	0.35 %	0.47 %
Italy	4.17	31.41	16.69	0.50 %	3.78 %	2.01 %
Luxembourg	0.06	0.48	0.26	0.45 %	3.61 %	1.95 %
Netherlands	2.52	20.43	8.62	0.83 %	6.75 %	2.85 %
Norway	0.17	0.92	0.88	0.15 %	0.82 %	0.78 %
Portugal	0.16	1.16	0.73	0.21 %	1.51 %	0.95 %
Spain	1.89	12.88	8.15	0.44 %	3.01 %	1.90 %
Sweden	0.25	1.02	1.21	0.14 %	0.58 %	0.69 %
Switzerland	0.90	7.86	3.81	0.38 %	3.32 %	1.61 %
United Kingdom	5.71	47.97	23.17	0.68 %	5.69 %	2.75 %
Total EUR 17	33.32	254.47	128.43	0.49 %	3.75 %	1.89 %

Table 67: Congestion costs, tax revenues and additional time costs by country 1995

Table 68 below lists the estimated congestion costs, road user charge proceeds and additional time costs by country and network type. The main road network includes motorways, other rural roads and major urban access roads. In a European average 25.3% of congestion costs are estimated to occur in inner-urban traffic, while – due to reasons of traffic demand characteristics – inner-urban traffic will only contribute to 11.4% of the overall revenues from congestion charging. The conclusion of this rough estimate is that urban congestion problems can be addressed much more effectively with pricing instruments than congestion on inter-urban roads.

Congestion costs, revenues and additional time costs 1995 by type of network	Dead weight loss			Revenues			Additional time costs			Ratio to DWL	
	Main network	Inner-urban	Total	Main network	Inner-urban	Total	Main network	Inner-urban	Total	Rev.	Scarc.
	Billion Euro 1995			*Billion Euro 1995*			*Billion Euro 1995*				
Austria	0.49	0.17	0.66	4.16	0.59	4.75	1.36	0.94	2.30	7.22	3.49
Belgium	0.86	0.23	1.09	7.70	0.70	8.39	2.67	1.26	3.93	7.68	3.59
Denmark	0.04	0.21	0.25	0.31	0.67	0.97	0.09	1.18	1.26	3.88	5.03
Finland	0.21	0.09	0.30	1.16	0.21	1.37	0.32	0.47	0.79	4.53	2.60
France	3.44	1.74	5.18	32.75	5.08	37.83	11.35	9.86	21.21	7.30	4.09
Germany	7.96	1.70	9.66	68.74	5.71	74.44	24.51	9.29	33.80	7.71	3.50
Greece	0.21	0.10	0.31	2.07	0.34	2.41	0.80	0.61	1.40	7.87	4.57
Ireland	0.00	0.04	0.04	0.01	0.16	0.17	0.00	0.23	0.23	4.63	6.32
Italy	2.89	1.28	4.17	26.35	5.05	31.41	8.79	7.90	16.69	7.53	4.00
Luxembourg	0.04	0.02	0.06	0.39	0.09	0.48	0.14	0.13	0.26	8.16	4.48
Netherlands	2.24	0.29	2.52	19.44	0.98	20.43	7.07	1.55	8.62	8.09	3.41
Norway	0.05	0.12	0.17	0.43	0.49	0.92	0.13	0.75	0.88	5.53	5.29
Portugal	0.09	0.07	0.16	0.88	0.28	1.16	0.29	0.44	0.73	7.21	4.54
Spain	1.12	0.77	1.89	10.82	2.05	12.88	3.71	4.45	8.15	6.83	4.32
Sweden	0.05	0.20	0.25	0.48	0.54	1.02	0.15	1.06	1.21	4.11	4.89
Switzerland	0.69	0.22	0.90	6.91	0.95	7.86	2.44	1.36	3.81	8.70	4.21
United Kingdom	4.51	1.20	5.71	42.95	5.02	47.97	15.59	7.58	23.17	8.40	4.06
Total EUR 17	24.88	8.44	33.32	225.56	28.90	254.47	79.38	49.05	128.43	7.64	3.85

Table 68: Congestion costs, revenues and additional time costs by type of network and country 1995

5.2.3. Marginal Costs

Marginal external congestion costs per vehicle kilometre are defined as the difference between the marginal social costs a user imposes on the whole system and the private costs perceived by him. They are evaluated on the base of speed-flow diagrams and are accordingly presented by road type as a function of lane occupancy. While the marginal external costs per user at the current level of road occupancy describes the extra costs this user is imposing on other users, the marginal external costs at the optimal traffic level Q^* denote the optimal congestion charge. Whenever talking about marginal congestion costs, these two values need to be considered in common. Figure 28 displays the ratio between these two values for motorways by Level-of-Service.

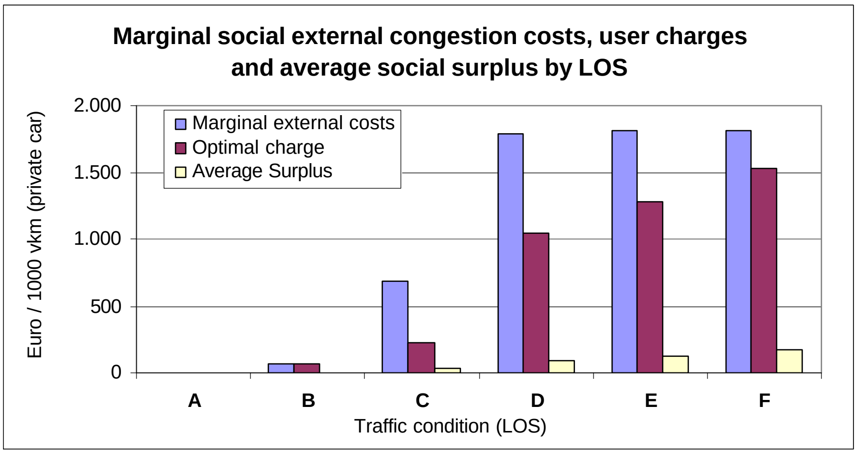

Figure 28: Development of marginal congestion costs measures by LOS

The absolute level of these values is varying by the type of vehicle considered, by the capacity of the road segment and by the price-elasticity of traffic demand. The difference between vehicle types is proportionally growing with its specific number of passenger car units. Traffic demand is usually more elastic (-0.8) for urban traffic than it is for inter-urban travel (-0.3) and respectively the difference between the optimal and the current marginal social costs is much higher for urban travel. The differences in marginal congestion costs between the different types of roads can be explained as follows:

- Due to the well-ordered traffic conditions on motorways traffic flows may grow up to a high density without resulting in a major disturbance between the single users. Accordingly the marginal external costs per user are rising lately, but sharply when vehicles start to disturb each other. In this case traffic flows break down rather quickly.
- The conditions on secondary rural roads in principle are equal to motorways. The decisive difference, however, is the lower designed or permitted speed. This means that the reduction of the overall travel speed by a certain amount in relative terms is not as dramatic as it may be on a motorway with its high designed speed.
- Urban roads consist of a considerably higher amount of disturbing elements, such as curves, level crossings and exit points. This results in a much higher potential of an additional traffic unit to deteriorate traffic situations even when roads are occupied rather thinly. The result is that the marginal external cost function is increasing in a moderate way, but as its increase begins quite early, the resulting congestion charge ranges well above the those calculated for inter-urban traffic.

Table 69 finally summarises average marginal external costs for inter-urban and urban main roads for dense, but still flowing traffic. While the figures might rise up to several Euro per vehicle kilometre, under relaxed traffic conditions average congestion costs are close to zero. The values are presented per mode of transport as vehicle-, passenger- and tonne-kilometric figures using average European time values and occupancy rates.

Aggregated marginal congestion values (Euro / 1000 km)	Marginal values per vkm			Marginal values per pkm / tkm		
	MSEC	Charge	Av. DWL	MSEC	Charge	Av. DWL
Passenger car						
- Inter-urban	1977	1004	78	1041	529	40,8
- urban	2708	1595	60	1934	1139	42,9
Motorcycle						
- Inter-urban	988	502	39	899	456	35,3
- urban	1354	798	30	1231	725	27,3
Bus						
- Inter-urban	3955	2009	155	198	100	7,8
- urban	5416	3190	120	361	213	8,0
LDV						
- Inter-urban	2966	1506	116	9887	5021	387,8
- urban	4062	2392	90	13540	7975	300,4
HDV						
- Inter-urban	4944	2511	194	883	448	34,6
- urban	6770	3987	150	1209	712	26,8

Table 69: Average marginal congestion costs under dense traffic conditions

A further differentiation of average congestion costs by traffic conditions and road categories is presented in the following table. The values put light on the great diversity of marginal social costs and user charges regarding different traffic situation and road types. Traffic situations are categorised by “relaxed” (500 - 800 PCU / h, lane), “dense” (up to 1000 PCU / h, lane) and “congested” (above 1000 PCU / h, lane). The values for free flow situations (up to 500 PCU / h, lane) are rather close to zero and hence are not presented explicitly. Inter-urban roads are specified into motorways and other rural roads according to the discussion of their characteristics above.

Looking at the development of marginal costs with traffic density as shown above it is not surprising that marginal congestion costs are well above average costs. The ratio marginal to average costs strongly increases with growing traffic density.

Detailed marginal congestion values (Euro / 1000 km)	Marginal values per vkm MSEC	Charge	Av. DWL	Marginal values per pkm / tkm MSEC	Charge	Av. DWL
Passenger car on motorway						
- relaxed traffic	11	11	0.0	5.6	5.6	0.0
- dense traffic	1'977	1'004	77.6	1'040.7	528.5	40.8
- congestion	2'032	1'478	194.6	1'069.5	777.8	102.4
Passenger car on rural road						
- relaxed traffic	37	37	0.0	19.6	19.6	0.0
- dense traffic	1'254	803	2.1	659.8	422.6	1.1
- congestion	1'951	1'687	28.3	1'026.8	888.0	14.9
Passenger car on urban road						
- relaxed traffic	26	26	0.0	18.5	18.5	0.0
- dense traffic	2'708	1'595	60.1	1'934.3	1'139.2	42.9
- congestion	3'096	2'205	178.5	2'211.5	1'575.2	127.5
Motorcycle on motorway						
- relaxed traffic	5	5	0.0	4.9	4.9	0.0
- dense traffic	989	502	38.8	898.8	456.5	35.3
- congestion	1'016	739	97.3	923.7	671.7	88.4
Motorcycle on rural road						
- relaxed traffic	19	19	0.0	17.0	17.0	0.0
- dense traffic	627	402	1.0	569.8	365.0	0.9
- congestion	975	844	14.1	886.8	766.9	12.9
Motorcycle on urban road						
- relaxed traffic	13	13	0.0	11.8	11.8	0.0
- dense traffic	1'354	798	30.0	1'230.9	725.0	27.3
- congestion	1'548	1'103	89.2	1'407.3	1'002.4	81.1
Bus on motorway						
- relaxed traffic	21	21	0.0	1.1	1.1	0.0
- dense traffic	3'955	2'009	155.1	197.7	100.4	7.8
- congestion	4'064	2'956	389.2	203.2	147.8	19.5
Bus on rural road						
- relaxed traffic	75	75	0.0	3.7	3.7	0.0
- dense traffic	2'507	1'606	4.2	125.4	80.3	0.2
- congestion	3'902	3'375	5.6	195.1	168.7	2.8
Bus on urban road						
- relaxed traffic	52	52	0.0	3.4	3.4	0.0
- dense traffic	5'416	3'190	120.2	361.1	212.7	8.0
- congestion	6'192	4'411	356.9	412.8	294.0	23.8
LDV on motorway						
- relaxed traffic	16	16	0.0	53.5	53.5	0.0
- dense traffic	2'966	1'506	116.4	9'887.1	5'021.2	387.8
- congestion	3'048	2'217	291.9	10'160.2	7'389.2	972.9
LDV on rural road						
- relaxed traffic	56	56	0.0	186.6	186.6	0.0
- dense traffic	1'880	1'204	3.1	6'268.1	4'014.6	10.4
- congestion	2'926	2'531	42.4	9'754.3	8'436.4	141.4
LDV on urban road						
- relaxed traffic	39	39	0.0	129.3	129.3	0.0
- dense traffic	4'062	3'292	90.1	13'539.9	7'974.5	300.4
- congestion	4'644	3'308	267.7	15'480.5	11'026.5	892.3
HDV on motorway						
- relaxed traffic	27	27	0.0	4.8	4.8	0.0
- dense traffic	4'944	2'511	193.9	882.8	448.3	34.6
- congestion	5'080	3'695	486.5	907.2	659.7	86.9
HDV on rural road						
- relaxed traffic	93	93	0.0	16.7	16.7	0.0
- dense traffic	3'134	2'007	5.2	559.7	358.4	0.9
- congestion	4'877	4'218	70.7	870.9	753.3	12.6
HDV on urban road						
- relaxed traffic	65	65	0.0	11.5	11.5	0.0
- dense traffic	6'770	3'987	150.2	1'208.9	712.0	26.8
- congestion	7'740	5'513	446.1	1'382.2	984.5	79.7

Table 70: Marginal congestion costs for different traffic situations

6. Corridor estimates

The description of marginal costs in different traffic situations (chapter 4 and 5.3) has shown, that the evidence of country-specific average cost values is rather limited or might even be misleading under particular circumstances. As an attempt to overcome this problem the present chapter contains four corridor-application of short-run marginal costs of passenger and freight transport. The analysis of these case studies provides the opportunity to draw a more realistic picture of the magnitude of marginal external costs for different modes of transport. It provides some numerical input information to the discussion on the internalisation of the external costs of transport. For this reason it was decided to calculate marginal, rather than average costs along the selected corridors. The case studies do not intend to provide a totally comprehensive set of optimal externality charges and hence typical vehicles and loading rates are chosen for a selected number of uni-modal and inter-modal travel alternatives.

6.1. Definition and methodology

6.1.1. The corridors

Average costs per country and marginal costs for particular situations are not able to provide an evident comparison among the different transport modes. To achieve this goal, four European corridors have been selected, for which the marginal costs per passenger or per tonne of freight are calculated. The main alternatives considered in passenger transport (corridors I and II) are car, traditional and high speed rail and air transport (including car access). In freight transport road haulage, accompanied and unaccompanied combined rail transport and waterborne transport are considered. Due to their limited importance, bus and motorcycle traffic on the passenger side and LDV and air freight transport are not included in the analyses. Apart from the brief description of the corridors, which is given below, annex 2.9 of this report presents the details of mode and route definitions.

Corridor I: Paris -Vienna (long-distance passenger transport)
This case study aims to compare the marginal costs of a long-distance car trip to traditional rail and air passenger transport. The route by road follows the E60 and E52 from Paris via Strasbourg, Stuttgart and Munich to Vienna and has a total length of approximately 1440 kilometres. The railway line follows the same route, but is calculated to be 60 km less in length.

The vehicles used are an ordinary petrol car (Euro-I standard) which is occupied 1.9 passengers, an electric powered international passenger train (UCPTE electricity mix, occupancy 248 passengers) and an average aeroplane, loaded with 149 passengers. For the access to and from the airports in Paris and Vienna a journey of 20 km each via densely occupied urban roads is assumed.

Corridor II: Paris - Brussels (short distance passenger transport)
With this case study it is tried to compare a typical high-speed railway link to road and air traffic. While the latter two are defined equally to corridor I, the international passenger train is replaced by a modern high-speed, in the current case by the Thalys-Express. The distance of this corridor with approximately 300 km is considerably less than the route Paris - Vienna and hence it is assumed that the utility of air transport is worse than in the previous corridor.

Corridor III: Cologne - Milan (combined Trans-Alpine freight transport)
The case study aims to compare the land-based freight transport modes road (28-t and 40-t HDV), rail (container transport including initial and terminal shipments by HDV, 50 km at each at origin and destination) and the rolling motorway (from Basle to Chiasso) to each other. The corridor leads from Cologne along the river Rhine, via Basle, the Gotthard pass and Chiasso to Milan in Italy. It has a length of about 860 km on the road and 920 km by rail.

In road haulage two types of HDVs are considered: A 28-t lorry running through Switzerland and a standard 40-t lorry taking the route via France (+140 km). The initial and final transport for unaccompanied combined rail transport and the use of rolling motorway are calculated for the 40-t lorry. The abolishment of the Swiss 28-t limit is not considered.

Corridor IV: Rotterdam - Basle (uni-modal harbour-hinterland freight transport)
The purpose of this case study is to compare the external marginal costs of the land based uni-modal freight transport modes to inland navigation. For rail transport, which again represents a container shipment, neither initial nor terminal shipments from and to container terminals by road haulage are considered. The loading rates of the direct freight train is assumed to be considerably lower than the loading rate of a Trans-Alpine container shuttle (corridor III). In inland navigation a typical share of 50% empty headings is assumed.

6.1.2. Modes of transport

In the corridor description above it is mentioned that each route constitutes of uni-modal and multi-modal transport alternatives. The uni-modal alternatives further comprise road and rail transport, while in passenger travel air transport is always multi-modal. The same holds for container shipments and the use of rolling motorway services in rail transport. Although waterborne freight transport is usually multi-modal, in the special case of corridor IV (Rotterdam - Basle) terminal-to-terminal shipments of containerised goods are analysed and hence access-free inland navigation is compared to a direct freight train.

The most sensitive figures determining the relative costs per ton kilometre are the vehicle loading factors. The values chosen reflect local conditions rather than European average value and consequently the resulting figures should not be applied to different cases. A detailed discussion of the assumptions undermining the loading factors chosen is given in Annex 2.9; the final parameters of the transport modes considered are summarised by the table below.

Vehicle type	Symbol	Details	Load	Corridors
Passenger car inter-urban	Car	Petrol, Euro-I	1.9	I, II
Passenger car urban	Car	Petrol, Euro-I	1.4	I, II (air access)
Heavy duty vehicle, 28t	L28	Diesel, Euro-I	6.5	III (FR)
Heavy duty vehicle, 32t-40t	L40	Diesel, Euro-I	10.8	III (CH, rail access), IV
Passenger train (EC)	Rail	UCPTE-Mix	248	I
High speed rail (Thalys)	HSR	UCPTE-Mix	313	II
Freight train - combined transport	UCT	UCPTE-Mix	529	III
Freight train - rolling motorway	RMW	UCPTE-Mix	157	III
Freight train - Wagon load	RWL	UCPTE-Mix	350	IV
Aircraft - short distance	Air		81	II
Aircraft - medium distance	Air		149	I
Inland navigation vessel	Water		1139	IV

Table 71: Details of transport modes

6.1.3. Cost evaluation principles

The cost analysis is based on short-run marginal costs for a single trip. The costs are hence based on the marginal costs caused by a typical passenger car, lorry, train, aircraft or freight ship and on typical loading factors rather than on the application of European average values. The limitation on short-run marginal social costs implies that some cost components are neglected as they are only relevant in the long-term. This in particular concerns infrastructure-related cost elements, such as effects on nature and landscape, separation effects and partly up- and downstream effects.

Following the general structure of this report, external congestion costs are presented separately from the system-external cost categories (accidents, noise, air pollution, climate change additional costs in urban areas and up- and downstream effects). Both, the marginal external costs referring to the current traffic level and the optimal user charges are calculated and presented for the uni-modal road alternatives as well as for the access of airports and combined freight transhipment terminals. The detailed approaches for the costs components evaluated per corridor and mode are commented in turn.

Accidents
Marginal accident costs in road traffic are calculated as average costs per country and road type based on the accident rates reported in IRTAD road accident database. In rail traffic, accident rates per passenger and freight train kilometres are total national accident cost rates, which are not further differentiated by class of train. In air transport

a total European average accident rate is assumed, while waterborne traffic is regarded to cause no external accident costs.

Noise

The short-run costs of traffic noise are calculated using region-specific target levels for daytime noise exposure. In road traffic also the current traffic volume is considered as a determinant of cost factors. This information is not available for rail or air transport and hence for these modes average values are assumed.

Air pollution and climate change

Air pollution is assessed by the high value including top-down estimates of building damages. The corresponding vehicle-specific emission factors assume a Euro-1 petrol car in road passenger transport and a Euro-1 standard truck engine. Passenger and freight rail are assumed to apply electric traction using an UCPTE electricity mix. The values are applied per type of region for road transport. Rail air and water-borne transport means are assessed with an overall average marginal cost value.

Other effects

While the effects on nature and landscape and separation effects are skipped totally, additional urban effects are only considered for region type 4. In road transport these effects are differentiated by type of land use, while in rail, air and inland navigation average values are applied. Finally, the short-run marginal costs for up- and downstream effects are considered.

Congestion

Marginal social congestion costs and road user charges per vehicle kilometre are computed by road type and level-of-service according to the elaboration in chapter 5.3. For the computation of unit costs an average European time value of 14 Euro per PCU-hour is used; data on traffic mix and volumes is taken out of the IWW transport model for each corridor segment (compare annex 2.9).

A selection of cost items (in Euro per 1000 vehicle kilometres) is presented by the following table. The values of cost categories, which are calculated according to traffic volume are presented as average figures (noise) or examples for dense traffic (congestion). For accident rates average figures of different countries are presented. For a more detailed listing of cost items in different traffic situations the reader is referred to chapter 4 on marginal system-external costs and to section 5.2.3 on marginal congestion costs.

Mode	Area	Accid. 2)	Noise 3)	Air	Climate	Urban	UDE 5)	TOTAL	Cong. 4)	Tolls 4)
Passenger-car	1	25.3	0.0	1.5	21.5	-	5.7	**54.0**	695.3	240.4
	2	106.0	0.1	1.5	37.8	-	5.7	**151.2**	272.7	236.7
	3	149.0	1.2	9.0	37.8	-	5.7	**202.7**	695.3	240.4
	4	125.3	14.6	12.1	36.6	15,0	5.7	**209.3**	1042.9	373.1
HDV 1)	1	25.2	0.0	36.5	133.8	-	23.7	**219.2**	1738.3	601.0
	2	129.6	1.4	36.5	133.8	-	23.7	**325.0**	681.7	591.7
	3	140.4	9.9	151.0	134.6	-	23.7	**459.6**	1738.3	601.0
	4	129.6	133.9	488.7	215.6	45,0	23.7	**1036.5**	242.5	932.7
EC Train		148.8	280.0	535.0	1053.0	-	826.0	**2842.8**	-	-
HS Train		148.8	275.0	707.3	1512.0	-	826.0	**3508.1**	-	-
Freight train UCT		315.0	621.0	1832.1	3415.5	-	223.3	**6406.9**	-	-
Freight train RMW		315.0	621.0	916.1	1707.8		223.3	**3783.2**		
Freight train RWL		315.0	621.0	1172.5	2185.9		223.3	**4517.7**		
SD-plane		48.6	83.1	91.5	3199,5	-	467.0	**3889.7**	-	-
LD-plane		48.6	83.1	51.2	2713.5	-	467.0	**3363.4**	-	-
ship		0.0	0.0	5078.9	5400.0	-	0.6	**10479.5**	-	-

1) All HDV-types (28-t and 40-t).
2) Average accident rates; in corridor calculations specified by country
3) Average of traffic density; Rail: Values for area type 3 (suburban)
4) Average of road types traffic level 2 (dense)
5) Up- and downstream effects

Table 72: Selected cost values used for corridor estimates in EURO / 1'000 per vehicle km

6.2. Results

The results of the corridor analysis are presented in Euro per 1000 passenger / tonne kilometres to eliminate the different distances of the four routes[47]. The table of results is differentiated by corridors, travel alternatives and cost components. It should be noted that the summary row does not include congestion.

47 The distances of the combined transport alternatives passenger air and rail-road container shipment (UCT) include the length of the respective road access by car / HDV.

Results Euro/ 1000 pkm, tkm	Passenger transport Paris - Vienna Car	 Train	 Air	Passenger transport Paris - Brussels Car	 HSR	 Air	Freight transport Cologne - Milan L28t	 L40t	 UCT	 RMW	Freight transport Rotterdam - Basel L40t	 Rail	 Water
Accidents	15.9	0.6	2.6	14.0	0.6	9.2	4.6	3.2	1.1	2.7	3.9	0.9	0.0
Noise	0.3	1.3	1.2	1.5	0.1	1.6	0.6	0.4	0.5	0.6	0.6	0.7	0.0
Air pollution	2.1	2.2	0.7	3.5	2.3	0.9	16.5	11.5	4.5	10.5	9.4	3.4	4.5
Climate change	18.9	4.2	21.0	18.7	4.8	30.2	20.7	14.5	7.0	12.2	12.6	6.2	4.7
Urban effects	0.2	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Up/downstream	2.9	3.3	3.2	2.9	2.6	5.6	3.6	2.6	2.1	4.1	2.2	3.1	0.6
TOTAL env.	**40.2**	**11.7**	**28.7**	**42.8**	**10.4**	**47.5**	**46.0**	**32.2**	**15.2**	**30.1**	**28.7**	**14.3**	**9.8**
Congestion	226.4	0.0	53.6	376.5	0.0	227.1	186.9	130.8	6.1	103.9	118.5	0.0	0.0
User charges	120.2	0.0	33.0	195.9	0.0	139.8	85.5	59.8	5.3	47.3	85.2	0.0	0.0

HSR = High speed rail (Thalys), L28t / L40t = Lorry with 28t / 40t payload,
UCT = unaccompanied combined transport, RMW = rolling motorway,

Table 73: Corridor results

After the subsequent analysis of general results, a detailed discussion of environmental costs by corridor and some remarks on congestion costs and user charges is presented in turn.

6.2.1. General results

The comparison of total cost values among the corridors and to the European average figures (chapter 3.2) leads to the following comments:

- For all uni-modal travel alternatives (passenger and freight) short-run marginal costs are 40% - 60% below average costs. This is mainly due to three facts: (1) the regressive cost function of noise emissions, (2) the neglected long-run cost elements and (3) the relatively high road safety standards in the countries considered.
- This decrease does not hold for the costs due to the emissions of CO_2, which is - in contrast to average costs - dominating all other cost components because CO_2-emissions are neither influenced by vehicle technologies nor is the economic valuation sensitive to the type of area.
- Due to the comparably high external costs of road transport the intermodal travel alternatives air (passenger) and rolling motorway services show a rather unfavourable picture compared to unimodal rail transport. The relative external costs calculated are close to those of pure road transport.
- Especially in rail and waterborne traffic, but also in air passenger transport and road haulage, vehicle loading factors may vary widely and the average marginal costs per passenger or ton kilometre show a wide uncertainty range. This makes the environmentally less friendly but more occupied high-speed rail (corridor II) become comparable to the traditional inter-city train of corridor I. In the same

manner the highly loaded UCT-train through the sensitive Alpine region (corridor III) gets competitive to the wagon load train (corridor IV) driving along a less sensitive route.

6.2.2. Specific results for accident and environmental costs

In this section the results from the estimation of accident-, environmental- and other short-run marginal costs (excluding congestion) are examined by corridor. The results are presented for the entire routes including access to airports or freight transhipment terminals via road transport.

Corridor I (long-distance passenger transport Paris - Vienna)
The journey by car is characterised by a rather small share of real urban transport during the departure in Paris and the arrival in Vienna, the usage of highly frequented motorway segments in southern Germany and route segments leading through environmentally rather sensitive regions at the Alpine border. While rail traffic uses the same route, in contrast to noise effects, it does not consider locally differentiated air pollution impacts or accident rates. Air traffic is characterised by two 20-km car trips via urban roads. Under this background the results for corridor I can be commented as follows:

- The road alternative clearly causes the highest short-run marginal external costs, compared to traditional inter-city rail and mid-distance air travel. Per passenger kilometre rail causes approximately 30% of the external costs caused by road, while the ratio for mid-distance air travel (including road access) to pure road travel is around 0.7
- Compared to the European average cost figures, the advantage of the scheduled travel modes along the corridor Paris - Vienna is less evident.
- In terms of external costs, the difference between road and aviation is rather small, but still evident, even if the 7% of external costs which are caused by road access would be ignored. In this case the relative costs of air transport would rise from 28.7 Euro / pkm to 30.8 Euro / pkm.

The estimated relative costs for corridor I are depicted by the figure below.

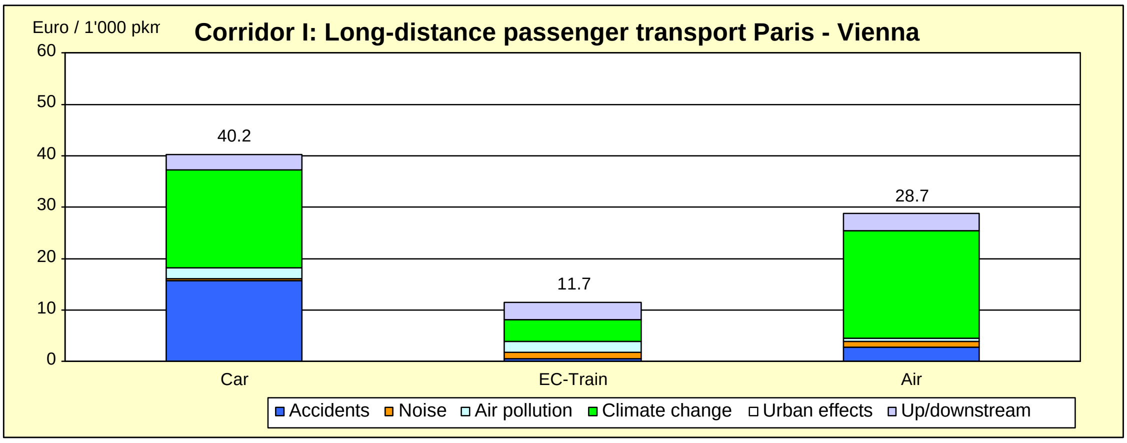

Figure 29: Results Corridor I (Marginal cost in Euro per Pkm)

Corridor II (short-distance passenger transport Paris - Brussels)

The second passenger corridor contains the same transport alternatives, but with two decisive differences to corridor I. First, in rail mode a high speed train service (THALYS) instead of a usual IC/EC train is applied and second, though the distance of the corridor is much lower compared to the route Paris - Vienna, the length and relative costs of the car access to the airports remain constant. The following remarks can be made to the computed relative costs (figure below):

- The relative costs of car and rail transport are about 10% higher than in corridor I, which is based on the higher share of urban travel.
- The higher occupancy rate of the high speed train (313 passengers) compared to traditional rail used in corridor I (248 passengers) lets the THALYS service over-compensate its high external costs per train kilometre compared to the IC/EC train. Assuming the same loading factor for the Thalys than applied in corridor I, the passenger-,kilometric external costs would be 13.1 Euro per 1'000 pkm, which is 12% above the results for rail mode found in corridor I.
- The air mode is no longer better than car travel. Two facts are responsible for the increase in relative marginal external costs in air transport: (1) the loading factor of the short-distance aircraft was assumed to be lower that on medium-distance flights and (2) the car access to and from the airport now is responsible for 18% of the external costs (7% in corridor I) due to the short flight distance.

The results are depicted as follows:

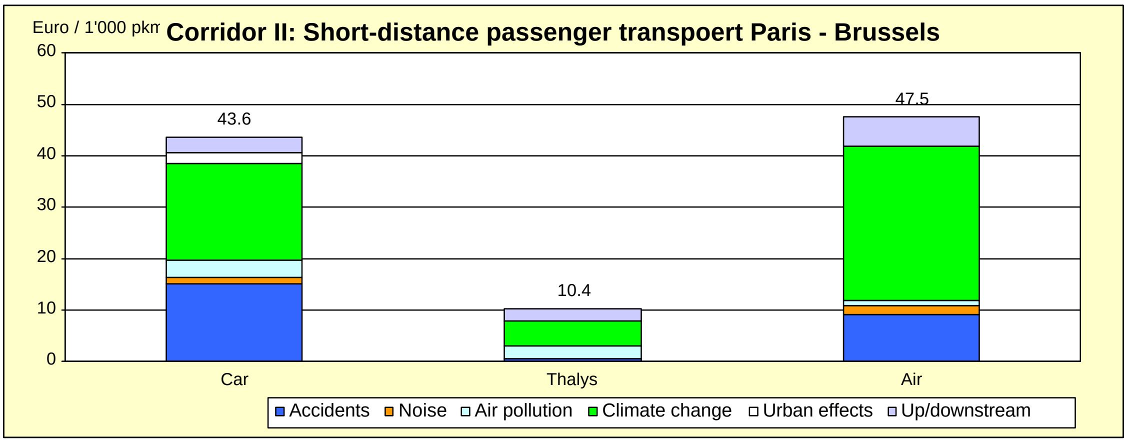

Figure 30: Results Corridor II (Marginal costs in Euro per Pkm)

Corridor III (inter-modal freight container transport Cologne - Milan)
The freight corridor Cologne - Milan is a classical inter-modal transport route. Due to the current political environment a direct truck transit from Germany to Italy using standard 32-40-t lorries is not possible due to the still existing 28-t-limit of Switzerland. Consequently, two alternative routes (40-t HDV via France versus 28-t HDV via the Gotthard tunnel) are examined. From the computed results the following observations have been made:

- Comparing the two alternatives “small truck through Switzerland” and “big truck via France (+140 km)” leads to the clear result, that the better loading factor of the French alternative is dominating the shorter direct path through Switzerland. In case the ban of 40-t lorries through Switzerland was abolished, for a direct transit with a 40-t HDV relative external costs of 26.7 Euro / tkm are computed, which is even below the results for the rolling motorway.
- The rail mode (unaccompanied combined transport) includes a 50-km access shipment at the origin in Cologne and the destination in Milan. Even including this, the relative external costs per tkm are only 46% of the costs of the better road alternative (40-t HDV through France), and still only 57% of road costs if the Swiss 28-t limit was abolished. While the rail shipment part of the transport chain comprises 90% of the overall distance, it is only responsible for 76% of the external costs, which is mainly a consequence out of the high loading factors of the Trans-Alpine container shuttles.
- Rolling motorway is not convincing to offer a real alternative to unaccompanied combined transport as the difference to pure road haulage is rather small. Even though it was assumed that an average RMW-train is only half as long as the competing UCT-train, and accordingly its environmental costs are 50% as high, the bad net loading factor of 157 t/train (against 529t in UCT) had the stronger (negative) effect for the rolling motorway service. Further it must be considered

that share of the whole the route chain where rolling motorway is used (Basle - Chiasso) is only 30%.

The comparison of the four shipment alternatives is presented as follows:

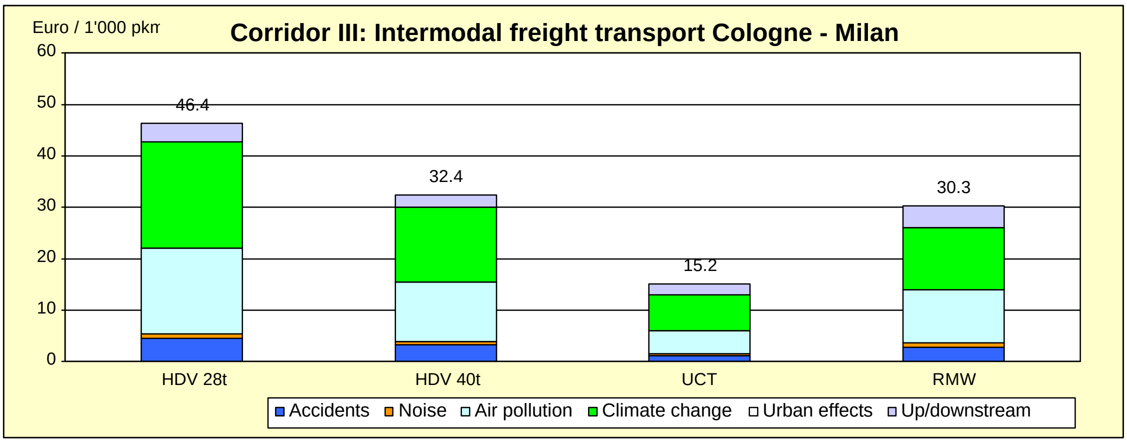

Figure 31: Results Corridor III (Marginal costs in Euro per tkm)
UCT: Unaccompanied combined transport
RMW: Rolling motorway

The lower external cost values found for 40-t HDVs should not be considered as an argument to abolish the Swiss 28-t limit without compensating measures. The existing framework and its envisaged replacement by the heavy duty tax aim to ban road traffic from the environmentally highly sensitive alpine area and hence has an important political dimension.

Corridor IV - Uni-modal harbour hinterland transport Rotterdam - Basle
In the final corridor IV neither rail nor the inland navigation consist of access by road (terminal - terminal shipments). According to local experiences the loading factors of rail and inland navigation are not set to the maximum vehicle capacity and accordingly the results of the cost estimation must be interpreted as follows:

- In contrast to the assumptions on HDV transport made in corridor III, the present route assumes a high loading rate per vehicle and a unrestricted route choice. Consequently, the relative costs per tkm are well below the results received for both road alternatives of the Trans-Alpine route in corridor III.
- Although the loading factors are not advantageous for rail and waterborne shipments, but rather good for road haulage, the mass transport services are still clearly competitive to road concerning marginal external costs. Apart from system-specific advantages of rail and water transport the reason for this result is located in the missing road access.

- Due to the rather moderate loading factors chosen for rail and water and due to the comparable high payload of the lorry considered, the difference is relatively low compared to the ratios of European average costs.
- In general it can be concluded that concerning marginal external costs uni-modal freight shipments by mass transport systems are much more favourable than the application of combined transport chains. But under optimal conditions, the latter is still advantageous compared to pure road haulage.
- The clearly higher loading rates of the Trans-Alpine container shuttle (529t) compared to the freight train Rotterdam - Basle (350t) is not sufficient to compensate the additional costs caused by the 50 km truck access. The extreme case of a long road access and the bad loading rates of the rolling motorway trains lead to a relative external cost value, which is considerably worse than the unaccompanied rail transport services and which is nearly as high as the estimates for pure road haulage.
- Even if the external cost values estimated for inland navigation in corridor IV are lower than the rail figures, the small difference is surprising. This is due to the bad loading factors of the Rhine vessels, which are resulting from an extremely unbalanced shipment demand.

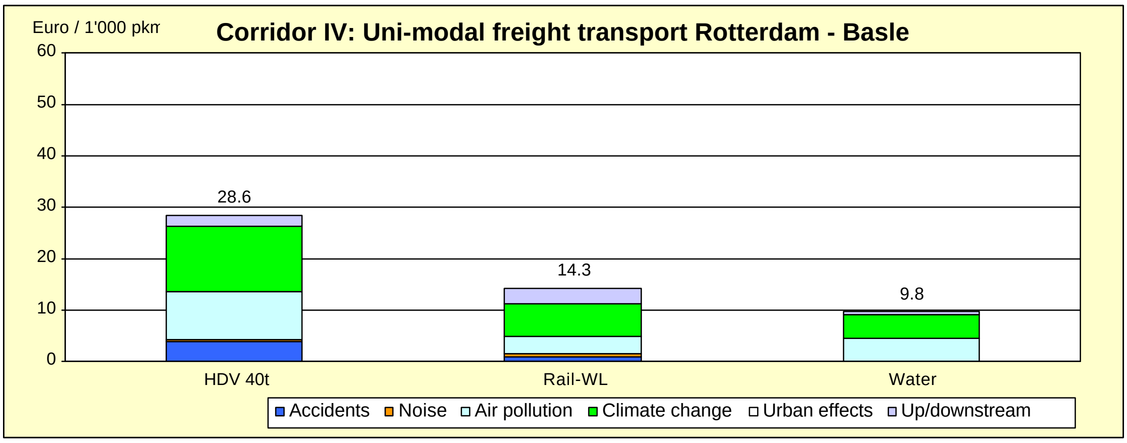

Figure 32: Results Corridor IV (Marginal costs in Euro per tkm)
WL: Wagon load

6.2.3. Marginal congestion costs and user charges

The results of the estimation of congestion costs and user charges can be commented as follows:

- With values of 200 and 350 Euro / 1000 pkm the congestion costs calculated for the car modes of corridor I and II are 5 or 10 times above the other externalities. Even the rather short access routes to the airports (20 km) cause congestion costs to clearly dominate the total short-run marginal external costs computed for the air alternatives.

- In road haulage congestion costs are estimated to be about four times higher than the "classical" externalities. For the access to CT-terminals they do not come out as a considerable cost component, but this of course varies with local traffic conditions.
- The ratio between internalisation charges and external costs ranges between 50% and 60%, depending on traffic densities.

In terms of congestion the difference between marginal costs and average (country-specific) figures becomes most convincing. While in European mean ratio between road congestion costs and other external costs for passenger cars is only 6%, the corridors show values of 565% (Paris - Vienna) and 874% (Paris - Brussels).

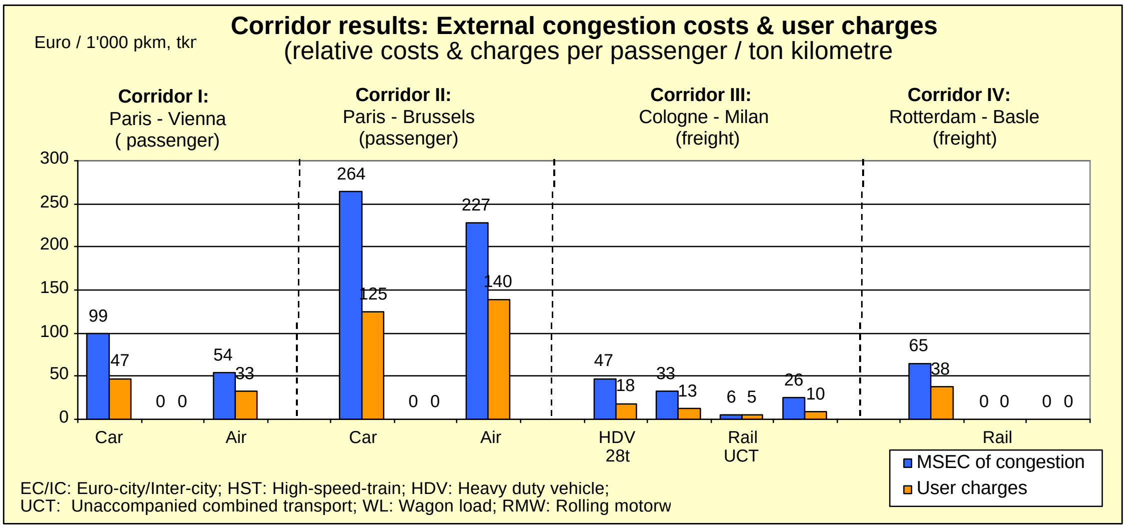

Figure 33: Results: Congestion costs and user charges (all corridors)

6.3. Conclusions

For the four corridor estimates carried out a number of concluding remarks can be made:

- Similar to the results found for average costs the relative marginal costs of road transport is clearly worse compared to rail and water transport.
- In general, intermodal passenger or freight transport is worse than single-mode mass transport alternatives (rail, air without road access) due to the high external costs of road transport.

- In passenger and freight transport the loading factors of vehicles are more decisive for relative costs passenger or ton kilometre than slight technical advantages.
- In road transport the share of urban roads is a driving element of the level of external costs (even excluding congestion).
- In air transport the travel distance has a great impact on the relative marginal external costs per pkm.

These results should not be generalised as the underlying corridor applications reflect only a small sample of marginal external costs and their variation with respect to varying traffic situations.

7. Interpretation of the results

7.1. Comparison with 1991

The following tables present the main changes between the results for 1991 (IWW/INFRAS 1995) on an aggregate level (EUR 17). The comparison is restricted to these cost categories which were estimated in the previous study.

billion Euro/year	1991			1995			% Change 91/95
	Passenger	Freight	Total	Passenger	Freight	Total	Total
Accidents	126.5	21.6	148.1	136.7	19.3	156	+5%
Noise	23.9	14.1	38.0	24.3	12.3	36.6	-4%
Air pollution	28.3	14.3	42.6	69.2	65.1	134.3	+215%
Climate	30.8	13.0	43.8	82.8	39.0	121.8	+178%

Table 74: Changes of accidents, noise, air pollution and climate change costs between 1991 (IWW/INFRAS 1995) and 1995. Significant changes can be stated in air pollution and climate change costs due to new approaches (GDP/capita 91/95: +15%).

Relation Rail-Road	1991		1995	
	in absolute terms	in relative terms	in absolute terms	in relative terms
Passenger (Cost per pkm)	40	1 : 5	67	1 : 4.3
Freight (Cost per tkm)	51	1 : 8	69	1 : 4.6

1) Additional cost of road compared to rail in Euro per 1000 pkm resp. tkm
2) Average cost road compared to rail, Rail = 1

Table 75: Relation between rail and road 1991 (IWW/INFRAS 1995) and 1995
In absolute terms, the differences between rail and road has increased due to higher values. In relative terms, the ratio has decreased.

The differences are quite significant, since new cost categories, new data and new valuation methods were used. The main differences can be explained as follows:

- Total accident costs are slightly increasing by 5%. The shift of costs between the road modes can be explained by the improved data base and allocation of total costs to the modes, that takes into account the responsibility for the accident. As a result, the share of accidents caused by road freight transport has decreased. The application of the same principle has very strong impacts for the railways, where nearly all accidents occurring at level crossings are caused by road modes.
- INFRAS/IWW (1995) did not take into account the increased risk of cardiac infarctions due to transport noise. The new study registers a moderate increase of

average costs per passenger and tonne kilometre. Due to the improved distribution of the external costs to the modes, the difference between passenger and freight transport is shrinking.

- Air pollution costs are more than twice as high compared to the previous study. This is definitely the most important change. The most important influence factor is on one hand the recent WHO-study, who delivers very high results for health costs which were not included explicitly in the previous study. Based on recent research (i.e. ExternE, Auto Oil Programme, etc.) there are a lot of important new elements to consider within the topic of air pollution. We have to state however, that the results presented here are still an intermediate step, since consistency between all sources is not fully given. The most important weak point is the estimation and modelling of the relevant emissions (particulate). Although there is quite a good knowledge on dose-response-function between concentration levels and damages (especially health), the modelling of the particulate matter is not yet developed satisfactory. At the same time the estimation of additional impacts (like building damages, damages to biosphere) is not yet developed well enough.
  Nevertheless there is enough evidence that air pollution costs are higher than initially estimated. This is especially true for road freight transport due to their high particulate emissions caused by diesel engines.
- Climate change costs are as well significantly higher due to higher unit values used. Here we can state that the unit values used are the maximum values of the three scenarios considered. These values will decrease with other unit values (see sensitivity analysis below).
- The new cost categories added are in total 15% of total costs. These categories (esp. nature and landscape as well as up- and downstream effects) are important for the road sector as well as for the railways sector. It has to bee seen however that these additional costs have a different relevance for transport pricing. Nature and landscape, urban space availability and additional costs from up- and downstream processes are not directly part of the social marginal cost approach since these costs are mainly infrastructure related and thus fixed in the short run.
- In general one has to consider as well a change in statistical figures between 1991 (base year of the previous study) and 1995. Although the data basis is not fully comparable, especially road transport increased between 1991 and 1995 by 16% (cars and LDV) and 19% (HDV), based on TRENDS database[48]. GDP per capita increased in the same time by 15%. The latter is the most important adjustment factor for all cost components.
- Definitely a very important explanation factor for all modes is the improved data basis which delivers different results on a country level as well. This is true for the

48 In a direct comparison to the traffic volume data of the 1995 INFRAS/IWW study the road transport increase between 1991 and 1995 would be 11% for cars and 67% for road freight transport (sum of LDV and HDV). This difference is probably due to different definitions of the vehicle types, and shows the importance of a stable and standardised European database.

robustness of 1995 data, the comparison between countries and the trend forecast 2010.

7.2. Sensitivity analysis

As mentioned in the previous chapters, several results are quite sensitive to their assumptions. In this section, we consider the most important sensitivities by cost category.

7.2.1. Overview

The following table summarises the most important uncertainties and presents the basic results of the sensitivity analysis.

Cost category	**Share of total costs**	**Relevance for transport means**	**Sensitivities considered**	**Range of sensitivities**
Accident	29%	Road	Risk value: 0.5 to 3 million Euro	-60% to +92%
Noise	7%	Road and Rail	Risk value Lower bound 50 dB(A)	-27% to +41% +58%
Air pollution	25%	Road	Risk value Consideration of forest damages	-40% to +59% +19%
Climate change	23%	All modes	Upper and lower bound for scientific shadow rate CO_2 Alternative (political) reduction aims	-48% to +48% -73% to –93%
Nature and Landscape	3%	All modes	Prevention cost approach	- 55% (road) +210% (rail)
Urban effects	2%	Road	-	-
Upstream effects	11%	All modes	acc. to air pollution and climate change	acc. to air pollution and climate change

Table 76: Sensitivity analysis: Overview of most important results per cost category

As mentioned already in chapter 2, one of the most important assumption is the risk value being important for nearly all cost components. Compared to the previous study one can state, that the range of uncertainty has decreased due to more robust data and more in-depth knowledge on several cost components. But nevertheless the uncertainty range will remain.

Note however that these sensitivity ranges vary to both sides. Thus the cost levels could be higher or lower. Note as well that the sensitivities can outweigh each other.

The overall range of uncertainties could even be lower than the uncertainty range for one individual cost component. Thus we can conclude, that the primary assumptions chosen in this study are representing a so called 'best guess'. There is no systematic under- nor overestimation of the results.

7.2.2. Results for each cost category

a) Accidents

The Risk Value is the most determining value for the calculation of accident costs. In order to assess the sensitivity, the Risk Value, presently estimated at 1.5 million Euro per fatality, is set at 0.5 million Euro, which is the average Risk Value estimated by Jones-Lee (1999). The Risk Values for injuries are changed accordingly. Total accident costs decrease by more than 60% to 60 billion Euro. The distribution of the costs to the modes is not changed significantly. If the ExternE value of 3 million Euro is used, the total costs increase by 92% to nearly 300 billion Euro.

b) Noise

The approach chosen is tested in order to reveal the sensitivity of various assumptions. The first test sets the Risk Value to 0.5 million Euro (Reference 1.5 million Euro). The total costs decrease by 27%. Railways are less effected than road and air modes. The second test sets the risk value to 3.0 million Euro: Total noise costs increase by 41%. Again railways are less effected. The third test indicates the sensitivity of the level for silence. (WTP = 0). If this level is decreased from 55 dB(A) to 50 dB(A) the total costs increase by 58%. If this approach is chosen, the noise costs for railways are doubled.

	Road	Rail	Air	**All Modes**
Reference (1.5 million Euro)	100%	100%	100%	100%
Risk Value 0.5 million Euro	72%	80%	75%	73%
Risk Value 3.0 million Euro	142%	130%	138%	141%
50 dB(A)	154%	200%	168%	158%

Table 77: Change of total noise costs compared to the chosen approach

If a retrofit rate of 100% (instead of 75%) is assumed for the railways for the forecast 2010, the average rail cost will improve slightly by about 10%.

c) Air pollution

There are several uncertainty ranges to consider:

- Variation of VSL: The share of mortality within health costs is 74%. If we include a higher VSL (3 million Euro), the health costs would increase by 74%, increasing total air pollution costs by 59%. If we take a lower value for VSL (0.5 million Euro), the health costs would decrease by 50%, leading to a decrease of total air pollution costs by 40%.

- Addition of damages to forests: Within the baseline estimations, the damages for forests (due to their uncertainty) was not included. These costs, based on (rough) estimations for Switzerland (and validated with Swedish values), would amount to 24 billion Euro for 1995, leading to an increase of total air pollution costs of 19%.
- PM_{10} emissions by abrasion of railways are very uncertain. In this study a value of 0.2 g/vkm was used. Newest experiments (Carbotech 1999, unpublished) talk about values of up to 5 g/vkm. Using 5 g/vkm, average health costs of rail would approximately double.

d) Climate change

The sensitivity analysis considers the scenarios mentioned in chapter 2, which focus the spread of avoidance costs and in addition somewhat different avoidance costs according to political reduction aims. The following table shows the implications for the different transport modes. The assumptions are quite sensitive, since the unit values vary between 9 and 200 Euro per tonne of CO_2. Besides climate change costs, as well a part of upstream effects is concerned, which vary with the fossil energy intensity and thus with climate change costs. Most sensitive is the choice of the different scenarios for air transport, where total costs might spread between +36% and -73%. For rail, the reduction is more sensitive than for road. Total rail cost would be increased (choosing the max scenario) by 12% or reduced (choosing the lowest scenario) in maximum by 40%.

	Change of climate costs	Change of total cost						
		Passenger			Freight			
Cost per tonne CO_2		Road	Rail	Air	Road	Rail	Air	Water
Min (70 Euro)	-48%	-9%	-12%	-36%	-10%	-12%	-36%	-10%
Max (200 Euro)	+48%	+8%	+12%	+36%	+10%	+12%	+36%	+10%
Kyoto – 8% (37 Euro)	-73%	-12%	-18%	-52%	-14%	-11%	-51%	-20%
Joint Implementation (9 Euro)	-93%	-21%	-40%	-73%	-25%	-29%	-72%	-36%
Damage costs ExternE (28 Euro)	-79%	-18%	-34%	-62%	-21%	-25%	-61%	-30%

Table 78: Climate change sensitivity: Consideration of the scenarios (see chapter 2): Reduction of climate change costs and total/average costs compared to the main estimation.

e) Nature and Landscape

Besides the repair cost approach, also prevention costs and willingness to pay approaches were roughly estimated. The prevention cost approach would lead to results with are 3.1 times higher (rail) resp. 2.5 times lower (road). The main reason is that the prevention cost approach does not take a basic network (year 1950) into consideration. Thus the rail and road network is treated in a similar manner. On the other hand, the chosen approach does consider repair costs for rail areas, which are usually – from a biological point of view – rather superior than the road areas, since the impacts of rail in the surrounding area are quite moderate compared to road.

The willingness to pay approach would lead to much higher values for all transport modes. In total the values would be 6 times higher.

f) Congestion

The figures of total and average congestion costs imply several uncertainties, which stem from the use of model results for the estimation of congestion costs, from the application of two different approaches for urban and inter-urban traffic, from the poor data situation for urban areas and from the assessment of users. and shippers. time preferences.

- Among these items, the error made by using a artificially loaded road network instead of referring to reports of traffic jams is rather small. The highest uncertainty comes from the different quality of network representations in the model. As stated in section 3.2, this effect has already most likely led to an under-estimation of inter-urban congestion costs in Britain, which might range between 10% and 20%.
- The overlapping of the two approaches applied for inter-urban congestion (based on traffic flow observations) and for urban congestion (based on average costs and estimated urban traffic volumes per country) might lead to a much bigger estimation error. It can be argued that the vast amount of congestion-affected commuting traffic is captured in the traffic networks and hence included in the inter-urban figures, so it is not quite clear to which extend the two approaches overlap. Anyway, it is much more probable that this problem leads to an under- than to an over-estimation of congestion.
- Quite more difficulties are caused by the lag of data required to built up a sophisticated model for urban congestion, which can be applied to the whole western European area. As this is a general problem which is not sufficiently solved yet, it must be stated that there is a need for further research on the topic of urban congestion. The general feeling is that urban congestion in big cities is under-estimated by the approach used, while on the other hand small cities might be over-calculated. It is assumed, that these effects in average equal out.
- Finally it should be stated that also the approach towards the calculation of the opportunity costs of congestion suffers from the difficulties in expressing people's preferences in monetary units. The value of time as the all-decisive cost factor is estimated very differently in national studies and investment manuals.

Considering these remarks it is likely that the results of the present study in the field of congestion costs are slightly under-estimated.

7.3. Concluding remarks

Estimations of external costs on a European scale face several challenges. Firstly a solid and comparable data basis is needed for all countries and all transport means. Secondly robust dose-response-functions and valuation principles for different cost categories are necessary in order to produce defendable results. Although the situation in comparison to previous studies has significantly improved, it is still important to interpret the results in an appropriate manner.

Most important are the relations between different means of transport. Inspite of several uncertainties, the relations remain stable and show the level of specific external costs. Within passenger transport railways are still the means of transport with the lowest level of external costs, although the values are significantly higher than in previous studies. Within freight transport rail and waterways transport are sharing this position.

The comparison shows as well the relevance of different cost categories. It is not surprising that the better known externalities (accidents, noise) remain rather stable, whereas the risks of air pollution and climate change has led to increased costs. One important reason is that research in natural science, in emission data procedures and in cost estimation has been concentrated on these issues in the past years. Especially health costs or future climatic changes are a rather new and recent research field. This effect will hold on. It is possible that in future new risks have to be added and integrated in cost estimations.

If we consider a trend growth, total and average costs will increase, despite of improved productivity and technology. Although this might be surprising at first sight, there are mainly three reasons for that. Firstly the trend of traffic growth will hold on and will increase total pollution levels in different areas. Secondly the willingness to pay (the care for scarcity, security and nature) will increase as well. In economic terms the willingness to pay will increase and will lead to higher unit values. Although it is difficult to say by which degree this will be the case, the direction is very clear. Thirdly we have to consider that productivity will increase in future for all transport means, but in different directions. There are some specific effects to consider which might offset the positive impacts. In passenger transport for example increased motorization and new forms of (more individual) leisure transport might lead to lower occupancy rates, increasing average costs. In freight transport similar effects are possible with increased degrees of globalisation and increased requests for logistic chains.

In this report average costs and marginal cost are compared for the first time. It came out that the definition of marginal costs plays a major role for this comparison.

Whereas it is very obvious that marginal costs differ from average costs for congestion and noise costs, since dose-response- and thus cost-functions are not linear, it is rather difficult to say such things for other cost components like for instance air pollution or climate change. There are however two other elements which became visible doing this comparison. Firstly the marginal cost approach – being mainly a bottom up approach – is very appropriate to provide differentiated results for different type of vehicles and different traffic situations, in order to make visible the range of costs. Secondly it is helpful to distinguish between short term impacts (directly related to the amount of traffic) and long term impacts (which consider production and life cycles as well). This is especially true for additional effects considered like nature and landscape of up- and downstream processes.

Finally one can state that it is very necessary to read, understand and interpret the results in a 'top down manner'. The general statements made above are very robust and should help to provide a sound basis for further cost estimation on the one hand and for policy implications (especially in the field of pricing) on the other hand. However it has to be considered at the same time that aggregated results are much more robust than disaggregated results, for example for specific countries or for specific traffic situations, since these values are derived from aggregated results. Thus the more detailed the results are, the more specific and thus the more illustrative they should be interpreted.

The study has as well shown the strengths and weaknesses of the estimation of external costs which is useful for future studies. We can conclude the following major issues to be treated more in-depth:

- National accounts and marginal costs for different traffic situations: The purpose of the estimation and the approach is quite different. Whereas the former can be used as a statistical and strategic information on national level, the latter is directly relevant for pricing issues. The comparability of the approaches should be improved. There is also more information needed about the shape of the cost curves varying with the most important factors of influence.
- Risk values: Being one of the most critical assumptions in estimating external costs, the definition of the risk values needs a lot of accurate evidence including political and societal discussions.
- Air pollution costs: As already mentioned above, there is more research needed for the particulate matter (modelling, relevance of different particulate) for the estimation of health costs. In addition the other cost elements (especially building damages, damages to biosphere) have to be improved by new estimations on dose-response-relations.
- Costs of climate change risks: An in-depth discussion is necessary on the question of the target level to be chosen being the main element of cost uncertainties.
- Congestion: Although there is enough evidence to estimate marginal congestion costs, the relevance of total (external) congestion costs is still not discussed entirely.

- Other external costs: Upstream effects are in certain cases considered especially for fuel production and for electricity production used by electric trains. Due to lack of scientific data, electricity used for vehicle production by example is not considered. Although their relevance is quite limited in comparison to the main cost categories, it is important to include them more accurately in future in order to communicate their levels properly.

Annex

1 General input data

1.1 Socio-Economic Data:

1995 Country	GDP 1), 3) [billion Euro]	Population 1) [1000]	GDP/ Capita [Euro]	Currency	Foreign exchange rate 1) [Euro]	Country Adjustment Factor EUR 17 = 100
Austria	178.50	7'968	22402	S	13	106.8
Belgium	205.90	10'113	20360	bfr	38.55	110.7
Denmark	132.50	5'180	25579	dkr	7.33	114.6
Finland	95.60	5'107	18719	Fmk	5.71	94.7
France	1'176.20	57'981	20286	ff	6.53	106.1
Germany	1'845.20	81'590	22616	DM	1.87	109.1
Greece	87.40	10'451	8363	Dr	302.99	64.8
Ireland	49.20	3'553	13847	Ir£	0.82	91.7
Italy	831.40	57'187	14538	Lit	2130.1	104.7
Luxembourg	13.30	405	32840	lfr	38.55	166.7
Netherlands	302.50	15'503	19512	hfl	2.1	105.7
Norway 2)	112.30	4'338	25888	nkr	8.27	120.7
Portugal	76.90	9'823	7829	Esc	196.11	66.3
Spain	428.10	39'621	10805	Ptas	163	75.7
Sweden	176.30	8'780	20080	skr	9.33	99.5
Switzerland 2)	236.40	7'202	32824	sfr	1.54	132.0
United Kingdom	842.40	58'258	14460	£	0.83	94.5
Total EUR 17	**6'790.10**	**383'060**	**17'726**			**100.0**

Data source *1) Statistisches Bundesamt Wiesbaden: Statistisches Jahrbuch 1997 für das Ausland*
2) Norway, Switzerland: OECD, Main Economics Indicators, 1960-1996
3) Gross Domestic Produkt at market prices 1995

Table 79: Socio-economic data framework (1995)

1.2 Transport Volume

1.2.1 The TRENDS database

TRENDS (**TR**ansport and **EN**vironment **D**atabase **S**ystem) is an EUROSTAT project funded by EU DG Transport. The final aim of the project is to produce a range of transparent, consistent and comparable environmental pressure indicators caused by the various modes of transport:

- Modes of transport: Road, rail, shipping and air transport, (different type of vehicles, passenger and freight transport),
- Countries: EUR 15 (Switzerland and Norway added separately),
- Environmental nuisances:
  - Air emissions (CO, CO_2, NMVOC, CH_4, NO_x, SO_2, Pb, PM_{10})
  - Noise emissions,
  - Waste production.
- Time span: 1990-2020.

The calculation system including the methodologies and related databases has to be transferred in a computer model within a PC-based MS Access environment.

The project has started 1998 and will continue until 2001. For the time being, consistent data for the road transport sector is available and used within this report. The fleet characteristics are based on a former EUROSTAT project called MEETS.

1.2.2 Transport volumes 1995

Road:

Road 1995	**Transport Volume 1995 (pkm and tkm)**					**Kilometrage (vkm) 2)**				
Country	Car 1)	MC 1)	Bus 1)	LDV 3)	HDV 3)	Car	MC	Bus	LDV	HDV
	million pkm	million pkm	million pkm	million tkm	million tkm	million vkm	million vkm	million vkm	million vkm	million vkm
Austria	76'779	839	12'499	580	82'201	51'864	743	417	1'935	8'349
Belgium	101'983	919	4'079	2'218	56'236	70'067	836	352	7'392	11'270
Denmark	57'797	416	13'615	875	47'747	31'077	333	682	2'916	5'389
Finland	29'506	900	8'224	922	21'350	21'061	900	637	3'075	3'432
France	543'996	6'883	58'213	23'070	183'945	292'390	6'328	3'143	76'899	39'743
Germany	733'036	12'800	83'491	7'756	303'983	508'529	12'800	4'503	25'853	66'565
Greece	66'355	910	2'754	3'468	52'509	33'508	867	257	11'559	7'122
Ireland	31'580	286	1'868	373	19'198	18'491	260	221	1'245	2'617
Italy	602'035	7'650	57'350	10'121	245'399	319'891	5'905	3'386	33'738	44'571
Lux.	5'380	37	711	56	4'764	3'368	33	40	186	700
Netherl.	111'873	1'200	9'950	53	116'541	68'566	1'200	448	176	15'576
Norway 4)	43'436	724	3'956	636	9'327	23'943	644	350	2'121	1'660
Portugal	92'599	1'578	11'537	1'489	31'338	37'657	1'170	417	4'965	7'943
Spain	308'161	1'960	33'122	19'616	155'100	152'820	1'454	1'316	65'386	27'634
Sweden	80'840	509	10'928	2'856	31'232	49'368	509	827	9'520	6'655
Switzerland 5)	73'194	1'926	7'029	838	12'284	43'794	1'728	375	2'794	2'186
UK	504'730	4'000	42'306	10'419	214'372	304'837	4'000	4'770	34'731	31'085
Total EUR 17	**3'463'280**	**43'537**	**361'632**	**85'347**	**1'587'527**	**2'031'231**	**39'711**	**22'141**	**284'491**	**282'498**

Sources:
1) Own Calculation, based on load factors and on TREND kilometrage
2) Source: TRENDS: Transport and Environment Database System, DGVII
3) Own estimation on basis of load factor of different HDV types (3.5-7.5t, 7.5-16t, 16-32t, >32t) and vehicle km (TRENDS)
4) Norway: Light/Heavy Duty Vehicles share: estimation on Swiss data base
5) Bundesamt für Statistik, Verkehrsstatistik Schweiz, 1995

Table 80: Road transport volume (1995)

Rail:

Rail Traffic 1995 Country	Pass.-km million pkm	Tonne-km million tkm	Total Train km [1000]
Austria	9'628	13'100	128'052
Belgium	6'757	7'300	87'551
Denmark	4'784	2'000	59'427
Finland	3'184	9'600	40'972
France 1)	59'100	49'100	483'595
Germany	68‘310	69'800	856'441
Greece	1'568	300	12‘831
Ireland	1'291	600	13'347
Italy	49'700	21'700	325'055
Luxembourg 2)	286	500	7'208
Netherlands	13'977	3'100	117'794
Norway	2'381	2'700	36'568
Portugal	4'809	2'000	37'199
Spain	15'313	10'000	161'073
Sweden	6'219	18'500	100'345
Switzerland 3)	13'408	8'686	194'169
United Kingdom 4)	29'216	12'500	411'700
Total EUR 17	**290'000**	**231'500**	**3'073‘327**

Source: UIC (1995)

1) Average of 1994 and 1996, as 1995 figures are lower due to strikes in France and thus not representative
2) Luxembourg: pkm = estimates
3) Switzerland: Bundesamt für Statistik (1995)
4) UK: Department of Environment, Transport and the Regions. Bulletin of Railway Statistics. Quarter 3 (1998/9).

Table 81: Rail transport volume (1995)

Aviation:

Aviation 1995	LTO (in thousand)			pkm (in mio)			tkm (in mio)		
Country	Commercial Air Transport								
	national	intern.	total	national	intern.	total	national	intern.	total [1)]
Austria	6.6	65.0	71.6	108	11218	11326	0.2	137.1	138.0
Belgium	0.1	110.9	110.9	0	17504	17505	0.0	617.7	617.8
Denmark [4)]	31.2	87.5	118.7	807	16269	17076	17.0	343.4	422.9
Finland	25.6	30.9	56.5	621	7095	7716	2.0	115.6	124.7
France	217.3	281.4	498.7	10345	64329	74674	98.1	1585.9	2043.7
Germany	292.6	428.1	720.7	10448	101737	112185	136.7	2406.0	3044.0
Greece [5) 6)]	28.8	32.1	60.9	1064	9380	10444	9.7	100.4	145.7
Ireland [7)]	7.9	56.7	64.6	169	11995	12164	2.5	118.7	130.3
Italy [5)]	117.4	142.0	259.4	5461	36292	41753	24.3	651.3	764.8
Luxembourg	0.0	18.3	18.3	0	1694	1694	0.0	401.8	401.8
Netherlands	5.4	140.0	145.4	44	34594	34638	0.0	1427.0	1427.0
Norway [5)]	95.2	36.9	132.1	2960	8019	10979	11.5	75.5	129.1
Portugal	17.2	53.4	70.6	677	14811	15488	7.6	147.1	182.6
Spain	194.7	212.6	407.3	9182	71116	80298	54.9	353.7	610.1
Sweden	71.3	72.9	144.1	2264	13350	15614	8.7	160.4	201.0
Switzerland	20.6	133.5	154.1	551	26726	27277	12.3	533.4	590.9
UK [6)]	152.2	407.2	559.4	5275	135262	140538	27.2	2258.1	2385.2
Total EUR 17	**1284**	**2309**	**3593**	**49976**	**581391**	**631367**	**413**	**11433**	**13360**

Source: ICAO Digest of Statistics No 442: AIRPORT TRAFFIC 1995 (Part B, yellow pages): SUM OF ALL AIRPORTS

Average flight distance: national =300 km; international = 1400 km

1) including crop dusting, aerial photography, pilot training, business and executive flying, military aircrafts

4) Denmark: allocation to natl. and int'nat. passengers based upon data of 1992. Allocation for freight and mail based upon passenger data

5) Greece. Italy, Norway: natl. and int. movement data and mail data of 1992-1994.

6) Greece: Grand total = commercial air transport only.

7) Ireland, Spain: mail allocation based on freight data

Table 82: Air transport volume (1995)

Waterborne Traffic:

Inland Waterways Country	Transport Volume 1995 Goods Transport [1000 million tkm]
Austria	2.1
Belgium	5.6
Denmark	
Finland	3.3
France	5.9
Germany	64
Greece	
Ireland	
Italy	0.1
Luxembourg	0.3
Netherlands	34.5
Norway	
Portugal	
Spain	
Sweden	
Switzerland	
United Kingdom	0.2
Total EUR 17	**116**

Table 83: Waterborne transport volume (1995)

1.3 Additional Traffic Data

Road Loading Factors:
TRENDS provides most road traffic data, but not loading factors and net loading of freight vehicles. For Passenger transport, national statistics and Eurostat database have been considered (cars average 1.7 p/veh., see Table 85). For freight transport, the assumptions shown in Table 85 have been made. Kilometrage of corresponding freight vehicles are given in TRENDS database, so that a resulting HDV loading factor can be calculated (see also Table 85). Other sources confirm these results, leading to relatively low loading factors.

Load Factors: (Road)	Car pas/veh	MC pas/veh	Bus pas/veh	LDV t/veh	HDV t/veh
Austria	1.48	1.13	30.0	0.30	9.8
Belgium	1.46	1.10	11.6	0.30	5.0
Denmark	1.86	1.25	20.0	0.30	8.9
Finland	1.40	1.00	12.9	0.30	6.2
France [1)]	1.86	1.09	18.5	0.30	4.6
Germany	1.44	1.00	18.5	0.30	4.6
Greece	1.98	1.05	10.7	0.30	7.4
Ireland	1.71	1.10	8.5	0.30	7.3
Italy	1.88	1.30	16.9	0.30	5.5
Luxembourg	1.60	1.10	17.7	0.30	6.8
Netherlands	1.63	1.00	22.2	0.30	7.5
Norway	1.81	1.12	11.3	0.30	5.6
Portugal	2.46	1.35	27.7	0.30	3.9
Spain	2.02	1.35	25.2	0.30	5.6
Sweden	1.64	1.00	13.2	0.30	4.7
Switzerland	1.67	1.11	18.7	0.30	5.6
United Kingdom	1.66	1.00	8.9	0.30	6.9
Total EUR 17	**1.74**	**1.12**	**17.2**	**0.30**	**5.62**

1) Interurban roads

Table 84: Loading Factors of Road vehicles.

Loading Factors LDV / HDV:	Loading [t]	Loading %	Real Loading [t]
Light Duty Vehicles (<3.5t)			**0.3**
Heavy Duty Vehicles:			
3.5 -7.5 t	3.5	40%	**1.4**
7.5 – 16 t	9	40%	**3.6**
16 - 32 t	22	45%	**9.9**
> 32 t	34	60%	**20.4**

Sources:
- BMUJF, Umweltbilanz Verkehr in Österreich 1950 - 1996, technischer Bericht, 1997.
- Heusch/Boesefeldt: Nutzfahrzeug-Jahresfahrleistungen 1990 (1986) auf den Strassen der Bundesrepublik Deutschland.
- Bundesamt für Statistik, Verkehrsstatistik Schweiz (1995)

Table 85: Assumption for loading factors of freight vehicles

Railway Energy Consumption:

1995	Diesel 1000 t Diesel	Electric million kWh
Austria	47	2011
Belgium	57	1039
Denmark	115	230
Finland	56	419
France	259	6353
Germany	653	8914
Greece	32	
Ireland	28	18
Italy	132	4654
Luxembourg	6	49
Netherlands	20	1158
Norway	32	405
Portugal	57	232
Spain	93	1842
Sweden	23	1496
Switzerland	9	1717
United Kingdom	415	2586
Total EUR 17	2034	33123

Table 86: Energy Consumption of Railways (source: UIC 1995/96 supplementary statistics).
1 tonne of Diesel = 42.8 GJ

1.4 Trend 2010

Growth of GDP per capita

Country	GDP per Capita 1995	GDP per Capita 2010	Change
Austria	22402	31333	+ 39.9%
Belgium	20360	28702	+ 41.0%
Denmark	25579	36090	+ 41.1%
Finland	18719	27286	+ 45.8%
France	20286	27919	+ 37.6%
Germany	22616	30119	+ 33.2%
Greece	8363	11437	+ 36.8%
Ireland	13847	20617	+ 48.9%
Italy	14538	20773	+ 42.9%
Luxembourg	32840	44907	+ 36.7%
Netherlands	19512	26323	+ 34.9%
Norway	25888	36418	+ 40.7%
Portugal	7829	12016	+ 53.5%
Spain	10805	16211	+ 50.0%
Sweden	20080	26915	+ 34.0%
Switzerland	32824	43199	+ 31.6%
United Kingdom	14460	20486	+ 41.7%
Total EUR 17	**17'726**	**24'608**	**+ 38.8%**

Table 87: GDP/capita growth 1995 – 2010 (PETS)

Traffic 2010: Road

Road Traffic 2010	**Car** million vkm	change to 1995	**MC** million vkm	change to 1995	**Bus** million vkm	change to 1995	**Light Duty Vehicles** million vkm	change to 1995	**Heavy Duty Vehicles** million vkm	change to 1995
Austria	85'676	*+ 65%*	937	*+ 26%*	454	*+ 9%*	2'598	*+ 34%*	11'208	*+ 34%*
Belgium	85'019	*+ 21%*	1'053	*+ 26%*	174	*-51%*	10'026	*+ 36%*	15'285	*+ 36%*
Denmark	35'247	*+ 13%*	420	*+ 26%*	954	*+ 40%*	3'408	*+ 17%*	6'298	*+ 17%*
Finland	27'631	*+ 31%*	1'134	*+ 26%*	645	*+ 1%*	4'357	*+ 42%*	4'864	*+ 42%*
France	329'224	*+ 13%*	7'977	*+ 26%*	3'438	*+ 9%*	95'829	*+ 25%*	49'527	*+ 25%*
Germany	621'890	*+ 22%*	16'134	*+ 26%*	5'281	*+ 17%*	31'391	*+ 21%*	80'822	*+ 21%*
Greece	46'656	*+ 39%*	1'092	*+ 26%*	127	*-51%*	14'473	*+ 25%*	8'917	*+ 25%*
Ireland	23'461	*+ 27%*	328	*+ 26%*	301	*+ 36%*	1'785	*+ 43%*	3'752	*+ 43%*
Italy	424'355	*+ 33%*	7'443	*+ 26%*	3'625	*+ 7%*	45'639	*+ 35%*	60'294	*+ 35%*
Luxembourg	5'097	*+ 51%*	42	*+ 26%*	52	*+ 30%*	197	*+ 6%*	741	*+ 6%*
Netherlands	78'703	*+ 15%*	1'513	*+ 26%*	520	*+ 16%*	244	*+ 38%*	21'554	*+ 38%*
Norway	30'179	*+ 26%*	812	*+ 26%*	373	*+ 7%*	2'796	*+ 32%*	2'162	*+ 30%*
Portugal	58'709	*+ 56%*	1'475	*+ 26%*	570	*+ 37%*	7'903	*+ 59%*	12'644	*+ 59%*
Spain	197'902	*+ 29%*	1'833	*+ 26%*	1'395	*+ 6%*	95'374	*+ 46%*	40'308	*+ 46%*
Sweden	61'572	*+ 25%*	642	*+ 26%*	744	*-10%*	13'254	*+ 39%*	9'265	*+ 39%*
Switzerland	55'200	*+ 26%*	2'178	*+ 26%*	399	*+ 7%*	3'682	*+ 32%*	2'848	*+ 30%*
UK	393'732	*+ 29%*	5'042	*+ 26%*	4'530	*-5%*	41'983	*+ 21%*	37'576	*+ 21%*
Total EUR 17	**2'560'253**	***+ 26%***	**50'053**	***+ 26%***	**23'583**	***7%***	**374'936**	***+ 32%***	**368'066**	***+ 30%***

Table 88: Road Traffic 2010 (Source: TRENDS database).

Traffic 2010: Rail

Rail 2010	pkm million pkm	tkm million tkm	1995 – 2010 Passenger (%)	Freight (%)
Austria	15'905	13'100	+ 65%	0%
Belgium	8'199	7'300	+ 21%	0%
Denmark	5'426	2'000	+ 13%	0%
Finland	4'177	9'600	+ 31%	0%
France	66'542	49'100	+ 13%	0%
Germany	83'538	69'800	+ 22%	0%
Greece	2'183	300	+ 39%	0%
Ireland	1'638	600	+ 27%	0%
Italy	65'930	21'700	+ 33%	0%
Luxembourg	433	500	+ 51%	0%
Netherlands	16'043	3'100	+ 15%	0%
Norway	3'001	2'700	+ 26%	0%
Portugal	7'497	2'000	+ 56%	0%
Spain	19'830	10'000	+ 29%	0%
Sweden	7'756	18'500	+ 25%	0%
Switzerland	16'900	8'686	+ 26%	0%
United Kingdom	38'294	12'500	+ 29%	0%
Total EUR 17	**363'293**	**231'500**	**+ 26%[1)]**	**0%**

1) like private cars

Table 89: Rail Traffic 2010 (see chapter 2.1.6)

Traffic 2010: Aviation

Annual Growth Rate 1995 - 2010: pkm:	**+5.0%**								
Annual Growth Rate 1995 - 2010: vehicle km:	**+4.1%**								
Annual Growth Rate 1995 - 2010: departures:	**+2.3%**								
Aviation 2010	**LTO (in thousand)**			**pkm (in mio)**			**tkm (in mio)**		
Country	Commercial Air Transport								
	national	intern.	total	national	intern.	total	national	intern.	total
Austria	9	91	101	224	23'322	23'546	0	285	287
Belgium	0	156	156	1	36'390	36'391	0	1'284	1'284
Denmark	44	123	167	1'678	33'822	35'500	35	714	879
Finland	36	43	79	1'291	14'750	16'041	4	240	259
France	306	396	701	21'507	133'735	155'241	204	3'297	4'249
Germany	412	602	1'014	21'721	211'503	233'225	284	5'002	6'328
Greece	41	45	86	2'211	19'500	21'711	20	209	303
Ireland	11	80	91	351	24'937	25'288	5	247	271
Italy	165	200	365	11'353	75'449	86'802	51	1'354	1'590
Luxembourg	-	26	26	-	3'522	3'522	-	835	835
Netherlands	8	197	204	92	71'918	72'010	-	2'967	2'967
Norway	134	52	186	6'153	16'671	22'824	24	157	268
Portugal	24	75	99	1'408	30'790	32'198	16	306	380
Spain	274	299	573	19'089	147'845	166'934	114	735	1'268
Sweden	100	102	203	4'706	27'755	32'460	18	334	418
Switzerland	29	188	217	1'145	55'561	56'707	26	1'109	1'229
UK	214	573	787	10'967	281'201	292'168	57	4'694	4'959
Total EUR 17	**1'806**	**3'248**	**5'053**	**103'896**	**1'208'671**	**1'312'567**	**858**	**23'769**	**27'774**

Table 90: Aviation 2010 (source ICAO)

Traffic 2010: Waterborne

No change to 1995 is assumed.

2 Detailed description of methodology

2.1 Accidents

2.1.1 Adjustment factors

Author	ECOPLAN 1991	Persson 1992	James 1991	Mattern 1988	IRTAD 1994
	Switzerland	Sweden	UK	Germany	Europe
Accidents	5.39	-	-	-	-
Injured	3.95	injured and disabled:		-	Light: 1.6
Disabled	1.30	2.3	2.6	-	Severe : 1.3
Killed	1.02	1	-	1.04	-

Table 91: Adjustment factors for road accidents

2.1.2 Estimation of Risk Value

Author/Study	Country/Source/Method	Country Value		EUR 17 Average *	
Euro 1995		Median	Mean	Median	Mean
Empirical CV studies in Europe					
Jones-Lee et al. 1985	UK 1982	1.2	3.4	1.2	3.5
Maier 1989	AU 1988		3.8		3.5
Persson 1992	S 1986	1.3	2.9	1.3	2.9
Kidholm 1995	Dk 1993	2.0	2.5	1.7	2.1
Persson et al. 1995	S 1993	1.5	4.0	1.4	3.9
Desaigues, Rabl 1995	F 1993	0.9		0.9	
Schwab, Soguel 1996	CH 1994	1.1	2.7	0.8	2.0
Persson 1998	S 1998		2.0		2.0
Jones-Lee et al. 1999	UK 1997	0.5	1.7	0.5	1.8
Average of recent studies				**1.0**	**2.0**
Meta Analyses					
ExternE 1995	Average of selected studies	3.1		3.1	
Elvik 1993	Average of selected studies	1.3		1.3	
ECMT 1998	Average of selected official values	1.7		1.7	
Calthrop 1996	Average of selected studies	2.9		2.9	
Secondary studies and official valuations					
Quits 1998	ExternE	3.1		3.1	
PETS 1998	based on SNRA 1997	1.4		1.4	
SNRA 1997	Swedish Nat. Road Admin.	1.4		1.4	
INFRAS IWW 1994	Swedish Nat. Road Admin. 1992	1.3		1.3	
FISCUS 1997	based on INFRAS/IWW 1994	1.2		1.2	
DETR 1997	UK Department of Transport	1.0		1.1	
* weighted with PPP and number of fatalities					

Table 92: Overview of the Risk Values based on CV in Europe

		Share of Fatality	
		Severe injury	Slight injury
Empirical Studies			
Persson 1995	S 1989	17%	1.4%
O'Reilly 1994	UK 1991	10%	0.6%
Schwab, Soguel 1996	CH 1994	37%*	0.5%
Persson 1998	S 1998	17%	1.5%
Other Sources			
INFRAS/IWW 1995	S 1992	16%	0.4%
DETR 1997	UK Department of Transport	10%	0.8%
SNRA 1997	1997	18%	0.8%
ECMT 1998		13%	
PETS 1998	S 1997	16%	0.9%
Cost 313	EU 1990	7%	0.5%
* disabilities only			

Table 93: Risk Value for injuries as a share of the Risk Value for fatalities

2.1.3 Discussion of the Risk Value

During the past ten years a more cautious approach towards contingent valuations has been adopted. The empirical studies are sorted by their publishing dates. It is obvious that the values are declining during the last 10 years. Persson and Jones-Lee have revised their former findings in recent surveys that result in values reduced by 50% or even more. Therefore, the average of the empirical studies only includes surveys undertaken in the past decade and excludes older studies from both authors mentioned above. This average amounts to 1 million Euro for the median Risk Value and 1.9 million Euro for the mean values.

Four meta analyses estimate the Risk Value between 1.7 million Euro and 3.1 million Euro and a number of secondary studies and official valuations range between 1.1 and 3.1 million Euro.

With regard to the declining values in the 1990s it is surprising that in the ExternE study conducted a meta-analysis of contingent valuation and hedonic pricing studies of the 1970s and 1980s. The Risk Value was estimated by eliminating outliers and calculating the average of the studies (ExternE 1995, Vol. 2, p. 508). No distinction between mean and median values is made. The recommended Risk Value amounts to 3.1 million Euro (1995 price level). However, the authors state (p. 511) that "taking an average … is averaging unknown errors and one cannot say what the final impact will be."

The ECMT regards the meta analysis from Calthrop (1996) as the "best value". However, ECMT applies a conservative approach by using an average of official values for road investment CBAs. The values stem from the early 1990s in Finland, Sweden, UK, Switzerland and Austria. A comparison with values published by Cost313 shows that the chosen Risk Value is well above the European average. This might be due to the fact that only a share of the values is considered to be external. E.g. Sweden regards the costs of self inflicted victims as internal costs.

The reasons for a more cautious approach towards CV were debated in 1994 on an international conference on "valuing the consequences of road accidents" held in Neuchâtel, Switzerland (Schwab, Soguel 1995). Dubourg (1995) conducted an empirical survey in the UK to evaluate the WTP for a risk reduction in accidents. He examines the imprecision of WTP statements which stem from the fact that "individuals rarely have the experience of repeated transactions with which to develop and refine their preference for non-market goods" (p. 138f). The author concludes that "valuation intervals are not only extremely wide, suggesting significantly imprecise preferences, but also particularly unstable, to the extent that they appear to be a direct function of the details of the elicitation methods employed".

This realisation is corroborated by Jones-Lee, one of the most senior researchers in the field of monetarisation of accident risks. The author is concerned by the fact that approximately 40% of the respondents in his first study (1985) reported identical WTP for two very different levels of risk reductions. " … Prominent … was a failure on the part of many respondents to take account of the magnitude of the risk reduction in CV questions … As a consequence of this, the estimated Risk Value for road risks could be increased over 100% simply by reducing the risk reduction posed in the CV question by a factor of three…" (Jones-Lee et al. 1999).

Country	**Risk Value in 1000 Euro (1990)**
Austria	796
Belgium	15
Denmark	419
Finland	864
France	164
Germany	905
Luxembourg	465
Netherlands	142
Norway	340
Portugal	203
Spain	58
Sweden	517
Switzerland	1345
UK	658
EU Average	**479**
Source: Cost 313	

Risk Values officially used for transport

These statements are corroborated by a UK study (O'Reilly et al. 1994) which compares the results of two theoretically equal methodologies to assess the marginal rate of substitution between fatalities and injuries: contingent valuation and standard gamble. A comparison of the two methods reveals a disparity with the results of the CV being 1.5 –10.5 times greater than the standard gamble. The author concludes that "… this disparity is almost certainly a reflection of substantial and systematic upward biases in the CV responses" (1995a, p. 124) and "… it is unwise to proceed as if most members of the population have stable, well behaved and highly articulated preferences which can be readily accessed by standard questionnaire surveys" (1995, 131).

Kidholm (1995, p. 59) confirms that the Danish CV estimates "seem to be biased upwards and the respondents appear to have problems understanding the differences in initial risk". In a review of CV studies, Schulze et al. (1994) found overestimations by factors around 2.5.

Desaigues and Rabl (1995) conducted about 1000 face-to-face interviews in France. The interviewees were asked how much additional taxes they would be willing to pay in order to save 50, 100, 500 and 5000 lives in France. "The resulting value … varies by a factor 20 depending whether the number of lives to be saved is 50 or 5000". The following patterns of the respondents answers were observed:

- 41% gradual increase of WTP with clustering around currency values (FF50, FF100, etc.)
- 36%: saturation of budget with increasing risk reduction during interview
- 19%: lump sum pattern: same WTP regardless how many lives saved
- 4% : constant WTP/life

Desaigues and Rabl found that the biases can be partly corrected with a Box-Cox transformation and the results are close to median WTP. In their survey three quarters of the respondents would have a lower WTP than the estimated mean WTP. Therefore, the authors emphasise that the "median appears more equitable".

Two major studies have been conducted after this conference taking into account the above mentioned problems concerning the CV methodology.

Persson (1995, p. 80) had found similar problems concerning the reference point of risk reductions in his studies in Sweden. In order to avoid these problems, he conducted a survey (1998) in which he asked the subjects to assess their own risk to be injured in a road accident and than state its WTP for a risk reduction. The returning 2884 questionnaires where analysed and those WTP statements excluded which were above 5% of the household's income. A regression revealed an exponential nexus between risk reduction and WTP. Persson regards a risk reduction of 30% starting from an initial risk of 8/100,000 as the relevant WTP, since it reflects the security improvements from new road investments.

However, the survey raises doubts whether above-mentioned reservations regarding the CV methodology have been met:

- The questionnaire asked directly about the WTP to reduce fatal risks. Respondents might not be able to give valuable answers for this highly abstract question.
- The survey uses postal questionnaires instead of personal interviews. Due to the absence of an enumerator the respondents could pose no questions.
- Even though the extreme values have been deleted, the regression reflects a mean value rather than a median. Surprisingly regression using 24 clusters with median

values produced considerable higher values. The author gives no explication for this phenomenon.

- The quality of the regression, represented by the regression coefficient is not given in the study.
- A linear regression results in a considerable lower Risk Value. The regression coefficient is missing as well.

The second study taking into account the criticism on the CV method was conduced by Jones-Lee et al. (1999) who developed a new survey methodology that combines CV and standard gamble. In a first step 167 households in the UK were interviewed on a one to one basis in 1997. They were asked about their WTP for a quick cure of a particular non-fatal road injury and their willingness to accept compensation (WTA) for sustaining the injury. In a second step the underlying preferences of the respondents were revealed and the trade-off between risk and wealth for non-fatal injuries estimated. In a third step the respondents were presented with standard gamble questions aimed at eliciting their willingness to trade off risk of the non-fatal injury against the risk of death[49]. Finally step two and three were combined to assess the Risk Value.

This study has the following advantages:

- CV questions are not related to fatalities, but to non-fatal injuries that most people can fairly readily conceptualise on the basis of their past experience.
- Respondents are not required to trade off money directly against changes in risk.
- The standard gamble questions are framed entirely in the domain of risk and is more a comparison of 'like with like'.
- The survey focuses entirely on the respondent’s own circumstances and avoids public goods problems.

The research revealed a range of the Risk Value from 0.5 million Euro (median value) to 1.8 million Euro (mean value). The results are characterised by the authors as "reasonably robust".

Conclusion:

- During the last decade a more cautious approach towards CV methods for the evaluation of Risk Value has developed, which resulted in a lower estimation of the WTP to prevent accidents.
- The scientific research indicates that CV surveys seem to overestimate the WTP for the Risk Value.
- A combination of standard gamble and CV seems to produce more stable results.

49 For the methodology compare Jones-Lee et al. (1993 and 1995b)

2.1.4 Risk Value for relatives and friends

A recent study by Schwab and Soguel (1996) offers a broader approach by including a WTP for the loss of a friend or relative. Before this study was conducted "respondents have always played the part of potential victims. As a result the WTP to avoid grief caused by the possible injury or death of a relative or friend has never been stated" (p. 278). The study that the death of a friend or relative is a more dramatic event than one's own death.

Jones-Lee (1991) criticises this altruistic approach from a utilitarian viewpoint. In his theoretical paper he proves that “to push the values for safety beyond the level implied by people’s willingness to pay for their own safety would result in an over provision of safety relative to the other determinants of their utility ” (p. 217). The inclusion of relatives and friends can be only justified for people who disregard those factors besides safety that contribute to their utility.

It can be argued that even a purely egoistic behaviour includes altruistic features and therefore the proposed methodology would entail double counting. Additionally, it has to be emphasised that any improvement of transport safety would not only be to the own benefit but also to the rest of the transport users.

The above outlined methodological critique might be the reason why most of the recent empirical surveys (Kidholm 1995, Desaigues, Rabl 1995, Persson 1998, Jones-Lee et al. 1999) do not include a WTP for relatives and friends. Therefore this study will not include any additional WTP for relatives or friends.

2.1.5 Other external costs

From the following costs components only the external part of the social costs is included:

- **Costs for medical care:** These costs comprise the costs for medical treatment before the person dies (in the case of a fatality) or until the person completely recovers from his/her injury. The medical costs are only partly covered by the transport insurance system; the rest is paid by the general health insurance, and should therefore be added to the external costs.
- **Replacement costs:** In addition to the medical costs, the costs for reintegration and/or shift of working-place for disabled persons have to be considered as external, if they are not covered by the transport insurance systems. In case of a fatality, the replacement cost at his/her former working-place are also assumed to be external, because the employer has to carry the cost for the victim's replacement.
- **Administrative costs:** These are costs for the police and justice which are not covered by the fines and fees paid by the party holding responsibility for the accident. Also, the administrative costs of insurance companies, which are distributed to all insured individuals, should be calculated as external costs. These costs only apply to registered accidents.

2.1.6 Internalised social costs

The following transfer payments reduce external costs:

- **Direct payments from the liability insurance of the party responsible**: daily allowances, pensions for the surviving dependants or disabled victims. The costs of the liability insurance are internalised through the insurance premiums paid by the vehicle owners.
- **Transfer payments: the personal insurance of the victim** (e.g. health insurance, accident insurance etc.) pay for the above listed costs. These costs are external, because the society pays for the insurance premiums. ECOPLAN (1991, p. 162) estimates that 90% of these costs are claimed back from the liability insurance of the party responsible. These transfer payments can be regarded as internalised.
- **Gratification payments are paid by the party responsible** of accidents to compensate for pain and suffering of the victim or their dependants. The amount paid in Switzerland is relatively small.

2.1.7 Total Accident Costs

		Reported		Not reported		All Injuries	
Euro 1995	Fatality	Severe Injury	Slight injury	Severe Injury	Slight injury	Severe Injury	Slight injury
Austria	1,747,968	221,080	19,485	5,513	957	140,243	15,209
Belgium	1,806,145	228,970	20,189	5,607	991	145,209	15,758
Denmark	1,817,824	236,389	20,901	5,099	1,022	149,655	16,313
Finland	1,499,062	195,233	17,267	4,154	844	123,578	13,477
France	1,693,845	218,809	19,356	4,607	946	138,484	15,107
Germany	1,779,037	225,705	19,904	5,491	977	143,125	15,536
Greece	999,612	132,998	11,814	2,213	574	83,954	9,220
Ireland	1,447,622	188,733	16,721	3,666	815	119,333	13,050
Italy	1,677,647	216,072	19,106	4,645	934	136,787	14,912
Luxembourg	2,818,449	346,748	30,425	10,262	1,504	220,566	23,751
Netherlands	1,704,984	218,465	19,285	5,078	945	138,445	15,053
Norway	1,996,254	250,251	22,019	6,672	1,084	158,909	17,188
Portugal	1,073,685	137,063	12,095	3,240	593	86,880	9,441
Spain	1,232,870	156,579	13,813	3,751	678	99,268	10,782
Sweden	1,627,484	206,274	18,155	5,439	894	130,961	14,172
Switzerland	2,319,787	276,446	24,110	9,922	1,203	176,500	18,824
UK	1,493,273	194,714	17,237	3,943	841	123,175	13,454

Table 94: External costs per casualty

	Fatalities			Severe Injuries		Slight Injuries	
	Road	Rail	Air	Road*	Rail	Road	Rail
Austria	1077	7	5	13,399	7	56,085	29
Belgium	1290	2	7	14,093	4	83,514	15
Denmark	518	4	7	4,911	2	8,063	7
Finland	393	3	3	2,690	1	11,259	3
France	7916	28	30	47,880	10	200,417	38
Germany	8417	30	45	136,281	17	564,373	69
Greece	2147	2	4	8,230	5	34,448	22
Ireland	389	0	5	3,345	1	14,001	5
Italy	6262	9	17	66,389	22	277,897	88
Luxembourg	61	0	1	487	2	1,391	7
Netherlands	1188	1	14	12,953	6	56,591	24
Norway	272	2	4	1,493	2	15,095	6
Portugal	2414	16	6	12,444	16	79,178	62
Spain	5120	3	32	39,452	2	124,475	7
Sweden	509	1	6	6,125	0	22,690	1
Switzerland	616	8	11	7,591	3	31,773	11
UK	3352	15	56	84,056	23	351,846	91
EU 17	41,940	131	253	461,817	121	1,933,099	484
Excluding causalities caused by non-motorised transport							

Table 95: Number of transport casualties in Europe

2.1.8 Accident Forecast 2010

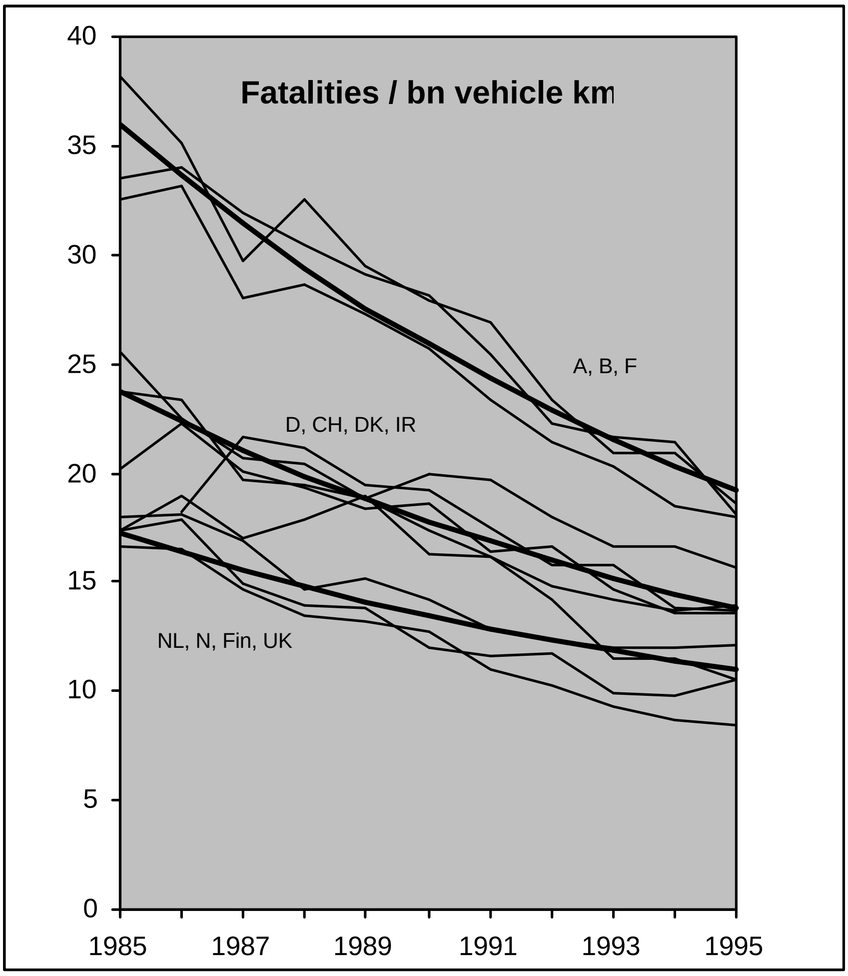

Figure 34: Estimation of road fatality rates 1985-1995

Table 96 shows the reduction of road accident rates until 2010. It is assumed that rates will decrease strongest (30%) in countries with very high accident rates. Average performing countries will experience a reduction of 5%.

Casualty rate 1995	**Reduction 2010**
Country Rate > 1.5 * European Average	10%
Country Rate > 2 * European Average	20%
Country Rate > 3 * European Average	30%
Else: average performing countries	5%

Table 96: Reduction of road accident rates in 2010

2.1.9 Marginal Accident Costs

Publication	Year/ Location	Traffic*	Accident rate function	Marginal / average rate	Remarks
Motorways					
Brilon 1976	Germany	veh/ hour	U shaped function	Ø = 0.66 var: -2.0 to 3.8 for < 2000 veh/h	
Brühning, Völker 1978	1968, 1970, 1973 Germany	ADT	Linear, slightly decreasing	1968: 1 1970: <=1 1973: <=1	1968: not significant 1970: α < 0.01 1973 α < 0.05
Leibnitz, Pöppel-Decker 1997	1995 Germany	ADT	slightly decreasing, no nexus (for ADT >10,000)	1 for ADT >10,000	α < 0.01
Winslot 1998	1995 Sweden	veh/ hour	Exponentially decreasing	1.19 - 0.28	
Interurban Roads					
Brilon 1976	Germany	veh/ hour	U shaped function	0.45 – 1.46 for < 1200 veh/h	traffic in both directions
Krebs, Klöckner 1977	Germany	ADT	linear decrease of rates	decreasing from 1.25 to 0.35	road width 7.25 - 8.75 m
Winslot 1998	Sweden	veh/ hour	Exponentially decreasing	1.19 – 0.41	
Urban Roads					
Taubmann 1987	Germany	ADT	slight exponential decline of rates	0.96	Urban transit roads
Dickerston 1998	London	ADT	constant for low volumes	low volumes: 1 high volumes: 1.4	Differentiation according to urban road types possible
* veh/ hour = traffic density at the hour of accident, ADT = Average daily traffic on road					

Table 97: Overview of studies on road accidents and traffic flow

Motorways

Brilon (1976) observed 5642 accidents on 10 sections of German motorways with a length of 126 km. He found that average accident rates have a U-shaped functional form. Driving accidents are highest on low volume sections (< 400 vehicles/h), while on segments with strong traffic, pile-up collisions dominate. Accordingly marginal rates fluctuate around zero for medium traffic volumes. Only sections with more than 2000 vehicles/hour show very high marginal accident rates.

Brühning (1978) published a survey about injury accidents on all German motorways in 1968, 1970 and 1973. The studies revealed that in 1968 no significant nexus exists between ADT and accident rates, i.e. the number of accidents are increasing proportionally with traffic volume. Same investigations in 1970 and 1973 show that the straight line of the regression has a minor downward slope, i.e. marginal rates nearly equal average rates.

Leipnitz and Pöppel-Decker (1997) corroborate these findings. The authors researched 42,000 accidents on German motorways. Winslot (1998) estimated accident rates on 83 Swedish road sections from 1989 to 1995. On Swedish motorways the following functions were estimated:

$$\text{Accident Rate: } AR(Q) = e^{-19.58} * Q^{-0.61}$$

Country roads
Brilon (1976) researched 984 accidents on 4 sections of German federal roads with a length of 30 km and a width of 7.5 m. Likewise on motorways, Brilon (1976) found a U-shaped function for accident rates on inter urban roads. Accordingly marginal rates fluctuate around Zero for low traffic volumes. Only sections with more than 12000 vehicles/hour show very high marginal accident rates. These findings can be compared to Krebs and Klöckner (1977) who observed a linear decrease of average and marginal accident rates according to the following function:

$$\text{Accident Rate: } AR(Q) = 2.011 - 5.41*10^{-5} * Q$$

Winslot (1998) observed three rural road types. Marginal rates vary between 120% and 40 % of average accident rates.

Urban roads
Taubmann (1987) did a study about accidents in built up areas in the region of Baden-Württemberg, Germany. The study comprised 53,774 accidents on 2,115 km of major roads (local transit). He observed a slight exponential decline of accident rates with increasing traffic volumes. The marginal rates are constant and therefore the ratio marginal/average is constant at 96%.

$$\text{Accident Rate: } AR(Q) = 3.43 + 595.2 * Q^{-1}$$

Dickerson et al. (1998) analysed the accident rates in inner and outer London. The observed number of accidents increases proportional with traffic and thus average accident rates equal marginal rates. However, the authors found out, that a differentiation of urban road types changes the picture. While for low to moderate traffic volumes accidents increase proportionally, denser traffic produces higher marginal rates than the average.

Costs per accident
On motorways Brilon (1976) observes a U-shaped function which is turned upside down. The costs used by the author include damage costs as well and therefore might

distort the picture. Winslot (1998) is not able to identify any nexus between accident costs and traffic flow. On interurban roads two studies suggest no functional nexus and one study observes a U-shaped function. The author of the latter study does not indicate the significance of his results. Traubmann (1987) observes a slight decline of accident costs in urban areas. The costs per accident decrease by 2% for an increase of 1000 vehicles/day. Unfortunately Taubmann does not indicate the significance of his results.

Ratio of marginal and average accident costs

	Traffic Flow			
	low	medium	high	
Motorways				
Brilon 1976	0.34	0.84	6.62	
Brühning, Völker 1978	0.99	1.07	0.83	2
Leibnitz, Pöppel-Decker 1997	0.99	1.07	0.83	2
Winslot 1998	1.19	0.44	0.28	
Standard Deviation	*0.32*	*0.25*	*2.59*	
Interurban Roads				
Brilon 1976	1.99	0.62	2.57	
Krebs, Klöckner 1977	1.14	0.86	0.31	1
Winslot 1998	1.19	0.61	0.48	2
Standard Deviation	*0.39*	*0.11*	*1.03*	
Urban Roads				
Taubmann 1987	1.07	0.97	0.91	1
Dickerston 1998	0.97	1.04	1.34	2
Standard Deviation	*0.05*	*0.03*	*0.22*	
1. Own calculations using external costs for Germany				
2. Own calculations using average costs per accident				

Table 98: Ratio of marginal and average accident costs

2.2. Noise

Share of per capita income	50-55 dB(A)	55-60 dB(A)	60-65 dB(A)	65-70 dB(A)	70-75 dB(A)	>75 dB(A)	Average*	WTP per dB(A)
Empirical Studies								
Pommerehne 1986	1.4%		2.3%		3.9%		2.0%	0.12%
Weinberger 1990	0.7%	1.2%	1.7%	2.2%	2.9%		1.6%	0.11%
Iten 1990	0.6%		1.6%		2.7%		1.2%	0.11%
Soguel 1994	0.2%	0.7%	1.1%	1.6%	2.0%	2.5%	1.1%	0.09%
IRER 1993	0.2%		1.3%		2.2%		1.0%	0.10%
					Average		**1.4%**	**0.11%**
Secondary Studies and other valuations								
Planco 1995	1.0%	1.3%	1.7%	2.1%	2.5%		1.7%	0.08%
INFRAS/IWW 1995		0.3%	1.3%	3.3%	6.6%		1.6%	-
SIKA 1995		0.7%	1.2%	1.7%	2.2%	2.7%	1.1%	0.10%
					Average		**1.5%**	**0.09%**
* weighted with population exposed to transport noise in EUR-17								

Table 99: Overview of noise cost evaluations

	Comments	**Target level dB(A)**	
Official targets in Europe		Day	Night
Sweden	Open air recreation	40	
Norway	Hospital, school	50-55	
Switzerland	Hospital, school, recreation	50	40
Denmark	Recreational areas	50	
Germany	Threshold value for noise calculation	50	40
France	Hospitals, health care	60	55
Belgium	Recreational areas	50	40
Greece	Urban strictly residential	50	
Italy	Hospital, school	50	40
Portugal	Hospital, school	65	55
Spain	Hospital, school	55	45
	Average	**52**	**46**
Scientific Studies:			
Weinberger 1990	Estimated as "nearly no noise" from WTP study	42	36
Soguel 1994	Derived from graph	48	
IRER 1993	Derived from graph	50	
Iten 1990	Derived from graph	50	
Pommerehne 1986	Derived from graph	35	
	Average	**45**	
Other studies and recommendations:			
INRETS 1994	Recommendations for new roads in sensitive areas, Europe	54	44
ECMT 1998	Baseline for external cost assessment	50	
PETS 1998	Recommendation for rural areas	55	45
SIKA 1995	Recommendation in Sweden	50	
ExternE 1995	Background noise level	45-55	40-45
WHO	Recommendation to avoid community annoyance	55	
Source for official targets: INRETS 1994			

Table 100: Target level for road noise in sensitive areas

Million Euro	Road		Rail		Air		All Modes		
	WTP	Health Costs	WTP	Health Costs	WTP	Health Costs	WTP	Health Costs	Total
Austria	349	391	11	9	20	23	**380**	**423**	**802**
Belgium	709	373	36	22	29	22	**775**	**416**	**1,191**
Denmark	193	173	7	4	10	7	**211**	**184**	**395**
Finland	84	106	16	17	13	14	**112**	**136**	**248**
France	3663	3145	46	38	161	119	**3,870**	**3,302**	**7,172**
Germany	5220	3462	568	160	300	311	**6,088**	**3,933**	**10,021**
Greece	195	118	4	2	12	8	**210**	**128**	**338**
Ireland	139	105	11	7	9	7	**159**	**119**	**278**
Italy	2616	1955	354	161	177	131	**3,147**	**2,248**	**5,395**
Luxembourg	30	10	1	0	2	1	**32**	**11**	**43**
Netherlands	617	190	24	19	446	146	**1,087**	**356**	**1,442**
Norway	174	140	1	0	4	1	**179**	**141**	**320**
Portugal	283	133	22	8	19	9	**324**	**150**	**474**
Spain	1231	921	88	48	83	62	**1,402**	**1,031**	**2,433**
Sweden	145	158	12	5	7	2	**164**	**164**	**328**
Switzerland	438	321	101	71	24	24	**563**	**417**	**980**
United. Kingdom	2683	1621	48	18	249	60	**2,979**	**1,699**	**4,678**
Total	18768	13322	**1348**	**589**	**1566**	**947**	**21683**	**14857**	**36,540**
	58%	42%	70%	30%	62%	38%	59%	41%	

Table 101: Breakdown of total noise cost

2.3 Air pollution

2.3.1 Review of existing studies

INFRAS, IWW (1995)
The method used in IWW/INFRAS (1995) to evaluate costs of air pollution for each country of EUR17 was based on the costs estimates for chosen countries. In order to adapt the cost figures to each country a correction factor considering the price level of each country and reference country as well as the ratio of emissions per square kilometre (as indicator for the damages to the ecosystem) and the ratio of urban densities as % of population living in urban area (as indicator for the health costs and damages to buildings) of both countries was used. The study considered the emissions of NO_x, VOC and SO_2 (SO_2 only for the estimate of prevention costs), but not the impact of particulates.

The reference costs figures were derived from three different cost estimates, which were calculated with the prevention and the damage costs approach. The average value of the upper and lower level of reference cost estimates was used for the country specific estimates.

Euro/1000 pkm-tkm	**Road**	**Rail**	**Air**	**Navigation**
Persons	1.9 – 10.3	0.6 – 3.5	1.4 – 8.6	
Freight	4.1 – 21.5	0.2 – 1.2		1.2 – 7.2

Table 102: Costs of air pollution related to transport mode (IWW INFRAS, 1995)

The reliability of the estimates depends basically on the reference studies resp. on the cost figures used. A linear relationship between emissions and impacts on health and ecosystems was assumed.

ECMT (1998)
ECMT (1998) gives an overview on recent studies in the field of estimates of external costs. Different approaches to derive shadow values for air pollution are presented: the damage and prevention costs approaches and approaches based on epidemiological damage studies.

Euro/1000 pkm-tkm	**Road**		**Rail**
	Petrol	Diesel	
Persons	7	5	2
Freight		20 – 23	1

Table 103: Average emission costs for NO_x, VOCs and particulates, based on a damage costs approach (ECMT 1998)

The air pollution damage costs of road transport were calculated also by an **alternative method**, using the particulate concentration in chosen European cities and estimates of total air pollution mortality in Europe. Due to a lack of data on PM10 concentration, three regions with different PM10 concentrations were distinguished. The air pollution related mortality rates were considered only for cities with a population of 50'000 or more. Further, it was assumed that transport emissions cause only 31% of total concentration. The value of life used in the report reflects income differences between European countries. The results of this alternative approach are lower than those achieved with the damage costs approach shown in Table 103, probably because of the restrictions of the cities considered.

FISCUS (1998)

In the framework of the analysis carried out for FISCUS[50] (1998) an overview of recent studies and an appraisal of the state-of-the-art in regard to **methodology** can be found. FISCUS distinguishes two main methodological approaches: a bottom up and a top down approach.

In FISCUS there is not an explicit distinction of unit costs or specific costs for different kind of externalities (impacts on health, buildings, ecosystems). The research is oriented towards urban case studies, without estimates of total damage costs of air pollution.

ExternE/IER (1998)

The objective of ExternE[51] is to quantify energy related external costs of transport with a bottom-up approach. Besides the direct impact of air pollution due to **vehicle use** (on which this chapter focus), the impacts of emissions of fuel production, vehicle manufacture, maintenance and support, infrastructure construction and maintenance are considered (see chapter 4.8).

The main working steps carried out for the estimate of external costs are similar to those:

- emission calculation,
- dispersion modelling,
- estimation of the impacts through exposure response functions and
- monetary valuation of the impacts.

A wide range of pollutants with their specific impact on human health, crops, materials, forests and ecosystem were considered. For each pollutant a specific

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50 Cost Evaluation and Financing Schemes for Urban Transport Systems, project founded by the European Commission, 4th framework programme.

51 Project founded by the European Commission in the framework of the Non Nuclear Energy Programme, JOULE III

exposure response slope was defined, based on the most latest available (epidemiological) researches. The exposure response functions are defined as linear and non-linear functions (the latter especially for damages to the ecosystem). These assumptions correspond to the most recent conclusions of different research studies (EIR 1998).

A model was developed which calculates the impacts of an increase of emissions on a specific road (road network is included by a GIS-programme), actual concentrations of pollutant, population density, actual traffic flows, etc. The model estimates the **marginal costs** of an increase of emissions, albeit total costs and average costs can also be calculated.

In the estimates, the Value of a Life Year Lost was considered for the economic valuation of the risk of dying from an acute illness. This approach is based on the Value of a Statistical Life (3.1 million Euro). The values used for morbidity impacts stem from new European studies and some US studies of the mid 1980s (the same cost figures are used to evaluate external accident costs).

The costs of soiling are calculated based on the willingness to pay per year to avoid the soiling damage respectively the cleaning costs per person per year (based on the cleaning costs data for Paris).

The visibility damage costs were quantified through a willingness to pay for visibility changes during the year.

Table 104 shows the results of country specific case studies which were calculated with the model.

Euro/1000 vkm	**Road**	**Rail**	**Air**
Persons	7.3 – 109	36.8 – 500.6	804.0
Freight LGV HGV urban HGV interurban	 20 – 133.8 219.3 – 912.6 53.9 – 343.5	91.0 – 723.1	

Table 104: External costs for different vehicle categories (ExternE, in CAPRI 1998)

The specific costs depend primarily on the trip (especially population density along the road) and the vehicle technology considered (vehicles with or without catalytic converters, petrol or diesel cars).

The figures are calculated with economic values which are based on willingness to pay studies. They represent therefore the total value of external costs (also non-use values are considered).

It can be concluded that ExternE represents a very complex and complete model for the estimation of external costs of air pollution. It is based on the most recent available researches on this field. Some damage costs, like soiling and building damages, will be analysed more deeply in the next months. The time schedule foresees the conclusion of the project by the end of 1999.

INFRAS (1995)/ECOPLAN (1996)
In Switzerland, official studies are available which quantified separately the effects of air pollution on human health (ECOPLAN 1996) and buildings (update INFRAS 1995).

The approach used to estimate health effects is based on epidemiological exposure response functions for two main pollutants, particulates and NO_2 emissions (similar to the ExternE approach). The study considers the effects on mortality, invalidity and different forms of morbidity. The economic valuation of the costs is based on the medical treatment costs, on production losses and on cautious estimates of immaterial costs. The study distinguishes costs caused by passenger and freight transport. Costs figures are expressed as specific costs per vehicle kilometre (Table 105) and as costs per tonne PM10 and NO_x (to be used if PM10 emissions are not available). The latter are recommended to be used for more detailed estimates of external costs (ECOPLAN 1998).

The air pollution costs of buildings has been estimated in 1992 and updated for the year 1995 (INFRAS 1992, INFRAS 1995). The estimates are based on a comparison of renewal and cleaning cycles of buildings exposed to high traffic levels with buildings in non-traffic-loaded areas. The economic valuation is based on the renewal costs of the façades (costs per m^2) and the cleaning costs. The additional renewal costs were considered for all buildings, independently of the exposure levels. Instead of that, the additional cleaning costs were considered only for buildings exposed to high concentration levels. The damage costs were calculated for three different regions (city centres, urban and rural regions) and differentiated for cars, vans, trucks, busses, motorcycles and mopeds. Cost figures are also available as costs per building exposed to transport emissions or costs per hectare of exposed building surface (differentiated for urban and rural areas as well as for city centres). It is recommended to use costs figures related to the exposure of the buildings for more detailed estimates of external costs (ECOPLAN 1998).

The costs of air pollution on agriculture and forests were estimated based on the yields losses of crops and forest harvests. These costs figures represent cautious estimates of the real air pollution damages to the ecosystem.

Euro[52]/vkm	Health costs	Costs to buildings	Costs to the ecosystem	Total Costs
Persons				
Road	0.01	0.043	0.003-0.008	0.057-0.061
Rail			0.025-0.068	0.025-0.068
Freight				
Road	0.05	0.026	0.014-0.036	0.09-0.112
Rail			0.06-0.17	0.06-0.17

Table 105: Specific external costs of air pollution in Switzerland (INFRAS 1995, ECOPLAN 1996)

WHO-study on health costs
The WHO-study on health costs (1999) was co-commissioned by several organisation from the participating countries (Austria, Switzerland, France). Its methodology is based on a top down approach. The methodology is similar to the Ecoplan (1996) study, which was commissioned for Switzerland. One important difference is the use of a VSL (according to the assumptions of Jones-Lee 1999) instead of a lower human capital value. The results are therefore significantly higher than those in the Ecoplan study. For Switzerland, the difference is about 120%. Besides improved modelling of particulates, the assumptions on VSL are most sensitive. A VSL of 1.4 million Euro was chosen and corrected according to the age profile to 0.9 million Euro.

Since it is the most recent study in this field, the results were chosen for the top-down approach (see chapter 2.4).

There are significant differences to the ExternE modelling (see further below in the chapter on marginal costs).

2.3.2 Total cost estimation

Health Costs
Compared to the earlier UIC-study (UIC 1995), the methodology for the calculation of air pollution health costs was changed significantly. In the past five years, several studies on health-effects of air pollution were conducted and new knowledge was gained. The earlier study (UIC 1995) used NO_x as tracer substance for the attribution of health costs, whereas the new study uses particle matter with an aerodynamic diameter of less than 10 µm (PM_{10}). We based our estimation of external health costs on findings of the project "Health Costs due to Road Traffic-related Air Pollution. An impact assessment project of Austria, France and Switzerland." (WHO 1999) which was prepared for the WHO Ministerial Conference on Environment and Health in June

52 1.6 SFR.= 1 Euro

1999. This study was chosen because it represents the most complete assessment of air pollution related health costs to date in Europe.

The mentioned study uses population weighted PM_{10} average exposure due to transport to estimate morbidity and mortality cases for every country. As PM_{10} concentration data is not widely available, a correlation analysis between weighted PM_{10} and NO_x emissions and PM_{10} exposure data was conducted for countries where both datasets were available (Austria, France, Switzerland). The resulting function was used to estimate PM_{10} exposition for the remaining countries. These exposition values were then used to calculate the cases of morbidity and mortality which were finally multiplied with country adjusted WTP values to receive total external transport health costs. The attribution of total costs to the means of transport was based on their share of the total weighted PM10 and NO_x transport emissions.

PM_{10} emissions for road transport were taken from TRENDS data framework (TRENDS 1999), emission data for rail transport[53] were taken from UIC statistics (UIC 1996), aviation and waterborne transport emissions from the Swiss Study "Ökoinventar Transporte" (INFRAS 1995b). Unfortunately these studies only consider tailpipe exhaust PM10 emissions, which only represent one part of the total PM_{10} emissions. Major parts are related to road abrasion, tyre and clutch abrasion as well as re-suspension. Recent studies (see INFRAS 1999a) indicate that about 80% of road PM_{10} emissions are caused by non-exhaust processes (see Table 15). This effect is not important for air and waterways transport. To correct for these missing non-exhaust emissions, an non-exhaust emission factor was used additionally to the existing exhaust emissions. Table 15 presents these emission factors. The total emissions are presented in annex 2.4.3.

Mean of Transport	Non-exhaust PM10 [g/vkm]	Percentage of exhaust PM10 [EUR17 mean]	Percentage of non-exhaust PM10 [EUR17 mean]
Car	0.12	12%	88%
Bus	1.2	37%	63%
LDV	0.205	56%	43%
HDV	1.2	31%	69%
Rail Passenger	2	49%	51%
Rail Freight	2	61%	39%

Table 106: Emission factors for non-exhaust PM10 emissions and share of particle emissions due to exhaust and non-exhaust processes (INFRAS 1999a).

Using correlation analysis with weighted mean of NO_x and PM_{10} emissions (including non-exhaust emissions) and PM_{10} exposition data for Austria, France and Switzerland,

53 Both direct diesel emissions and emissions due to electricity production were considered.

following relationship was computed (where $PM10_{PWA}$ is the population weighted average PM_{10} exposition):

$$PM10_{PWA} = 1.38 \cdot \frac{\text{weighted mean of NOx and PM10 emissions}}{\text{country area}}$$

Using this formula, following exposition values were calculated:

Country	Weighted mean emission of NOx and PM10 per capita [kg/year and capita]	Estimated PM10 population weighted average [μg/m3]
Austria	6.2	8.1
Belgium	7.9	8.8
Denmark	9.2	8.5
Finland	6.4	7.8
France	6.2	8.9
Germany	6.3	8.1
Greece	5.1	7.6
Ireland	6.2	7.8
Italy	6.3	8.1
Luxembourg	10.6	9.5
Netherlands	6.5	7.9
Norway	6.6	7.8
Portugal	5.2	7.7
Spain	6.1	8.1
Sweden	7.3	8.0
Switzerland	5.6	7.4
UK	6.0	7.7

Table 107: Estimated population weighted PM10 exposition values.

Exactly the same health effects were assessed as in the WHO-study (WHO 1999):

- Long-term mortality (adults >= 30 years)
- Respiratory Hospital admission (all ages)
- Cardiovascular Hospital admission (all ages)
- Chronic Bronchitis incidence (adults >= 25 years)
- Bronchitis (children< 15 years)
- Restricted Activity Days (adults >= 20 years)
- Asthmatics: Asthma attacks (children < 15 years)
- Asthmatics: Asthma attacks (adults >= 15 years)

For the calculation of the additional cases caused by transport PM10 emissions, the fixed baseline increase function from the WHO-study was used. It describes, how many additional cases are generated by an increase of PM10 exposition of 10 υg/m3 and one million inhabitants. The values used are presented in Table 108.

	Fixed baseline increment per 10 ug/m3 PM10 and 1 million inhabitants cases (+-95% Conficence Interval)			
	Austria	**France**	**Switzerland**	**Mean**
Long-term mortality (adults >= 30 years)	374	340	337	**350**
Respiratory Hospital dmission	228	148	133	**170**
Cardiovascular Hospital Admission (all ages)	449	212	303	**321**
Chronic Bronchitis Incdence (adults >= 25 years)	413	394	431	**413**
Bronchitis (children< 15 years	3'196	4'830	4'622	**4'216**
Restricted Activity Days (adults >= 20 years)	208'355	263'696	280'976	**251'009**
Asthmatics: Asthma attacks (children < 15 years)	2'325	2'603	2'404	**2'444**
Asthmatics: Asthma attacks (adults >= 15 years)	6'279	6'192	6'366	**6'279**

Table 108: Numbers of additional cases per 10 ug/m3 PM10 and 1 million inhabitants. For all countries with the exception of Austria, France and Switzerland, mean values were used.

Using the estimated population weighted PM10 exposition, following numbers of additional cases were computed:

	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland	Italy
Long-term mortality (adults >= 30 years)	2'533	3'856	2'310	1'574	16'876	24'910	2'595	1'065	17'402
Respiratory Hospital admission (all ages)	1'544	1'868	1'119	762	7'346	12'064	1'257	516	8'428
Cardiovascular Hospital Admission (all ages)	3'041	3'537	2'119	1'444	10'523	22'848	2'380	977	15'962
Chronic Bronchitis Incdence (adults >= 25 years)	2'797	4'542	2'721	1'854	19'556	29'342	3'057	1'255	20'498
Bronchitis (children< 15 years)	21'646	46'405	27'797	18'945	239'736	299'774	31'227	12'818	209'422
Restricted Activity Days (adults >= 20 years)	1'411'147	2'762'839	1'654'967	1'127'935	13'088'472	17'847'711	1'859'185	763'132	12'468'390
Asthmatics: Asthma attacks (children < 15 years)	15'747	26'901	16'114	10'982	129'199	173'778	18'102	7'430	121'401
Asthmatics: Asthma attacks (adults >= 15 years)	42'526	69'113	41'399	28'215	307'338	446'461	46'508	19'090	311'897

	Lux.	Netherl.	Norway	Portugal	Spain	Sweden	Switzerl.	UK
Long-term mortality (adults >= 30 years)	207	4'894	1'385	2'480	11'672	3'101	1'888	16'772
Respiratory Hospital admission (all ages)	100	2'370	671	1'201	5'653	1'502	745	8'123
Cardiovascular Hospital Admission (all ages)	190	4'489	1'270	2'274	10'706	2'844	1'697	15'383
Chronic Bronchitis Incdence (adults >= 25 years)	244	5'765	1'631	2'921	13'749	3'652	2'415	19'756
Bronchitis (children< 15 years)	2'491	58'897	16'665	29'839	140'463	37'314	25'894	201'836
Restricted Activity Days (adults >= 20 years)	148'332	3'506'574	992'204	1'776'533	8'362'777	2'221'590	1'574'105	12'016'762
Asthmatics: Asthma attacks (children < 15 years)	1'444	34'142	9'661	17'298	81'426	21'631	13'468	117'004
Asthmatics: Asthma attacks (adults >= 15 years)	3'711	87'717	24'820	44'440	209'195	55'573	35'664	300'600

Table 109: Estimated values of additional morbidity and mortality cases due to air pollution.

For the valuation of air pollution health effects, the WTP-values computed by the WHO study were used. As in the WHO study we corrected the risk value for age. Because the mortality risks are increasing with additional age, the risk value is lowered to 61% of 1.5 million. Euro (see WHO 1999 for detailed argumentation).

Incident	**Value [Euro]**	**unit**
Long-term mortality (adults >= 30 years)	915'000 (61% of 1.5 million.)	per life lost
Respiratory Hospital admission (all ages)	7'870	per admission
Cardiovascular Hospital admission (all ages)	7'870	per admission
Chronic Bronchitis incidence (adults >= 25 years)	209'000	per case
Bronchitis (children< 15 years)	131	per case
Restricted Activity Days (adults >= 20 years)	94	per day
Asthmatics: Asthma attacks (children < 15 years)	31	per attack
Asthmatics: Asthma attacks (adults >= 15 years)	31	per attack

Table 110: Willingness to pay values for the valuation of air pollution health costs.

Crop losses

For the valuation of crop losses a rather simple methodology was used. The costs computed for Switzerland (INFRAS/ECONCEPT/PROGNOS 1996) for 1993 were scaled to the other European countries using NO_X exposition levels and value of agricultural production. NO_X exposition was estimated by dividing NO_X emissions by country area. Following formula was then used to compute crop losses (CL), while α=0.0037 [m^2/t]:

$$CL = \boldsymbol{a} \cdot \frac{NOx\,Emissions}{Country\ area} \cdot Agricultural\,production\,.$$

Building damages

For the valuation of building damages a similar methodology was used. The costs computed for Switzerland (INFRAS/ECONCEPT/PROGNOS 1996) for 1993 were scaled to the other European countries using NO_X exposition levels and building surface. NO_X exposition was estimated by dividing NO_X emissions by country area. Building surface was estimated using population. Following formula was then used to compute crop losses (BD), while β=0.322 [EUR/t]:

$$BD = \boldsymbol{b} \cdot \frac{NOx\,Emissions}{Country\ area} \cdot Building\,surface \cdot PPP$$

Forest damages
For the valuation of forest damages a similar methodology was used. The costs computed for Switzerland (INFRAS/ECONCEPT/PROGNOS 1996) for 1993 were scaled to the other European countries using NO_X exposition levels and forest area. NO_X exposition was estimated by dividing NO_X emissions by country area. Following formula was then used to compute crop losses (FD), while η=0.025 [EUR/t]:

$$FD = h \cdot \frac{NOx\, Emissions}{Country\ area} \cdot forest\, area \cdot PPP$$

2.3.3 Marginal cost estimation

The approach
The marginal costs are based on ExternE model results, based on a subcontract with IER.

The dispersion modelling approach can be described as follows:

Local scale:
Close to the source (i.e. up to about 25 kilometres on each side of the road) pollutant dispersion depends primarily on meteorological parameters such as wind speed and wind direction. On this 'local scale. the Gaussian dispersion model ROADPOL was used to calculate annual average pollutant concentrations for line sources. Full details of the model are available in (Vossiniotis et al. 1996). Around the road section considered a grid is generated and from the emissions on this section the annual average pollutant concentration is calculated for each grid cell. From this, together with the number of receptors affected in each grid cell and the dose-response-functions, impacts are calculated.

Regional (that means here 'European') scale

- Primary pollutants, nitrate and sulphate aerosols:
  At longer distances from the emission source atmospheric chemistry and pollutant removal via dry (e.g. gravitational settling) and wet deposition (rain) have to be taken into account. On the 'regional scale. (including the whole European continent up to the border of the former Soviet Union), WTM, a windrose trajectory algorithm which is an adaptation of the Harwell dispersion model (see Trukenmüller and Friedrich 1995) was applied. Atmospheric chemistry considered includes the formation of nitrate and sulphate aerosols from NO_X, SO_2 and NH_3.
- Ozone:
  For calculating ozone concentrations, a model based on statistical data was used. Available ozone statistics include AOT40 for crops (1 May - 31 July), AOT60 (1 April - 30 September), and 6-monthly (1 April - 30 September) mean of daily maximum 6-hour average ozone concentration. The so called SROM (source-receptor ozone model) is based on source-receptor relationships from the EMEP MSC-W oxidant model for five years of meteorology (Simpson et al. 1997). Input

for SROM are national annual NOx and anthropogenic NMVOC emissions data from 37 European countries, while output is calculated for individual EMEP 150x150 km2 grid squares by employing country-to-grid square matrices.

Avoiding of double-counting
When adding impacts of local and regional scale calculations the problem of double counting arises in the sense, that receptors (and thus impacts) considered on the local scale are included in the regional scale calculations as well. This was avoided by subtracting the ‘local scale. receptors from the receptors considered on the regional scale.

References

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- Vossiniotis, G. Arabatzis, G., Assimacopoulos, D.: Dispersion Modelling on a Local Scale in the ExternE Transport Project. A Description of ROADPOL. Position Paper, National Technical University of Athens, Laboratory of Industrial and Energy Economics, 1996.

With the help of the ExternE models (see as well details and model descriptions in ExternE/IER 1997) values for specific traffic situations in Germany were created. They are used as follows:

- Urban area: Average of
  Berlin (Main road) and GBF Spandau – GbF Moabit (rail)
  Stuttgart Hauptstätterstr. (Main road and Hauptbahnhof rail)
- Interurban high density:
  Baden-Württemberg Heimsheim-Karlsbad (Highway) and
  Illingen-Kämpfenbach (rail)
- Interurban low density:
  Mecklenburg-Vorpommern Güstrow-Neustrelitz (Trunk road and rail)

Since the values are valid for Germany they are adjusted to an European average, using the GDP-per capita correcting factors.

Comparison with the top down approach for total and average costs
There are significant differences between the two approaches:

- The dispersion models for health costs: Whereas the top down approach, based on the WHO study (1999) uses a particulate based modelling, including as well particulates from tyres and clutches, the ExternE model (see above) is basing their models on exhaust emissions of transport and dividing it into a regional and a local part.
- The adjustment of VSL for health costs: Whereas the WHO-study based on a VSL of 1.4 million Euro, ExternE bases its assumptions on a VSL of 3.2 million Euro. The adjustment factors are different however.
- The comparison of the health with the two approaches show that the average values based on the WHO study are similar to the results of ExternE. One conclusion is, that the above mentioned differences are offset, since both approaches are based on the same dose-response-functions.
- The building damages, based on estimations of a shortage of renovation cycles or damages to cultural buildings are not considered explicitly within the ExternE model. Their approach for material damages might therefore be an underestimation.
- The methodology for the estimation of crop losses is comparable.

2.3.4 Input data

Emission Factors:

Road:

TRENDS provides estimation for road transport emissions for the EU15 countries. The emission factors vary between the countries, according to vehicle stock, vehicle use and diesel/petrol share.
However, it was also necessary to calculate the emissions of CO_2, NO_x and PM_{10} "bottom-up", as not all traffic means and not all countries are given by TRENDS (motorcycles, and the countries Norway, Switzerland). The emission estimation for Norway and Switzerland are based on the following emission factors for 1995:

Car emission factors (1995)	**CO_2**	**NO_x**	**PM**
(used for Norway, Switzerland only)		g/km	
Car: petrol, average, no cat. 1)	206	2.50	0.03
Car: petrol, average, cat. 1)	188	0.53	0.01
Car: diesel, average 1)	198	1.50	0.46
Van: petrol, average, no cat 1)	313	4.90	0.05
Van: petrol, average, cat 1)	285	0.75	0.01
Van: diesel, average 1)	299	1.90	0.20
Bus: average 1)	1014	14.00	1.30
HGV: average, 1990 built 2)	1087	18.00	1.54
HGV: average, 1998 built 2)	1042	2.00	0.12
HGV: truck with trailer 1)	1337	13.00	1.50
Motorcycle 3)	112	0.30	0.00

1) Finland/LIISA 97
2) Netherlands/CBS (1995)
3) Paris/Gallez (1995)

Table 111: Car emission factors used for those countries not provided by TRENDS. An estimation for 2010 was made by using the average reduction rates for emissions as used in TRENDS (for EUR 15) for Norway and Switzerland.

Rail:

Diesel traction emissions: the emission factors per GJ are considered to be the same all over the EUR17 countries for CO_2, NO_x, and PM_{10} emissions. A comparison of various sources show an uncertainty for PM_{10} emissions. The reason for this seems to be the difficult definition of particles. An overview for existing estimates is shown in Table 112. The used emission factors in this study are based on the work of Borken et al. (1996) and on TRENDS (Lewis). See also Table 113.

Diesel Train emissions (g/GJ)		CO_2	NO_x	PM_{10}
Hahn	1989		1’020	-
UBA	1989	82’000	1’160	190
IIASA	1991		1’190	61
Prognos	1993		1’280	33
DIW/IFEU/IVU (Germany)	1994		1’280	70
Borken et al. (Germany)	1996		1’280	60
Lewis (TRENDS)	1997	74’440 (70000 – 76000)	1’320 (1210 – 1500)	76 (41 – 140)
DB AG	1995	78’912	1’179	28.9
ExternE (Meets)	1999			167

Table 112: Diesel Train Emission Factors. Existing estimates.

Diesel Trains: (g/GJ)	CO_2	NO_x	PM_{10}
1995	74440	1280	60
2010	68020	151	7

Table 113: Emission Factors for Diesel Trains, used in this report

Electric Traction: The emission factors in the following table are based on various sources:

- The TRENDS database provides emission factors of electricity production by country, in g per GJ.
- In consideration to the fact that railway companies often have their own electricity production mix (other than the countrywise mix), the TRENDS emission factors have been corrected according to the difference between the national and the railway mix (where available), assuming that the same type of power plant produces the same amount of emissions all over Europe.
- The emission factors of PM_{10} are subject to sensitive discussions about the definition of particulate matters. The PM_{10} value of all countries was corrected using the value of DB AG (TREMOD). Another (insignificant) correction was made using Borken et al. (1996) for NO_x values.
- 2010: we assume that for the forecast 2010 a single electricity production mix can be used all over EUR 17, due to a certain globalisation effect. The production mix is mentioned in the following tables.

	1995			2010		
	CO_2	NO_x	PM	CO_2	NO_x	PM
	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Austria	54'526	47.8	0.7	112'650	128	3
Belgium	96'494	176.2	3.3	112'650	128	3
Denmark	248'367	466.0	7.3	112'650	128	3
Finland	242'285	285.6	4.4	112'650	128	3
France	9'120	18.8	0.5	112'650	128	3
Germany	171'147	164.4	6.1	112'650	128	3
Greece	285'605	225.7	7.2	112'650	128	3
Ireland	206'172	387.2	8.6	112'650	128	3
Italy	159'354	321.9	4.8	112'650	128	3
Luxembourg	75'911	39.9	0.3	112'650	128	3
Netherlands	180'650	172.4	2.3	112'650	128	3
Norway	*25'956*	*31.6*	*0.5*	112'650	128	3
Portugal	163'269	289.1	6.8	112'650	128	3
Spain	135'160	262.7	7.4	112'650	128	3
Sweden	28'446	34.7	0.5	112'650	128	3
Switzerland	*8'583*	*10.5*	*0.2*	112'650	128	3
United Kingdom	150'672	337.5	7.5	112'650	128	3

Table 114: Emission factors of electricity production. (1995: TRENDS/DB/INFRAS; 2010: estimation for a single electricity mix in EUR17)

	Electricity production mix 2010 (EUR 17)
Hard Coal	18.0%
Lignite	5.0%
Oil	10.0%
Natural Gas	15.0%
Other Gas	2.0%
Total Fossil	**50.0%**
Hydro	15.0%
Nuclear	35.0%
Other	
Total	**100.0%**

Table 115: Electric power production mix 2010 (Estimation).

% of Energy Use (Passenger and Freight)	Diesel	Electric
Austria	4.7%	95.3%
Belgium	14.0%	86.0%
Denmark	68.6%	31.4%
Finland	35.3%	64.7%
France	10.0%	90.0%
Germany	18.0%	82.0%
Greece	100.0%	0.0%
Ireland	85.7%	14.3%
Italy	3.7%	96.3%
Luxembourg	46.2%	53.8%
Netherlands	12.5%	87.5%
Norway	22.2%	77.8%
Portugal	37.8%	62.2%
Spain	15.1%	84.9%
Sweden	4.1%	95.9%
Switzerland	2.7%	97.3%
UK	51.6%	48.4%
Total EUR 17	**27.0%**	**73.0%**

Table 116: Share of diesel and electric traction.

Aviation:

	1995			2010		
	CO_2	NO_x	PM_{10}	CO_2	NO_x	PM_{10}
kg per LTO cycle 1)		9.82			11	
g per pkm (short distance) 2) 3)			0.00117			0.001
g per pkm (long distance)		0.813	0.00076		0.69	0.0006
kg per 100 pkm (short distance) 4)5)	22.7	0.92		20	0.8	
kg per 100 pkm (long distance)	13.5			12		

Sources:
1) EWI93/BEW 93 (INFRAS/IWW 1994)
2) NOx: EWI 93
3) PM10: Ecoinventory Transport INFRAS
4) CO2: Swissair TEM (1995)
5) NOx: Information from "Dienst GVF: Umweltindikatoren im Verkehr", Bundesamt f. Zivilluftfahrt
Estimation of 2010 values by INFRAS.

Table 117: Aviation emission factors.

Waterborne Traffic:

Emission Factors: (mg/tkm)	CO_2	NO_x	PM_{10}
1995	31'000	590	39
2010	28'300	69	5

Table 118: Inland Ship emission factors (1995: UBA 1993 / INFRAS, IWW 1994). The reduction 1995 – 2010 is estimated on HDV emission reductions.

Emission of transport, 1995:

NO_x [1000 t/a]	Car	MC	Bus	LDV	HDV	Rail Passenger	Rail Freight	Air Passenger	Air freight	Water
Austria	58	0.2	6.6	2.6	72.3	1.0	1.5	0.7	0.0	1.2
Belgium	73	0.3	5.6	9.3	70.1	1.6	1.5	0.9	0.2	3.3
Denmark	52	0.1	10.1	4.0	47.4	5.5	0.8	1.0	0.1	0.0
Finland	36	0.3	10.4	3.9	26.0	0.9	2.2	0.5	0.0	1.9
France	329	1.9	50.2	97.7	242.1	6.8	7.4	4.5	0.4	3.5
Germany	560	3.8	70.6	34.1	376.3	16.8	18.9	6.4	0.7	37.8
Greece	46	0.3	3.2	16.9	55.5	1.5	0.3	0.6	0.0	0.0
Ireland	25	0.1	3.5	1.5	17.2	1.0	0.5	0.6	0.0	0.0
Italy	425	1.8	54.8	45.9	288.5	4.5	2.8	2.4	0.1	0.1
Luxemb'g	3	0.0	0.6	0.3	4.8	0.1	0.2	0.1	0.1	0.2
Netherl.	77	0.4	7.1	0.3	124.2	1.0	0.1	1.2	0.2	20.4
Norway	33	0.2	4.9	6.0	24.8	0.8	0.9	1.3	0.0	0.0
Portugal	54	0.4	5.4	5.6	40.9	1.8	1.3	0.7	0.0	0.0
Spain	188	0.4	17.1	88.8	187.4	2.6	2.5	3.9	0.1	0.0
Sweden	92	0.2	13.1	16.9	41.4	0.4	0.9	1.4	0.1	0.0
Switzerl.	42	0.5	5.3	6.1	28.8	0.3	0.2	1.4	0.1	0.0
UK	420	1.2	72.0	52.4	249.8	20.5	2.3	5.1	0.4	0.1
EUR 17	**2'514**	**11.9**	**340.5**	**392.3**	**1'897.4**	**67.2**	**44.2**	**32.6**	**2.7**	**68.4**

Table 119: NOx emissions in 1000 tonnes per year, 1995 (Source: TRENDS/INFRAS).

PM10 [total t/a]	Car	MC	Bus	LDV	HDV	Rail Passenger	Rail Freight	Air Passenger	Air Freight	Water
Austria	12'175	62	803	884	14'856	155	227	8.1	0.5	82
Belgium	17'440	70	678	3'576	19'220	176	158	11.2	2.1	218
Denmark	6'532	28	1'271	1'224	9'812	367	53	12.0	1.3	0
Finland	5'034	76	1'068	1'597	5'591	65	168	5.7	0.4	129
France	72'656	532	6'072	39'125	68'661	787	857	54.8	6.2	230
Germany	115'784	1'075	8'624	13'012	112'567	1'687	1'898	80.2	9.3	2'496
Greece	6'964	73	457	5'038	12'769	101	18	7.9	0.4	0
Ireland	4'024	22	425	648	4'351	66	33	8.8	0.5	0
Italy	75'873	496	6'583	16'844	76'145	661	409	31.4	2.5	4
Luxemb'g	738	3	76	59	1'184	11	19	0.6	0.7	12
Netherl.	15'506	101	865	36	28'012	272	24	21.7	4.7	1'346
Norway	5'881	54	875	575	4'106	75	81	9.2	0.4	0
Portugal	8'116	98	750	2'739	13'257	133	93	11.4	0.6	0
Spain	39'094	122	2'368	32'703	48'492	307	303	63.1	1.7	0
Sweden	10'444	43	1'593	2'403	11'465	85	177	12.1	0.7	0
Switzerl.	10'706	145	938	795	5'069	253	160	19.0	2.0	0
UK	66'295	336	8'980	13'530	56'815	1'779	198	100.5	8.5	8
EUR 17	**473'260**	**3'336**	**42'423**	**134'788**	**492'371**	**6'980**	**3'691**	**457.8**	**42.5**	**4'524**

Table 120: Total PM10 emissions in tonnes per year, 1995. Including tailpipe exhaust and non-exhaust emissions (Source: TRENDS/INFRAS).

2.4 Climate change

2.4.1 Review of existing studies

The impacts of climate change are very wide and depend crucially on the country considered. A change of global temperatures has regional consequences on rainfalls, frequency of hurricanes and dry periods, on sea level and eventually also on sea currents. These changes in global climate can imply land losses (inundation) in highly populated regions (as for example in India, Bangladesh, etc.), damages caused by hurricanes activities and other extreme climatic events, crop losses due to desertification and aridification, health effects (for example due a widening of the regions infested with malaria) etc.

Climate change is caused by several greenhouse gases (GHG). The most important are:

- carbon dioxide (CO_2),
- N_2O,
- methane (CH_4).

Additionally, other substances like volatile organic compounds (VOC), carbon monoxide (CO) and nitrogen oxides (NO_x) provoke chemical reactions in the atmosphere causing GHG (precursor substances for O_3).

The time period needed for a natural abatement of these gases in the atmosphere depends on the kind of emissions considered:

- CO_2 has a long resistance time, in order of a century or more
- CH_4 concentrations in the atmosphere need a period of 9 to 15 years to adjust to emissions levels
- N_2O has a lifetime of about 120 years.

The resistance period increases if emissions occur at high altitudes (emissions caused by air transport). That means that with a stabilisation of today's emissions, the GHG concentration in the atmosphere will increase further for the period of some decades up to centuries (for the concentrations of CO_2).

The greenhouse gases are produced prevalently by the combustion of fossil fuels: 85% of anthropogenic CO_2 emissions, 34% of NO_2 emissions and 23% of methane emissions are caused by combustion. Industrial processes are responsible for the emissions of HCFC. Most emissions of GHG are produced in industrialised countries (70-80%). In transportation, the highest CO_2 emissions per 100 passenger-km are caused by air-craft's, followed by motor vehicles. Rail transport causes in comparison minor CO_2 emissions (UIC 1997).

The climate models forecast an increase in average temperature of around 0.3 degree per decade if GHG emissions increase with the same growth rate as in the last years. As a consequence, at the end of the next century global temperature would increase by around 1.5 until 4.5 degree, which would have disastrous consequences on earth.

The studies on climate risks can be distinguished according to approaches used:

1. **Damage costs:** This method requires an estimate of **future** damages provoked by climate change. These costs are quantified by the **expenditures** necessary to **repair damages** or directly by the **economic losses** in form of agricultural production and an increase in starvation in developing countries. Further, health costs have to be quantified.
2. **Avoidance costs:** The avoidance cost approach considers the costs society incurs when lowering respectively abating emissions. This approach has to forecast the technologies which in future may be available to reduce GHG emissions and/or to enlarge sink potentials. Further, it is essential to know approximately the magnitude of the costs linked with these technologies (definition of reference technologies and additional costs) and those associated with a change of individual behaviour (for example costs due to a change in mobility behaviour).
3. **Willingness to pay, willingness to accept:** These approaches are **direct methods** of estimation of climate costs. They focus on the individual willingness to pay/accept for preventing a climate change and are usually based on inquiries.

Studies based on the damage costs approach
There exist several estimates for damage costs which vary according to the assumptions and to the degree of detail and number of considered effects.

In order to make some simple cost benefit comparison, **OECD** (1995) has used three alternative damage functions (logistic, linear function and a catastrophe scenario). Damages are measured as losses of world GDP and vary between a loss of 5% and 10% of world GDP by the year 2100.

Hohmeyer (Hohmeyer et al. 1997) illustrates the sensitivity of results according to the assumptions felt. He focuses on three ethical assumptions: Discounting rate, value of life in developing and developed countries, the valuation of food output (by producer surplus or nutritional value). Hohmeyer shows that damages due to a loss of agricultural production in 50 years can be valued at 0.7 $ in the one extreme and at 3.3 million $ in the other.

The overview of different estimations indicates the wide range of results:

Author(s)	Estimation	Source
Nordhaus	0.3 - 65.9 $/tC	Nordhaus 1991
Maddison	14.7 - 15.2 $/tC (value 1990, damage costs for 2021-2030)	Maddison 1994
Cline	11.8 - 221 $/tC (value 1990, damage costs for 2021-2030)	Cline 1992
IPCC	5 - 125 $ per tC (1990 US)	IPCC 1995
Hohmeyer/ Gärtner	220 $/t CO_2	Hohmeyer/Gärtner 1992

Table 121: Results of selected studies based on the damage costs approach.

A rough estimate of the damages for USA carried out by **Cline** (1992) and based on a „business as usual" scenario shows by the year 2025 and with an average increase in temperature of 2.5°C damage costs of around 1% of US-GDP. Estimates of damage costs for the year 2250, considering an increase in temperature of 10°C, give an order of magnitude of 6% of US-GDP.

In **Barbir et al.** (1990) different impacts of climate change were estimated: health costs, agricultural production losses, losses of areas with forest, costs of floods, etc. Total costs are around 330 bill. US$ p.a.

Fankhauser (1995) has estimated the impact of damage costs for different costs categories and different regions. The most significant costs arise from losses of human lives and from costs due to water damages. The country with the highest damages in terms of share of GDP is China (with damages in the order of magnitude of 4.7% of GDP of 1988). The damages in EU countries correspond to 1.4% of GDP (this share corresponds to the average global damage).

Differences in the estimate results can be explained to a great extent with model assumptions. **Smith** (1995) has shown that if the studies are based on the same framework conditions, that means:

– an increase of 100% of CO_2 emissions by the year 2050 in comparison to a pre-industrial level
– a global temperature increase of 2.5° by 2050
– an increase in sea level of 50 cm
– a discount rate for the damage of the year 2050 of 4% (baseline year 1990)

they achieve results of the same order of magnitude (between 42.3 and 52.8 billion dollar or around 1% of GDP of USA in the year 1990 (Meier 1998)).

In **ExternE/IER** (IER 1998) costs of climate change will be estimated through impacts pathways, an approach consistent with the ExternE methodology for air pollution described above. The impacts which it is planned to consider in the estimates of damage costs of climate change are: health impacts, costs of an increase of sea level, costs of crop losses, damages due to extreme climatic events and damages to ecosystems and biodiversity. Since actual estimates of damage costs in the framework of ExternE are not yet available, the authors recommend to use the damage range quoted by IPCC, which vary between 5-125$/t C (that means 1-30 Euro/t CO_2). QUITS[54] (for an overview see FISCUS 1998) uses the same damage costs values as in ExternE. In the estimates of ExternE the risks of climate change are considered with a low and a high value (18 Euro/tCO_2 and 46 Euro/tCO_2).

	Low Euro (1995)/t CO_2	High Euro (1995)/t CO_2
Conservative estimate	3.8	139
Illustrative restricted range	18	46

Table 122: Global values from the ExternE project, values used in QUITS for greenhouse gases (FISCUS 1998, source: Eyre et al. 1997)

Studies based on the avoidance costs approach
Empirical and theoretical estimates of marginal abatement costs (MACs) vary widely, according to source and model simulation. A wide variety of models and modelling types exists (see for example WRI 1997). MACs generally increase with the percentage level of reduction; they are high in industrialised countries and lower in the EIT's[55], lowest in DC's. Table 123 synthesises results from different models and from different empirical studies. It gives values for "average", "high" and "low" marginal abatement costs in different regions and countries (see INFRAS 1998e).

If all reduction commitments had to be fulfilled by domestic reductions the MAC of Western Europe would be 48 US$/t CO_2.

ECMT (1998) assumes marginal costs of meeting the European Union's target at 50 Euro per tonne CO_2 (or 184 Euro/tC) for measures implemented within the EU[56]. It has been estimated that in order to cut emissions by 15% by 2010 would roughly double these costs.

There exist ambiguities, uncertainties and some confusion about the data of marginal abatement cost. Depending on the economic models MAC estimates can differ widely from one to the other source and from one to the other economic model - especially top-down versus bottom-up-models (see e.g. the model discussions in IPCC 1996 and 1997, or WRI 1997)[57]. In this situation the figures from different sources were compiled

54 Quality Indicators for Transport System, project founded by the Transport Programme with the EC 4th Framework Programme

55 EIT: Economies in transition, DC: Developing countries

56 Costs are based on estimates carried out by INFRAS/IWW 1995.

57 Bottom-up (engineering studies) approaches suggest a considerable no-regret potential. That means that these measures can be introduced at zero or negative economic costs, i.e. the costs of implementing the measures are equal or lower than the value of resulting energy savings. In top-down (macroeconomic) models this possibility is generally ignored (OECD 1995).

and qualified as low, medium and high cost calculations. The last column in Table 123 shows the MACs at a medium average level which were the base cost data for the following market simulations (qualified average of low, medium and high estimates from different sources and models, top-down and bottom-up).

Two studies were consulted for the interpretation of the wide variations in MAC values found in the literature - often derived with different economic models[58]. These studies explicitly analyse the root causes for these differences which often seem to be inexplicable: The consequences of the ***assumptions*** in the exogenous framework conditions (reference development assumed, long term energy prices, existing structure of economy), and assumptions buried in the „architecture and structures of models“ (treatment of dynamic aspects, price elasticity's/elasticity's of substitution, etc.) which lead to different MAC results.

58 INFRAS/ECOPLAN (1996), and WRI 1997.

	Commitments Kyoto 97				Marginal Abatement Costs			
	Reduction commitments		Target 2010	Reduction from baseline	low	medium	high	Main scenario
countries/region	% 1990	% baseline	mil. t CO2	mil. t CO2	$ / t CO2	$ / t CO2	$ / t CO2	$ / t CO2
	1	2	3	4	5	6	7	8
ANNEX I	-6%	-21%	12898	-3520				
OECD	-7%	-21%	9557	-2500				
Western Europe	-8%	-12%	3088	-406	25 [2]		70 [5]	**48**
Austria	-13%	-16%	52	-9				
Belgium	-8%	-20%	105	-26	31 [1]	80 [4]	100 [3]	**70**
Denmark	-21%	-21%	41	-11	4 [1]			
Finland	0%	-15%	54	-10			40 [3]	
France	0%	-11%	367	-43	0 [1]			
Germany	-21%	-6%	801	-53	0 [3]		12 [1]	**6**
Greece	25%	-17%	103	-20			179 [1]	**179**
Ireland	13%	-15%	35	-6				
Italy	-7%	-17%	401	-85	170 [3]		331 [1]	**251**
Netherlands	-6%	-7%	158	-12	1 [3]	25 [4]	352 [1]	**126**
Norway	1%	-20%	36	-9	95 [3]		>170 [6]	**95**
Portugal	27%	-14%	54	-8				
Spain	15%	-10%	261	-30			1227 [1]	**800**
Sweden	4%	-1%	64	-1	110 [3]		170 [4]	**140**
Switzerland	-8%	-9%	41	-4	25 [3]		160 [4]	**93**
United Kingdom	-13%	-15%	505	-90		10 [1]		**10**
North America (NA)	-7%	-26%	5045	-1805				**62**
USA	-7%	-27%	4610	-1690	16 [2]		110 [3]	**63**
Canada	-6%	-21%	435	-115		40 [3]	140 [4]	**60**
Pacific (PAC)	-3%	-17%	1423	-289				
New Zealand	0%	-20%	25	-7				
Australia	8%	-16%	312	-58				
Japan	-6%	-17%	1086	-224	41 [2]			**55**
EIT	-2%	-23%	3342	-1021		6 [2]		**6**
Bulgaria	-8%		76			9 [6]		**9**
Czech Republic	-8%		153					
Estonia	-8%		35					
Hungary	-6%		67					
Latvia	-8%		21					
Poland	-6%		390			10 [6]		**10**
Romania	-8%		157					
Russian Federation	0%		2389					
Slovakia	-8%		54					

1 Crash Programme, CEC DG XII JOULE (1991): Cost effectiveness analysis of CO2-reduction options: Synthesis report, Brussels.
2 GREEN (OECD 1994)
3 Jepma 1997a
4 Krom et al. 1996 (ETSAP-study)
5 IEA (Econ 1996/58)
6 Econ 1996/58, corresponding reduction unknown
7 Jepma C. 1997b, in JIQ Vol. 3/4, Dec. 97
see also WRI 1997

Legend: MAC in column 8 = MAC for the last reduction of the reduction commitment of Kyoto, = average of the low, medium and high MAC figures in column 5+6+7 (or estimations)

Table 123: Annex I countries: Marginal abatement costs (MAC) of CO_2 emissions; reductions compared to 1990. Generally, costs differ more between countries than between regions (INFRAS 1998c, sources: see in table above).

The publication of the third IPCC assessment report will allow to update the cost figures in Table 123.

In **Econ** (1996) marginal abatement costs for different regions have been calculated for the stabilisation scenario and for a 20% reduction of emissions. The differences between countries are significant (Table 124), if a trade in carbon emissions entitlement (TCEE) were allowed, OECD countries would purchase emissions entitlements.

World regions, in $/ t C	**Stabilisation**	**20% Reduction**
US	64	188
Japan	93	184
EU	65	169
Other OECD	56	213
CEE	15	49
FSU	9	27

Table 124: Marginal abatement costs of stabilisation and 20% reduction in 2020 compared to 1990, in 1985-$/t C.

In Econ (1996) illustrates that in a situation with a trade in carbon emissions entitlements the equilibrium price which would result is about 30 $/t CO_2 (price level 1985) for a reduction of 20% in 2020 compared to 1990, and 10 $ for a stabilisation on the level 1990.

Some country specific estimates of abatement costs are shown in Table 125.

Study	$/t CO2	Reduction targets
Norway		
Green Tax-Commission 1996	140	Emissions at 1989 level in 2005
Environmental Tax Commission 1991	170	Emissions at 1989 level in 2005
Switzerland INFRAS (1992)	165 – 90[59]	- 20% of emiss. Level 1990 by 2005
INFRAS (1992)	36	- 20% of emiss. Level 1990 by 2025
Cicero (1998)	In % of GDP	
EU	0.005-0.08	-10/-30% of emiss. level 1990 by 2010
USA	0.010-0.20	-10/-30% of emiss. level 1990 by 2010
Japan	0.015-0.25	-10/-30% of emiss. level 1990 by 2010

Table 125: Marginal abatement costs of stabilisation and reduction. In 1985-$/t C and in % of GDP.

The overview of the country specific studies illustrates that the level of prevention costs depends crucially – besides on the model used – on the definition of emission reduction targets. Further it can be ascertained that the state of the art in the field of prevention costs has not really changed in comparison to the situation in INFRAS/IWW (1995). Especially, no new international studies are known which estimate the costs of a reduction of CO_2 emissions in transport.

A recent study for Germany (IWW 1998) is proposing a shadow value for Germany of 400 DM (~200 Euro) per tonne of CO_2. Similar amounts are proposed for Sweden.

Studies based on the willingness to pay/accept approach
This approach has been applied in Switzerland for estimating the WTP for a complete or a partial avoidance of climate change (INFRAS/IPSO 1994). It has been assumed that Switzerland acted in a global framework and that all other countries would implement similar policies. The WTP of Swiss population reached in the year 1993 a magnitude of around 0.2-0.4% of GDP. This estimate represents probably a lower boundary of the real willingness to pay since some of the interviewed persons were not informed enough in order to quantify in monetary terms their willingness to pay for preventing climate change.

59 Rate of change 1 $ = 1.4 CHF

Climate risks of air transport

A particular impact on climate change is caused by air transport, since there is some evidence that condensation trails as well as CO_2, H_2O and NO_x emissions caused by air transport have a major impact on climate risk. Water vapour allows to sun light to get into earth atmosphere but prevents heat radiation to leave atmosphere, accelerating the greenhouse effect. Some studies show that if the sky is covered by condensation trails by 5% (which is the case on regions with a high density of flights), average temperature on ground raises by around 0.6 degrees. NO_x emissions do not have a great greenhouse potential on ground but they built 20-30 time more ozone on high level atmosphere. More than 50% of nitrogen oxides present in atmosphere at a distance between 8 and 12 kilometres from ground – where the ozone layer is particularly fragile – are caused by air transport. Furthermore, at the usual cruising altitudes is the resistance period of nitrogen oxides and water vapour strongly enhanced compared with levels near the ground (Egli 1995). As a consequence, the chemical composition of atmosphere has already altered. In regard to CO_2 emissions, 13.5% of human made emissions of transport are caused by air transport.

These figures on climate risks of air transport must be completed with the high growth rate of air transport forecasted for the next years. Improvements in fuel efficiency of aeroplanes are more than compensated by the additional passenger and freight transports.

The evaluation of external costs of climate change caused by air transport can be evaluated with the same methods presented above. Some additional problems are connected with the monetary evaluation:

- One problem concerns the attribution of emissions to a specific country. This is particularly difficult for air transport since it mostly deals with long distance flights for which origin and destination country differ (at least in Europe). One method is to share emissions on the origin/destination airports (i.e. countries). One other possibility is to consider all emissions caused by starting aeroplanes. Since nearly all starting planes/passengers come back, this would imply to account the emissions of one way to the origin airport/country, and those of the flight back to the destination airport. Further, there are studies which consider the emissions of both ways (there and back) for the calculation of external costs.[60] Finally, it is possible to consider the kerosene selling of each country. We propose to use this cost approach to evaluate CO_2 emissions caused by air transport.
- Since aeroplanes transport both passengers and freight, external costs have to be distributed according to the weight share of freight and passengers. This share can vary significantly between flights. Short distance flights have an average freight share of 6.7%, whereas this share increases on long distance flights to 32.4% (INFRAS 1995b). One possible method to distribute external costs on freight and passengers is to consider the weight share (method used by Lufthansa). Passengers

60 Method used by the first German climate commission (1. Klima-Enquête-Kommission des Deutschen Bundestages), see Die Weltwoche, Nr. 20, 19. Mai 1994.

are considered with a weight of 190 kg per person, including infrastructure present on planes (see INFRAS 1995b), for the distribution of external costs of airport infrastructure, passengers are weighted with 100 kg.

- Theoretically, the evaluation of external climate costs should not be limited to the CO_2 emissions, since these are only a weak indicator for climate risks of air transport. Due to the particular emissions area (stratosphere) other emissions like water vapour and nitrogen oxides are of great relevance for the impact on climate. Some cautious model results indicate that emissions of air transport are twice as dangerous as other forms of transport, which should be considered also in the cost figures used for evaluation. Since there is no further evidence for weighting differently the pollutant, we focus on CO_2 emissions of air transport for the estimation of the risks of climate change.

2.4.2 Input data

See also emission factor in the air pollution part.

CO_2 [1000t/a]	Car	MC	Bus	LDV	HDV	Rail Passenger	Rail Freight	Air Passenger	Air freight	Water
Austria	10'235	83	455	565	6'673	221	324	1'447	92	65
Belgium	13'091	94	385	2'072	6'719	286	256	1'993	370	174
Denmark	5'619	37	744	853	4'187	500	72	2'142	238	
Finland	4'024	101	693	845	2'297	151	393	1'021	78	102
France	53'188	709	3'430	22'112	22'340	495	539	9'924	1'109	183
Germany	109'376	1'434	4'914	7'563	37'384	3'564	4'009	14'433	1'673	1'984
Greece	7'157	97	239	3'431	5'057	87	15	1'429	79	
Ireland	3'379	29	241	360	1'657	69	34	1'575	83	
Italy	62'805	661	3'667	10'017	27'995	1'908	1'182	5'688	451	3
Luxemb'g	598	4	44	47	452	12	21	102	127	9
Netherl.	13'706	134	489	52	11'468	750	67	3'847	833	1'070
Norway	4'687	72	355	678	1'637	67	73	1'690	65	
Portugal	6'682	131	388	1'472	3'882	187	131	2'045	108	
Spain	30'752	163	1'226	20'446	17'285	600	592	11'376	309	
Sweden	10'634	57	903	2'769	3'929	73	153	2'199	117	
Switzerl.	8'409	194	380	883	2'146	50	32	3'377	356	
UK	64'623	448	5'205	10'703	22'331	2'452	273	17'951	1'507	6
EUR 17	**408'966**	**4'448**	**23'758**	**84'870**	**177'440**	**11'472**	**8'165**	**81'998**	**7'834**	**3'596**

Table 126: CO_2 emissions in 1000 tonnes per year, 1995 (Source: TRENDS/INFRAS).

2.5 Nature and landscape

2.5.1 Transport infrastructure and their major ecological effects: A qualitative description

Effects on ecosystems and animal populations
Road vehicles are prolific killers of terrestrial vertebrates. Nevertheless, except for a small number of rare species, roadkills have minimal effects on population size. The ecological effect of road avoidance (the animals are keeping away from roads) caused by traffic disturbance is probably much greater than that of roadkills seen splattered along the road (Forman R.T.T. et al. 1998). Other cause of road avoidance are traffic noise, visual disturbance, pollutants, and predators moving along a road.

Many roads and railways serve as barriers or filters to some animal movement. Infrastructure width and traffic density are major determinants of the barrier effect which subdivides populations, with demographic and probably genetic consequences (Forman R.T.T. et al. 1998). Further, sealed transport infrastructure accelerate water flows and sediment transport, which raise flood levels and degrade aquatic ecosystems.

Pollution of soil and groundwater
Deicing salt and heavy metals are the two main categories of pollutants in road runoff. The primary deicing agent, NaCl, corrodes vehicles and bridges, contaminates drinking water supplies, and is toxic to many species of plants, fish and other aquatic organisms. NaCl tends to increase the mobility of heavy metals in soil. This process facilitates contamination of groundwater, aquifers, and streams. Many other chemicals enter roadsides. Herbicides (for example atrazine which is used by the maintenance of railways) often kill non-target plants. Fertiliser nutrients affect roadside vegetation and nitrogen from vehicular NO_X emission alter vegetation. The wide range of existing studies lead to the conclusion that chemical impacts tend to be localised near roads.

Other effects of transport infrastructure
At the landscape scale, the major ecological impacts of transport network are the disruption of landscape processes and loss of biodiversity. Interrupting horizontal natural processes, such as groundwater flow, stream flow, fire spread, foraging, and dispersal, fundamentally alters the way the landscape works. It truncates flows and movements, and reduces the critical variability in natural processes and disturbances.

We can assume that the road-effect zone (area over which significant ecological effects extend outward from a road) is many times wider than the road surface plus roadsides. An estimated 15-20% of the US land area is directly affected ecologically by roads (Forman R.T.T. 1998). These estimates reemphasize the immensity and persuasiveness of ecological road impacts.

2.5.2 Review of existing approaches

Reviewing existing studies, we can distinguish different issues and valuation approaches.

Anthropocentric approaches
Different studies have analysed the willingness to pay for different types of landscapes (see for example Hampicke 1991, Blöchlinger/Jäggin 1996, Nielsen 1994), either by stated preference (questionnaire) or by measuring the individual expenditures. Within a Swiss study on the cost and benefits of nature and landscape (Infraconsult 1998), the essence of these results is summarised. According to that, specific willingness to pay per unit of m^2 can be extracted which are shown in Table 127.

Although the WTP approach is quite well developed, there is a wide range of uncertainties to consider. Usually the surveys are not directly linked to transport infrastructure and results are difficult to transfer from one country to another, since the initial state (i.e. scarcity of nature) is quite different. Thus these approaches are appropriate to measure additional costs and benefits of measures (or infrastructure projects) which are directly improving the quality of nature.

	in ha	specific willingness to pay		willingness to pay per type of area [Fr.]
		[%]	[Rp./ m2]	
Forest and other wooded land				
Forest	1'085'750	100	2,5	271'437'000
Bush forest	56'110	130	3,3	18'235'000
other wooded area	111'950	175	4,4	48'979'000
Agricultural land				
Crop land, grassland, pasture-land	940'990	50	1,3	117'623'000
Fruit-growing, gardening	67'380	120	3,0	20'213'000
Agricultural area in the mountain	556'890	150	3,8	208'832'000
Settled areas (without traffic area, buildings and industries)				
Relaxation area, green area	13'820	75	1,9	2'592'000
Unproductive surface (without vegetationless areas)				
Lakes	141'920	75	1,9	26'610'000
Rivers, running water	30'720	90	2,3	6'912'000
Unproductive vegetation	248'430	150	3,8	93'163'000
TOTAL	**3'253'940**			**814'596'000**
Average willingness to pay (Rp. per m2, use point and year)				2,5

Table 127: Specific willingness to pay per type of area (Source: Infraconsult 1998)

We will use this approach for the plausibilisation of the calculated costs with the biocentric approaches.

Biocentric approaches
Another approach starts from the definition of the scarcity of nature defined by a natural scientist. Looking at the practice of recent infrastructure projects, different compensation and avoidance costs are raising due to specific affords of environmental impact analysis. Thus the average costs per km of infrastructure of new infrastructure (e.g. motorways) are significantly higher than the cost of old infrastructure. A recent

study for Germany (IWW et al. 1998) has developed a new approach for the consideration of these effects for the 'Bundesverkehrswegeplan'. They recommend a three phased approach:

- **Avoidance costs** (avoidance of nature and landscape effects) due to other alignments. This is especially important for the protection of very important nature areas.
- **Compensation costs** for damages of nature and landscape: In order to value existing damages, the costs of a reasonable set of compensation measures can be estimated. These costs can be derived from recent infrastructure projects or from expert statements.
  This approach can be used as well in regard to the space consumption of additional transport infrastructure. Based on the assumption that the level of ground sealing of different infrastructure should not increase, every additional m^2 of sealed infrastructure has to be compensated. For Germany (IWW 1998), an average unit value of 50 DM/m^2 has been proposed. This approach is of interest for new infrastructure or for the valuation of (long term) marginal cost, if new infrastructure is required.
- **Repair cost** can be used in a similar sense like compensation costs, especially for existing infrastructure, where repair measures would be possible in order to improve the situation. This holds true for nature (e.g. construction of green bridges, improved measures at banks) and for water protection (e.g. groundwater). Like above, specific costs per km of new (environmentally optimised infrastructure) can be used to measure the level of damages of old infrastructure (see Bosch & Partner 1993).

Discussion of the approaches

In comparison to the other cost components discussed above, we deal here partly with virtual costs, since the depletion of resources has already taken place and in general cannot be reversed. Looking at the practice in different countries, the biocentric approach using different cost elements is of more practical relevance and is as well easier to communicate and thus more transparent. The approach is also recommended for a basic study in Switzerland (Ökoskop 1998). To determine the area loss due to transport infrastructure they analyse aerial photographs which is very costly.

We recommend a **biocentric approach** considering different types of infrastructure and different levels of damages. The willingness to pay approach can be used as a plausibilisation of the so generated values. The level of differentiation depends very much on the availability of data, as well for the transport infrastructure and the level of intrusion of nature and landscape.

The interlinkages of environmental data with the transport sector is quite difficult. Specific data are not available. Even the use of GIS-systems are not able to guarantee the necessary information, as first consultations have shown. Therefore the aggregation to national data has to follow a rather pragmatic approach.

2.5.3 Repair cost approach for road, rail and air transport

Network data and determination of the sealed and additional impaired area by traffic infrastructure

a) Road network

The lengths of the roads (by type of road) are given in IRF (1996). The different road widths are available from Germany and Switzerland (BfS 1991, Gühnemann 1999). We take the average width by type of road and aggregate it for the other European countries. We conclude that the roads in Germany (especially motorways) are generally wider than in Switzerland (a lot of roads with three and four lanes per direction). We assume that the road widths of Germany correspond to Europe's big countries (France, Italy, Spain, GB) and the Swiss data correspond to the smaller ones (Scandinavian countries, Luxembourg, Portugal).

We want to calculate the additional sealed area caused by road infrastructure since 1950. It is difficult to estimate which part of the roads this area corresponds to. Further we neglect the roads in urban regions because their effects on nature and landscape are not relevant. We consider 100% of the motorways although some of them had been built before 1950 (30% in Germany, 0% in Switzerland) because their impacts to nature and landscape are severe (barrier effects). For the other roads, we count a percentage of 30% which is built after 1950 and goes through rural regions. These percentages are estimated and are confirmed by experts as far as possible.

Road-construction-related activities, as well as affiliated road features such as rest stops, maintenance facilities and entrance/exit areas are excluded.

In addition to the direct area loss due to infrastructure, there are negative impacts to the side area of transport infrastructure. We assume that the wider the road the bigger is the additional influenced area. A German study (IWW 1998) assume that at least 5 m roadsides correspond to a total loss of area.

b) Rail network

The railway data are given in UIC (1996b). They distinguish between single tracks and double or more tracks. We take an average width of 6 m for a single track resp. 13 m for the double or more tracks (IWW 1998).

As mentioned above, the state of infrastructure at 1950 is not relevant because the rail network has not been grown since then. In Switzerland for example, the rail network was at that time 90 km longer than today (which corresponds to 2 % of the total rail network). In Germany, today's rail network is even 15 % shorter than in the year of 1950. Nevertheless, the rail infrastructure has negative effects to nature and landscape (especially the high speed network which was built after 1950). We assume that 10% of the total rail network have negative effects to nature and landscape.

Rail tracks do not cause a total loss of soil functions like sealed infrastructure (for example water can trickle away). A German study (IWW 1998) estimates that the rate of sealing of rail infrastructure is 50 %.

To calculate the additional impaired area at rail track sides we take an additional width of 5 m into consideration.

c) Infrastructure of air traffic

The area of all airports per country has to be estimated. We distinguish between national and regional airports. The number of airports is taken from the Airport Search Engine ASE. The airport Zurich-Kloten for example has a sealed area of 300 hectares. We assume that this area corresponds to the average sealed area of a national airport in Europe; for a regional airport we take an area of 80 hectares.

Most of the airports were built after the second world war. Thus we take the whole sealed area of airports (100%) for the calculation. The additional impaired area by airports is calculated by assuming an additional radius of 50 m (national airports) resp. 25 m (regional airports).

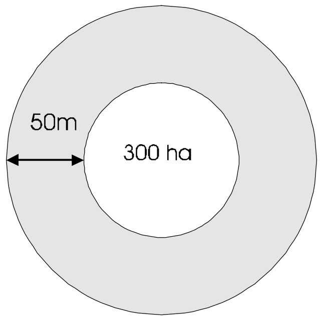

Figure 35: Additional impaired area around airports

Cost determination per module

The idea of this approach is to divide the external costs for nature and landscape up into different cost components (modules). We want to quantify the repair and compensation measures of each cost module. The different modules are independent of each other.

We try to express these costs in costs per m^2 of sealed area or of additional impaired area. As mentioned before, several externalities of nature and landscape cannot be quantified. We consider only the concrete costs and more or less calculable ones.

The costs are given in the German currency (DM). We express these costs in Euro/m^2 (Exchange rate 1995: 1 Euro = 1.87 DM).

- **Unsealing costs:** We want to repair or compensate the damages of nature and landscape caused by transport infrastructure. The first thing to do is to unseal this area. Schemel et al. (1993) estimates unsealing costs of 25 DM/m^2 (transport and deposit costs are included). Froelich & Sporbeck (1995) calculate a value of 85 DM/m^2. A German study (IWW 1998) assume an average value of 50 DM/m^2 which we will use as well.

- **Restoration costs of target biotopes:** When the area is unsealed, initial biotopes are not yet 'repaired. properly. Existing studies (Bosch & Partner 1993, IWW 1998) have calculated restoration costs of a lot of target biotopes.

Table 128 which indicates average values shows that there is a wide range of restoration costs. In this study, we exclude the very valuable biotopes (like extensive used biotopes) because most of the traffic network goes trough 'normal. (intensive used) areas. Thus, we assume that the average costs of reinstall a target biotope are 20 DM/m². This value is multiplied with the total sum of calculated area (sealed area plus additional impaired area).

No.	Group of biotope structure	Target biotope	Total compen-sation costs per ha (dependent on developing time)
I	Waters	*Average costs*	850'000 DM
II	Extensive used biotopes of dry habitats	*Average costs*	720'000 DM
III	Extensive used biotopes of humide habitats	*Average costs*	770'000 DM
IV	Forests, other wooded area	*Average costs:* ***Natural forest***	750'000 DM
		Average costs: ***Silviculture***	360'000 DM
V a	Greenland, extensive	*Average costs*	340'000 DM
V b	Greenland, intensive		120'000 DM
VI a	Arable land,extensive	*Average costs*	200'000 DM
VI b	Arable land, intensive		120'000 DM
VII a	Special cultures, extensive		500'000 DM
VII b	Special cultures, intensive		120'000 DM

Table 128: Restoration costs for some target biotopes (Source: IWW 1998)

- **Soil/water pollution:** The estimation of these costs is very difficult. No experts can quantify these costs in relation to transport infrastructure. An existing study (Froelich & Sporbeck 1995) however have calculated some costs of repair measures. They calculated costs of 70 DM/m³ soil which have to be carried off and deposited. We know that these costs are probably too little because there is no purification process of soil included. We assume that the soil is polluted to a depth of 20 cm. We assume that the water purification costs are in the same order of magnitude (no data available).
- **Other impacts:** There are no data available to quantify the other negative impacts to nature and landscape (barrier effects, visual effects, ...). Existing qualitative studies (Forman R.T.T. et al. 1998) assume that the importance of these effects are important. Thus, we include these costs in this approach by estimated costs of 20 DM/m².

Time period
We calculated the additional sealed area since 1950. Because we want to know the annual external costs, we have to divide the total costs by the number of years (45 years).

Correction according age structure
In order to consider the different levels of damages, we assume that new infrastructure – due to the use of environmental impact analysis and improved environmental legislation – is less harmful than old infrastructure. Economically the inverse argumentation is correct. The older the infrastructure the less harmful it is because the good "nature" is today more valuable (tighter) then forty years ago. We assume that the two different time aspects will neutralise each other. Thus no discount rate is applied.

Country aggregation
The opportunity cost of a society depends on its purchase power. Thus, we will consequently translate the values - derived from a representative sample of studies - from one country to another. Therefore we use the purchase power parity rule. Unit values will be adjusted by weighing exchange rates with purchase power values.

Table 129 summarises the calculated concerned area and external costs by type of transport infrastructure.

Country	Road		Rail		Air		**Total**	
	sealed area [km2]	additional impaired area [km2]	sealed area [km2]	additional impaired area [km2]	sealed area [km2]	additional impaired area [km2]	**sealed area [km2]**	**additional impaired area [km2]**
Austria	222.1	225.8	4.8	2.7	13.8	1.4	**240.7**	**229.9**
Belgium	234.9	248.6	3.9	1.7	14.8	2.1	**253.6**	**252.3**
Denmark	117.9	121.7	2.2	1.2	20.8	1.8	**141.0**	**124.7**
Finland	132.1	133.0	4.4	2.9	32.8	3.8	**169.3**	**139.7**
France	2131.2	1488.1	31.8	15.9	140.8	14.6	**2303.9**	**1518.6**
Germany	1529.3	1151.4	39.7	20.8	118.8	15.2	**1687.8**	**1187.3**
Greece	182.1	188.5	1.3	0.8	51.8	4.4	**235.2**	**193.7**
Ireland	131.8	144.3	1.6	1.0	23.8	2.3	**157.2**	**147.6**
Italy	1006.4	633.0	14.8	8.0	77.8	7.6	**1099.0**	**648.6**
Luxembourg	10.8	10.1	0.3	0.1	4.8	0.3	**15.9**	**10.6**
Netherlands	214.3	214.1	2.0	1.4	29.8	4.0	**246.1**	**219.5**
Norway	152.8	160.8	2.9	2.0	61.8	4.9	**217.5**	**167.7**
Portugal	135.7	120.5	2.1	1.3	27.8	2.6	**165.6**	**124.5**
Spain	987.1	639.7	9.9	5.9	59.8	6.9	**1056.9**	**652.4**
Sweden	252.0	236.0	7.7	4.9	59.8	7.1	**319.5**	**248.0**
Switzerland	161.4	143.9	4.5	2.5	23.8	2.1	**189.7**	**148.4**
United Kingdom	738.2	612.5	19.0	8.5	157.8	17.2	**915.0**	**638.1**
Total	**7341.2**	**6472.1**	**152.8**	**81.5**	**920.6**	**98.3**	**8414.6**	**6651.8**

Table 129: Calculated sealed and additional impaired area of transport infrastructure

We conclude that road infrastructure has the most important influence to nature and landscape. That's due to the big area use of roads because the external costs are directly related to its use (the road network is much more complex than those of rail or air traffic). An allocation to passenger car units of the externalities of the different means of transport would permit a better comparison.

2.5.4 Repair cost approach for waterborne transport

The repair cost approach is used for plausibilisation of the main approach based on compensation costs.

The marsh lands of running waters are very sensitive ecosystems which are influenced by natural dynamic processes (erosion, sedimentation, very variable level of (ground)water). This dynamic is responsible for the diversity of alluvial biotopes.

When river systems are enlarged and used as waterways, there are negative impacts to these humid biotopes. The most important negative impacts of waterways are the loss of dynamic of these ecosystems. Further channels which are artificial waterways, cause a loss of natural area.

The construction of waterways cause irreversible damages to nature and landscape because there is a conflict of interest. Waterways should create levelling conditions for waterborne (like water depth, flows). These new conditions run afoul of the natural dynamics of alluvial biotopes.

The avoidance of negative effects in form of detouring the area is not possible. Local avoidance measures to reduce the separation effects of artificial channels are constructed (overpasses for fauna and water) but there are no data available about their costs. Thus we use a methodology which is based on repair and compensation measures.

a) Methodology

Figure 36 presents the detailed approach which is trying to determine the costs of some repair and compensation measures.

Network data

The length of channels (artificial waterways whose construction destroyed natural area) have to be known to determine the most important negative effects of waterborne transport. These data are given in the EUROSTAT statistical yearbook of regions (EUROSTAT 1997). Unfortunately, data are lacking for some countries.

Determination of impaired area by channels

A German study (IWW 1998) estimates that the total use of area is between 9 and 10 hectares per km channel (included are slopes, dimensioning of waterways and waterway ancillaries like sluices). They assume that the sealed area which depend on the lining of the bottom and the sort of slopes is at least one hectare per km channel. Further we assume that the renaturation area corresponds to the area of slopes which cover between 3 and 4 hectares per km channel (IWW 1998).

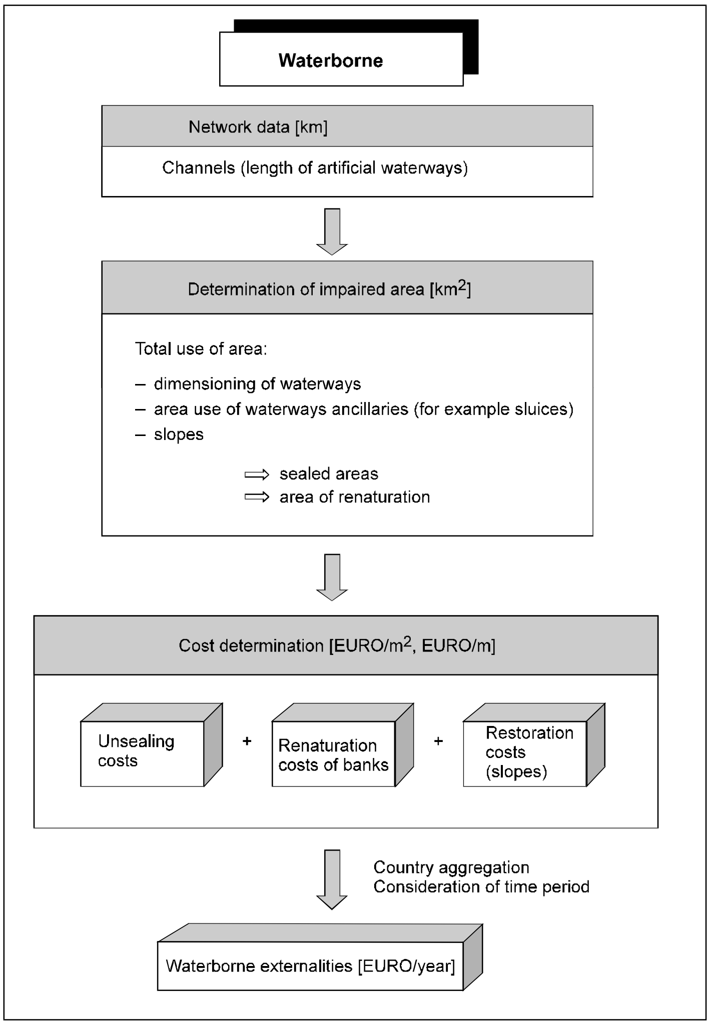

Figure 36: Methodology of the repair cost approach for waterborne transport

Cost determination

- **Unsealing costs:** We take unsealing costs of 50 DM/m² as for the other means of transport (see chapter 4.1.2)
- **Restoration costs for slopes:** The IWW study recommends average costs of 770 DM/m² to reinstall extensive used biotopes at humid habitats (as marsh lands, reed beds).
- **Renaturation costs of banks:** The renaturation costs of enlarged banks are 700 DM/m (IWW 1998).

Country aggregation/Consideration of time period

The calculated values are adjusted by weighing exchange rates with purchase power values. Further we consider a time period of 45 years which corresponds to the time from 1950 till 1995.

b) Results

Table 130 shows the calculated externalities of waterborne transport.

Country	Total unsealing costs [Mio EURO]	Total compen-sation costs [Mio EURO]	Total renaturation costs [Mio EURO]	Total costs (PPP) over time period [Mio EURO]	Total costs per year [mio EURO/y]
Austria	n.a.	n.a.	n.a.	n.a.	n.a.
Belgium	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	0.00	0.00	0.00	0	**0.0**
Finland	n.a.	n.a.	n.a.	n.a.	n.a.
France	n.a.	n.a.	n.a.	n.a.	n.a.
Germany	0.52	32.33	734.81	768	**17.1**
Greece	0.00	0.00	0.00	0	**0.0**
Ireland	0.00	0.00	0.00	0	**0.0**
Italy	0.11	6.59	149.73	233	**5.2**
Luxembourg	n.a.	n.a.	n.a.	n.a.	n.a.
Netherlands	1.00	61.37	1394.76	1590	**35.3**
Norway	n.a.	n.a.	n.a.	n.a.	n.a.
Portugal	n.a.	n.a.	n.a.	n.a.	n.a.
Spain	n.a.	n.a.	n.a.	n.a.	n.a.
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	0.00	0.00	0.00	0	**0.0**
United Kingdom	0.06	3.54	80.48	119	**2.6**
Total	**1.7**	**103.8**	**2359.8**	**2709.7**	**60.2**

Table 130: Externalities of waterborne transport

We conclude that the total external costs due to waterborne transport can be neglected compared with them caused by the other means of transport. It has to be proved if these externalities can be neglected if they are allocated to passenger car units.

2.5.5 Prevention approach for road and rail

New infrastructure projects like roads or rail tracks cause damages to nature and landscape. The use of natural area and its fragmentation are grave interventions. These impacts can not be compensated; they are irreversible. That is why impacts on nature and landscape should be avoided or if not possible should be reduced to a minimum level. Thus, the principle of this approach is to avoid or reduce the impacts of transport infrastructure on nature and landscape. The objective of this approach is to estimate the additional costs of constructing measures to avoid damages to nature and landscape. This approach is only used to determine the costs for road and railway infrastructure (no data are available for air and waterborne transport).

a) Methodology

Figure 37 gives an overview of the prevention approach which is based on infrastructure costs.

Network data

- **Road network:** Total road length is given in the World Road Statistics (IRF 1996). We do not distinguish any more between different road categories because we know only the total infrastructure costs of an average road km.
- **Railway network:** The rail network data are taken from the International Railway Statistics 1995 (UIC 1996b). Because we are finally interested in the total infrastructure costs per country which are given separately, we do not absolutely need any network data. Nevertheless, we want to calculate the infrastructure costs per km rail track to compare them with the costs per km road. The UIC statistics distinguish only between single tracks or double and more tracks. We express these data by the length of single tracks (we count the length of double and more tracks two times) to get consistent data over all countries.

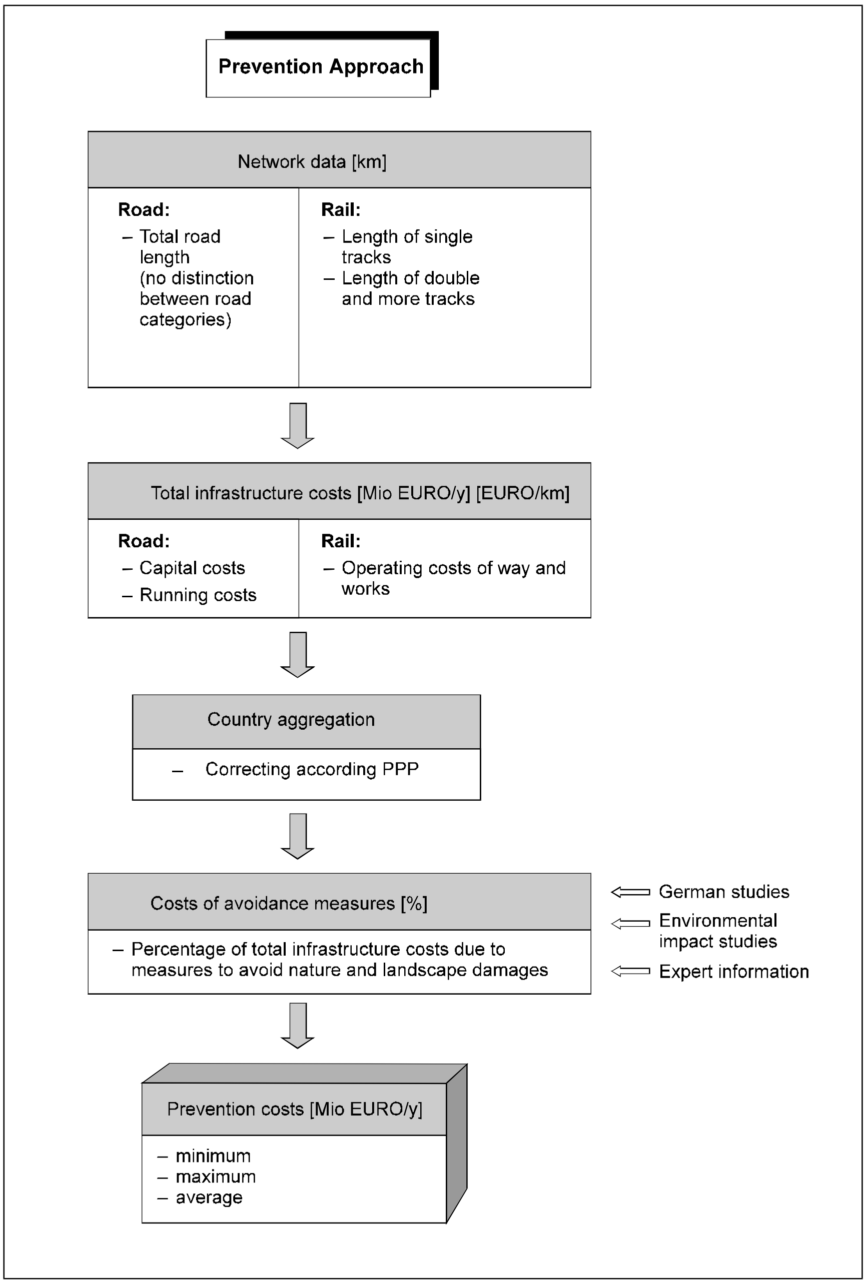

Figure 37: Methodology of the prevention approach for road and rail transport

Infrastructure costs

- **Road infrastructure costs:** The practice of road cost accounts in Europe is rather heterogeneous. The middle European and Scandinavian countries use quite sophisticated methods to estimate their yearly road costs on an economic basis, whereas in southern countries the national accounts are not very well developed. One important reason for these differences is the legal state of infrastructure. As soon as parts of the road network are operated privately, cost accounting is a private duty in order to develop a consistent pricing scheme, while in countries with public road network structures, the knowledge of cost allocation is of political interest.

According to the EC-regulation 1108/70, EU-member countries are obliged to report their yearly road expenditures by which the following differentiation is required:

- Investments (new roads, enlargements, renewal)
- Current expenditures (maintenance, operation)
- General expenditures (administration)

The data of the different infrastructure costs for each country are taken from DIW, INFRAS, HERRY, NERA (1998). The data for France, Greece, Italy and Norway are estimated because they are lacking in this study. The total costs, the sum of capital and running costs, therefore give the total annual costs of providing the road network.

The estimation of the capital costs is based on the capitalisation of the road investments by a specific method using assumptions concerning life expectancies and interests. The running costs are those annual expenditures necessary to ensure that roads provide an acceptable quality of service but which do not maintain that quality. They include items such as: sweeping and cleaning, cutting of grass verges, winter maintenance, street lighting, police and administration.

The road categories for which expenditures have to be reported differ from country to country. In general, information is required for national motorways, trunk roads and provincial resp. communal roads.

- **Railway infrastructure costs:** For the railway annual infrastructure, the operating costs of fixed installations from the Supplementary Statistics 1994 to the International Railway Statistics (UIC 1996a) are used. The following cost categories are included: General management and departmental costs at central and regional levels; monitoring and operating signalling systems, manning of level crossings; maintenance of fixed installations (track, structures, safety and telecommunication installations, fixed installations for electric traction, buildings and other installations); depreciation and renewal of fixed installations; other costs.

Costs of avoidance measures

The damages to nature and landscape can be avoided by detouring the sensitive area. The avoidance costs are derived from the additional length of infrastructure. They consist of the additional constructing costs. If detouring of the sensitive area is not possible, a tunnel have to be built to avoid damages to valuable biotopes.

A lot of the impacts to nature and landscape are not avoided. The improvement and constructional alterations of the transport network is more important in society than the protection of nature. Nevertheless, environmental impact studies demand a reduction of the damages by technical measures like green bridges, passages for vertebrates and passages for waters.

Since now, the additional costs of technical planning and local reduction measures like green bridges are not shown separately. There is no differentiation between these costs and the general building costs. The determination of these costs is very difficult. The most problematic points are the following ones:

- The costs of such a measure differ in dependence of its dimension and quality
- There will be considerable deviations from the practical application of avoidance measures between road and rail infrastructure
- Regional differences of costs due to different laws and price levels
- Dimension and type of measures is dependent on the specific spatial conditions (topography)
- The decision of such measures refer to a single case

We can assume that there are no general conventions which regulate the use of such measures. A pragmatic way to determine the costs of avoidance measures countrywide is to assume a percentage of the total construction costs which reflects the additional costs of such measures.

- **Road infrastructure costs:** A non-published study from the German ministry of traffic (Bundesminister für Verkehr 1996) estimates that the costs for nature and landscape measures in Germany are 4.3 % of the total road costs in the year 1995. The values of the different regions vary between 1.03 % and 8.12 %. The rural regions have higher percentages than the urban ones. Most of the values are between 4.0 % and 5.5 %. The authors say that the average percentage of 4.3 % is probably too small.
- Most of the German and Swiss experts we contacted could not name an accurate percentage of avoidance costs by new transport infrastructure. They were very careful because, according to them, the determination of these costs is difficult (detailed data are not available for Switzerland) and a generalisation is not possible. For example, there are Swiss projects which have a percentage of costs up to 50% because tunnels had to be built. Thus we base our estimation on the German study cited above. We assume that the average percentage is 6 % of the total annual infrastructure costs. Additionally, we calculate minimum and maximum costs of avoidance measures, which correspond to 4% and 8%.
- **Rail infrastructure costs:** No study is available which estimates the costs of avoidance measures by the construction of rail tracks. We assume that these costs are comparable with those of road infrastructure projects. To get consistent results, we assume that the percentage of avoidance costs are the same; in average 6 % of the total annual infrastructure costs.

Country aggregation

The opportunity cost of a society depends on its purchase power. Thus, we will consequently translate the values - derived from a representative sample of studies - from one country to another. Therefore we use the purchase power parity rule. Unit values will be adjusted by weighing exchange rates with purchase power values.

b) Results

Table 131 and Table 132 show the range of calculated prevention costs for nature and landscape for road and rail infrastructure and their ratio.

Country	RAIL Prevention Costs			ROAD Prevention Costs		
	minimum [Mio EURO]	maximum [Mio EURO]	**average [Mio EURO]**	minimum [Mio EURO]	maximum [Mio EURO]	**average [Mio EURO]**
Austria	28.4	56.9	**42.7**	127.1	254.2	**190.7**
Belgium	17.9	35.7	**26.8**	62.1	124.3	**93.2**
Denmark	10.0	20.0	**15.0**	56.3	112.6	**84.5**
Finland	21.3	42.6	**31.9**	61.3	122.6	**92.0**
France	97.0	194.1	**145.5**	1306.5	2613.0	**1959.7**
Germany	142.8	285.6	**214.2**	1168.2	2336.4	**1752.3**
Greece	0.2	0.4	**0.3**	88.0	175.9	**131.9**
Ireland	1.2	2.5	**1.9**	18.5	36.9	**27.7**
Italy	66.8	133.7	**100.3**	253.0	505.9	**379.5**
Luxembourg	2.1	4.2	**3.1**	6.0	11.9	**8.9**
Netherlands	15.9	31.8	**23.9**	188.7	377.4	**283.0**
Norway	12.0	24.0	**18.0**	63.1	126.2	**94.7**
Portugal	1.5	3.1	**2.3**	38.8	77.5	**58.1**
Spain	17.8	35.7	**26.7**	354.1	708.2	**531.1**
Sweden	42.1	84.3	**63.2**	94.8	189.7	**142.2**
Switzerland	45.2	90.4	**67.8**	181.1	362.2	**271.7**
United Kingdom	105.1	210.2	**157.6**	320.1	640.3	**480.2**
Total/*Average*	627.5	1255.0	**941.2**	3720.0	7440.0	**5580.0**

Table 131: Range of calculated prevention costs of rail and road infrastructure

Country	ROAD + RAIL Prevention Costs minimum [Mio EURO]	maximum [Mio EURO]	average [Mio EURO]	RATIO % of total prevention costs RAIL [%]	ROAD [%]	RATIO (ROAD/RAIL)
Austria	155.6	311.1	**233.3**	18.3	81.7	**4.5**
Belgium	80.0	160.0	**120.0**	22.3	77.7	**3.5**
Denmark	66.3	132.6	**99.5**	15.1	84.9	**5.6**
Finland	82.6	165.2	**123.9**	25.8	74.2	**2.9**
France	1403.5	2807.0	**2105.3**	6.9	93.1	**13.5**
Germany	1311.0	2622.0	**1966.5**	10.9	89.1	**8.2**
Greece	88.1	176.3	**132.2**	0.2	99.8	**472.7**
Ireland	19.7	39.4	**29.5**	6.3	93.7	**14.9**
Italy	319.8	639.6	**479.7**	20.9	79.1	**3.8**
Luxembourg	8.0	16.1	**12.1**	26.0	74.0	**2.9**
Netherlands	204.6	409.2	**306.9**	7.8	92.2	**11.8**
Norway	75.1	150.3	**112.7**	16.0	84.0	**5.3**
Portugal	40.3	80.6	**60.4**	3.8	96.2	**25.2**
Spain	371.9	743.8	**557.9**	4.8	95.2	**19.9**
Sweden	137.0	273.9	**205.4**	30.8	69.2	**2.3**
Switzerland	226.3	452.6	**339.5**	20.0	80.0	**4.0**
United Kingdom	425.2	850.4	**637.8**	24.7	75.3	**3.0**
Total/*Average* EUR 17	4347.5	8694.9	**6521.2**	14.4	85.6	**5.9**

Table 132: Ratio of prevention costs due to road and rail infrastructure

The costs per km railway infrastructure are much higher than those of road infrastructure (see annex). Nevertheless, the prevention costs of road infrastructure are in average six times higher because the road network is more complex and therefore much longer.

c) Comparison of the repair and prevention cost approach

Road results:
The externalities for road infrastructure calculated by the prevention approach are much smaller than those of the repair cost approach.

The raison of these differences might be due to the different principles of calculations:

1. The module approach calculates the costs of repair and restoration measures. In other words, this part of infrastructure which cause damages to nature and landscape (estimated percentage of total infrastructure) has to be 'destroyed. and the initial biotopes are restored.
2. In the contrary, the prevention approach considers only the costs spent for avoidance measures which reduce the damages to nature and landscape. Naturally, not all damages can be avoided.

The comparison shows that the assumed percentage of the total infrastructure costs is probably right. In the future, this percentage will increase due to stronger instructions by environmental impact studies.

Railway results:
The externalities calculated by the prevention approach are much higher than those of the repair cost approach. Thus we conclude that the assumed percentage of the railway infrastructure costs has to be too high. Probably only 2 – 4 % of the railway costs are due to nature and landscape measures.

2.5.6 Willingness to pay approach

We use this anthropocentric approach for the plausibilisation of the calculated results.

a) Methodology
The willingness to pay depends on individual perception of the value of nature. A concrete amount representing willingness to pay in Swiss francs per month is derived from existing empirical studies for the domain of nature and landscape. A Swiss study (Blöchliger/Jäggin 1996) calculate a willingness to pay of **CHF 30.- per person and month** for the preservation of nature and landscape in Switzerland. This value corresponds to the ‘value of nature. for an average Swiss people.

b) Results

Table 133 shows the calculated willingness to pay for the preservation of nature.

Country	Population [in thousands]	Purchasing Power Parity D=100	**Total willingness to pay (WTP)** [Mio EURO/y]	**Costs determined by module approach** [Mio EURO/y]	**Costs determined by module approach (expressed in % of WTP)** [%]
Austria	7'968	95.47	**1'721**	500	**29%**
Belgium	10'113	87.50	**2'383**	490	**21%**
Denmark	5'180	107.14	**997**	320	**32%**
Finland	5'107	99.11	**1'062**	347	**33%**
France	57'981	91.47	**13'069**	4078	**31%**
Germany	81'590	100.00	**16'822**	3326	**20%**
Greece	10'451	62.95	**3'423**	306	**9%**
Ireland	3'553	70.33	**1'042**	239	**23%**
Italy	57'187	67.06	**17'582**	1385	**8%**
Luxembourg	405	93.82	**89**	29	**33%**
Netherlands	15'503	91.66	**3'487**	479	**14%**
Norway	4'338	99.21	**902**	437	**48%**
Portugal	9'823	56.17	**3'606**	187	**5%**
Spain	39'621	69.15	**11'813**	1389	**12%**
Sweden	8'780	97.99	**1'847**	635	**34%**
Switzerland	7'202	113.38	**1'310**	438	**33%**
United Kingdom	58'258	70.63	**17'006**	1270	**7%**
Total	**383'060**		**98'162**	15854	**16%**

Willingness to pay:	**CHF /year**	**360**
	Euro/year	**234**
	Euro/year (PPP)	**206**

Table 133: Willingness to pay for the preservation of nature

As mentioned above, we use this approach for the plausibilisation of the results calculated by the other approaches. We compare the total external costs calculated by the repair cost approach (waterborne externalities are excluded) with the total willingness to pay per country (see Table 133**)**. A comparison shows that in average 16 % of the total amount which people would pay for the preservation of nature correspond to the calculated transport related externalities for nature and landscape. This seems to be reasonable.

2.6 Additional costs in urban areas

2.6.1 Separation effects

a) Review of existing studies

Cost results for specific urban areas are not available. Moreover, the methodological approach is discussed and proposals for the measurement of these effects are made. Both effects are used in the evaluation methodology within the German 'Bundesverkehrswegeplanung. (EWS 1997). They are as well recommended within the FISCUS-project within the 4th Framework Programme in the Transport sector.

According to EWS (1997) the following assumptions (for Germany) are used:

- Number of crossings per resident (pedestrian) per day
- Waiting time depends on traffic volume and type of road, based on empirical estimates
  WT = -53 + 8.31 ln Q
  WT = Waiting time per crossing (seconds)
  Q = Traffic volume (Vehicles per hour)
- For dense roads with two and more lanes, additional detours should be considered
- The residents affected are estimated as follows:
-

Type of road	Residents affected per 100 m (depending on type of building)
Local roads	7-20
Main roads(city motorway	0-10
Intercity motorway	0-5

Table 134: Residents per type of road

b) Procedure

It seems useful to use also the Planco (1990) approach, which makes a differentiation between three types of roads and their effects on time loss of pedestrians while crossing them: A road of type C (motorways) can only be crossed with special bridges or subway, therefore a time loss of 9 minutes per crossing is assumed. A type B road contains more than one track per direction and needs traffic lights to cross. A time loss of 135 seconds is assumed. Roads of „type A" have only one track per direction, but the waiting time for pedestrians is a function of the traffic volume. Until 400 vehicles per hour, the waiting time is negligible (=0), between 400 and 800 vehicles/hour an exponential function between 10 and 110 seconds is used, above 800 vehicles, pedestrians mostly have to use traffic lights, a waiting time of 110 seconds is proposed (see Figure 38). All the road types are matched with specific figures of affected residents. and with a figure for crossings per day (A: 3, B: 2, C: 1.5).

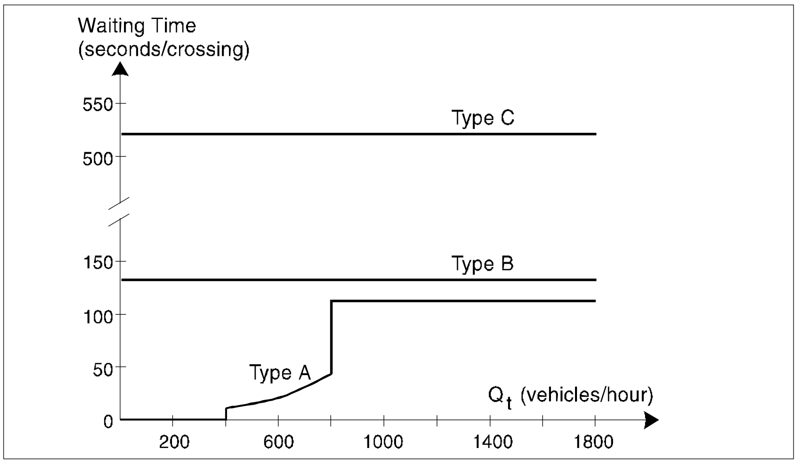

Figure 38: Waiting Time Models for Pedestrians at different road types (Planco 1990)

It is impossible to make a detailed calculation for every town, since data availability is very poor; thus a cluster assumption out of a selected sample will be used. The estimation is based on a simplified version. The following changes to the Planco model are made, as the data availability is insufficient:

- On all road types in town, a same value for affected persons per km is assumed: Total residents (plus a net value of commuters) per km of total road length.
- For the roads of type „A“, a mean value of 10 seconds per crossing is used.

In the EWS model (1997), the cost value for time losses is set to 5 Euro per hour and person. With this figure, the costs of pedestrian time losses can be estimated as about 50 Euro per (urban) person and year.

Model towns:

	affected persons	Road % Type A	Type B	Type C	Total km
Barcelona (Agglom.)	2'875'463	85%	7%	8%	**3904**
München	1'324'208	51%	44%	5%	**2284**
Southampton	205'451	79%	20%	1%	**565**
Zürich	500'000	75%	23%	2%	**735**

Table 135: Urban data for model cities.

Allocation to transport means

It seems useful to allocate the costs of time losses to freight and passenger traffic regarding traffic volume, using vkm * PCU.

How to get countrywise figures

We propose furthermore a very pragmatic way of extrapolation the cluster results to countrywise data and to all countries. It is very difficult to estimate time losses in rural or less urban areas, as the interrelation of traffic and pedestrians is very different. It is difficult to estimate the traffic (in vehicles per hour) and its change over a day.

We would assume that the specific time loss of a urbanely affected person can be extrapolated to all urban residents of a country. Urban residents are, in this study, residents of towns with a population of 50'000 and more:

	Population in cities > 50'000 inhabitants	Total population	% urban
Austria	2'469'450	7'968'000	31%
Belgium	3'334'454	10'113'000	33%
Denmark	2'494'723	5'180'000	48%
Finland	1'983'375	5'107'000	39%
France	13'431'801	57'981'000	23%
Germany	33'008'345	81'590'000	40%
Greece	3'653'811	10'451'000	35%
Ireland	1'349'679	3'553'000	38%
Italy	20'149'051	57'187'000	35%
Luxembourg	80'176	405'000	20%
Netherlands	6'958'372	15'503'000	45%
Norway	1'379'812	4'338'000	32%
Portugal	1'425'772	9'823'000	15%
Spain	20'258'875	39'621'000	51%
Sweden	3'174'224	8'780'000	36%
Switzerland	1'127'426	7'202'000	16%
United Kingdom	20'662'957	58'258'000	35%
Total EUR 17	**136'942'303**	**383'060'000**	**36%**

Table 136: Urban percentage of population.
Sources: World population statistics (http://www.koeln.netsurf.de/~stefan.helders/pop/popdeu.htm), Statistisches Bundesamt Wiesbaden: Statistisches Jahrbuch 1997 für das Ausland

Time losses due to interurban railway traffic

The effect of a railway track in an urban area is more or less the same as a motorway: pedestrians need a special way to cross it and loose, according to Planco (1990), 9 minutes per crossing. The Planco study does nevertheless not provide figures, as the clustering of railway track length in urban areas is more difficult. We would therefore assume that an analysis of a model town can result into an estimation for other towns. For this study, specific urban value for railway separation effects have been made on the basis of the region of Zurich. The railway tracks in tunnels and on bridges have no separation effects and are not included in the modelling.

These estimation for several European towns show following average unit costs, which have to be corrected with the country specific adjustment factor.

Road: 50 Euro per (urban) person and year
Rail: 17 Euro per (urban) person and year.

2.6.2 Space availability

According EWS (Germany 1997) the following working steps are necessary:

- Evaluation of existing road network: Additional bicycle lanes are affordable, where average daily traffic exceeds 10'000 vehicles.
- Elaboration of need for action: Additional bicycle lanes per spatial unit. A lane of 2 m width should be foreseen.
- Estimation of cost, based on unit costs per m^2, according to national (urban) experience.

With the definition of the relevant road network (roads of type B and C),

2.7 Up- and downstream processes

a) Review of existing shadow factors

There are different studies looking at the fuel and other life cycles of transport. The project ExternE (EU 4th framework programme) is estimating very detailed fuel cycles for every Member state, looking at the different plants composition within different countries. Based on the ExternE approach (see chapter air pollution) they estimate shadow prices for electricity. The following table gives an overview for the estimates in Germany (ExternE 1997b).

Production plant	Shadow price Euro/1000 kWh (lower value)	Shadow price Euro/1000 kWh (upper value)
Coal	17	138
Lignite	20	164
Oil	38	166
Gas	6	60
Fossil total in Germany		
– Former Federal Terrritory	24	151
– 'neue Länder'	373	579
Nuclear	4.4	7
Photovoltaic	1.1	8.1
Wind	0.37	1.3
Biomass	27	32
Aggregation Germany 1):		
Fossil fired	24	151
Nuclear	0.8	4.7

Table 137: Shadow factors for the electricity production in Germany (ExternE 1997b)

A similar study has evaluated the indirect effects of different electricity mixes for Switzerland (INFRAS/Econcept/Prognos 1996) specifically considering hydro-electricity and nuclear risks. The following table gives an overview of the results.

Shadow prices	Unit values
Shadow prices 1) for hydroelectricity	0.0025 – 0.0085 Euro per kWh
Shadow prices for nuclear risks	0.002 – 0.004 Euro per kWh (add. Risk factor: 0.002 – 0.22 Euro per kWh) mean: 0.035 Euro
Shadow prices for electricity (UCPTE-mix)	0.003 – 0.005 Euro per kWh

1) In addition to market prices, based on INFRAS/Econcept/Prognos 1996

Table 138: Shadow rates for hydroelectricity and nuclear risk for Switzerland

The shadow price for nuclear risks is based on two approaches:

- The basic value (0.002 – 0.004 Euro per kWh) reflects an expectancy rate which is estimated by real risk situations. This is based on statistical risk evaluations and engineering studies of existing plant types in Western Europe. The VSL used in these studies is similar to the values used for the accident risks.
- The risk factor considers the risk aversion of the society. It is based on different willingness to pay studies (Zweifel 1994, Infras/Prognos 1994b, based on the approach of Pratt 1964). These estimate hypothetical risk premia for different type of risk aversion and different type of risk. The results spread very much due to the fact, that the risk aversion of society is very difficult to measure.

b) Approach and database

The upstream effects considered in these report are based on additional air pollution and climate change costs and add the risk factor for nuclear energy mentioned above. The proportion of direct and indirect emissions is based on a specific inventory study (INFRAS 1995b, eco-inventory of transport). All transport nuisances were evaluated considering the above mentioned processes.

The eco-inventory of INFRAS provides information's on shadow rates for rolling stock and infrastructure (especially for air pollution and CO_2-emissions), which can be added to the estimations in those parts.

2.8 Congestion

2.8.1 Cost Functions

a) Theoretical aspects

Using the notation of the graph in chapter 5.1, total congestion costs are defined by the triangle (ABC). Point "A" the current equilibrium of traffic demand (W) and the private costs each user has to bear (PC), while "B" describes the intersection of the current traffic demand (Q) and the economically correct user costs - the marginal social costs (MSC). Point "C" finally identifies the equilibrium state, where marginal social user costs meet that traffic demand, which is adopted to the increased user costs. In a mathematical way, the problem of determining the dead-weight-loss for a given infrastructure segment can be formulated by the following equations:

$$
\begin{aligned}
&PC(q) = \frac{VOT}{v(q)} + FC(v(q)) \\
&TC(q) = q \cdot PC(q) \\
&MSC(q) = \frac{\partial TC(q)}{\partial q} \\
&MSEC(q) = SMC(q) - PC(q)
\end{aligned}
$$

with:

$$
\begin{aligned}
q &: \text{Traffic volume per time unit} \\
v(q) &: \text{Travel speed [kph]} \\
FC(v(q)) &: \text{Speed - depending fuel costs [ECU/km]} \\
VOT &: \text{Value of (congested) time} \\
PC(q) &: \text{Private user costs [ECU/km]} \\
TC(q) &: \text{Total costs} \\
MSC(q) &: \text{Marginal social costs} \\
MSEC(q) &: \text{Marginal social external costs}
\end{aligned}
$$

For the determination of the dead-weight loss further a demand function *D(c)* (where *c* is the costs per kilometre a user has to bear) is required. It describes the reaction of traffic when it has to bear the marginal social external congestion costs. The inverse of *D(c)* then describes the willingness-to-pay of users for bearing a particular traffic situation; this function is entitled as *W(q)*. Having this function available, the dead-weight-loss per kilometre and hour of a particular infrastructure segment is described by:

$$DWL(Q) = \int_{q=Q^*}^{Q} [MSEC(q) - W(q)] \cdot \partial q$$

where Q denotes the current observed traffic volume and Q^* is the optimal traffic volume at the intersection of *MSEC(q)* and *W(q)*. The cost functions required are quantified in turn.

According to the welfare-definition, congestion costs can be interpreted as the costs users cause to each other because they do not take into consideration the preferences of others or as the price we pay for not behaving in a rationale way. This viewpoint implies that congestion costs are only occurring in individual transport because in scheduled transport services a "higher intelligence" ensures an optimal use of existing infrastructure.

b) Speed-Flow Relationships and marginal social costs

Speed-flow curves are taken out of the German road investment manual (EWS 1997). The EWS speed-flow functions are defined for 47 types of inter-urban and urban roads in three parts: (1) free flow up to serious interference of vehicles, (2) strong interference to congestion and (3) congestion, which is characterised by a low but constant travel speed. While at low and high traffic volumes the functions are rather flat, the transition from acceptable to bad traffic conditions is extremely sharp.

This behaviour of speed-flow relationships implies that the marginal social external costs reach their maximum at the transition point from free flow to congestion and are zero for relaxed and very dense traffic. Therefore the application of the pure social welfare theory as described above is modified such, that $MSEC(Q) = MSEC(Q^T)$ for $Q > Q^T$ (where Q^T denotes the transition traffic volume). Figure 39 below displays the theoretically correct MSC-function (black line) and the chosen one (light grey area).

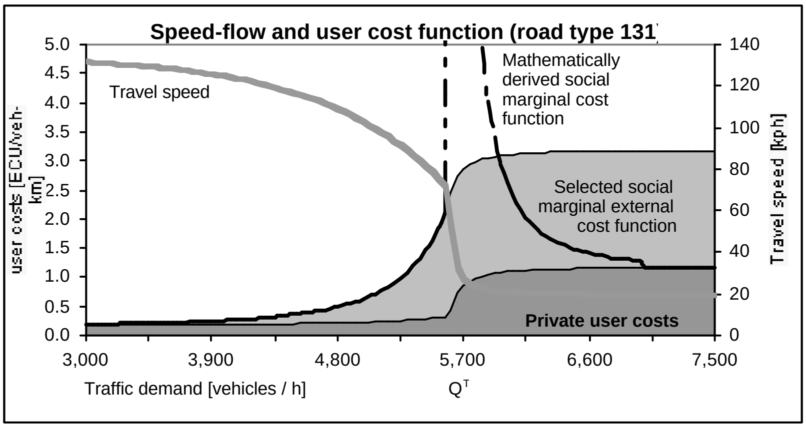

Figure 39: Speed-flow relationship and user cost functions

c) Traffic Demand Elasticity

The assumption underlying the definition of the user-WTP-function *W(Q)* is that traffic demand is responding is iso-elastic on changing user costs. I.e. regardless of the current situation, a 1% change of the user costs results in the same percentage change of traffic demand. On the basis of current research a demand elasticity in inter-urban travel of $\eta = -0.3$ and in urban travel of $\eta = -0.8$ was assumed.

The functional form of *W(q)* then is derived as follows:

$$W(q)=\left(\frac{q}{a}\right)^{\frac{1}{h}}$$

As the demand satisfied at the current observed traffic volume *Q* (i. e. *W(Q) = PC(Q)*) the parameter α can be determined individually for different traffic constellations.

d) The Value of Time

The value of travel time in passenger and goods transport is chosen depending on the travel purpose.

- For business travel the value of working time (European average: 21.44 Euro/h) was taken out of PETS (1998) and adjusted to the EUR-17 countries by the weighted income per capita. It is further assumed that 20% of car traffic are business trips.
- For private travel 25% of the business-time-value was selected and distributed accordingly. All trips performed by coach or motor cycle and 80% of passenger car traffic are assumed to comprise private.
- In goods transport a value of 37 Euro per shipment was assumed, which is based on stated preference studies in the Netherlands. The time value per light duty vehicles was estimated by 20 Euro per hour.

Based on national shares of passenger and freight vehicles, on the mix of travel purposes and on the differences in income and GDP per capita the following transport-sector specific values per vehicle-km are used:

Country	VOT Passenger	VOT Freight	Country	VOT Passenger	VOT Freight
Austria	13.07	39.43	Luxembourg	21.92	56.27
Belgium	12.98	31.65	Netherlands	14.04	36.85
Denmark	17.72	41.73	Norway	17.94	36.43
Finland	11.25	27.78	Portugal	13.79	11.91
France	16.17	27.19	Spain	12.95	15.59
Germany	12.93	37.92	Sweden	13.28	27.85
Greece	10.56	11.92	Switzerland	18.14	46.20
Ireland	12.62	23.20	United Kingdom	12.71	21.63
Italy	16.12	22.58	Average EUR 17	14.83	29.48

Table 139: Value of time by mode and country 1995

e) Other Operating Costs

In particular in goods transport driver's wages, capital costs of the rolling stock, administrative costs and expenses for fuel are considerable elements of user costs.

According to PETS (1999) marginal operating costs per HDV-km amount to 37 Euro and hence are close to the opportunity time costs per shipment. For reasons of simplification this the operating cost function of freight vehicles defined as 2 * VOT / travel speed.

In passenger transport only increased fuel consumption is considered as additional operation costs. With an estimated consumption rate of 10 l/km under free-flow-conditions (v = 100 kph) and of 20 l/km in congestion (v = 20 kph). The respective fuel cost function *FC(v(q))* then is defined as follows:

$$FC(q) = (22.5 - 0.125 \cdot v(q)) \cdot FP$$

where *FP* denotes the country-specific fuel price. It should be noted that due to the rather moderate influence of decreasing travel speed on fuel consumption the importance of other than time costs in passenger road traffic is very low.

f) The Unit Cost Function

By applying the time and operating cost functions (unitised by the value of time) and the EWS speed-flow curves (unitised by the number of lanes) the time-unit-consumption as a function of lane occupancy is received. Non-continuous parts of this unit cost function, which are resulting from the partial definition of the speed-flow-curves, are smoothened by estimating a logistic curve of the same functional form.

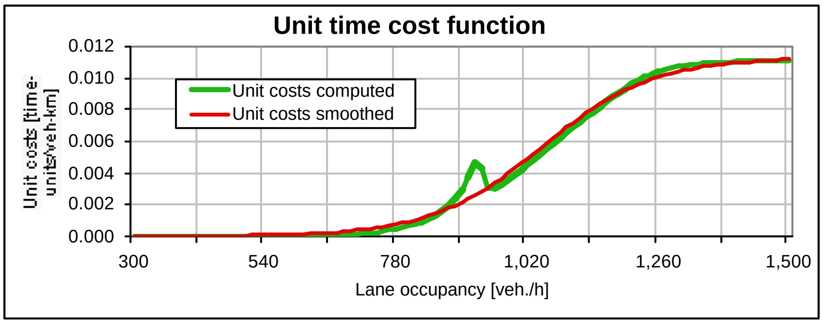

Figure 40: Unit-time costs by lane occupancy

The total costs per kilometre, lane and hour of a particular link then is calculates as: the product of the unit cost function (*UC*), the mode-dependent traffic volume (*Q*) and value of time (*VOT*). In a network notation the approach can formally be written as:

$$C = \sum_N \sum_T \sum_M (L_N \cdot Q_{N,T,M} \cdot p_M \cdot UC(Q_{N,T,M} \cdot p_M) \cdot VOT_{M,N} \cdot D)$$

with

C: Total Annual Congestion Costs
N: Index of road link
T: Hour of day (1 to 24)
M: Transport mode (passenger / freight)
L_N: Number of lanes of link N
$Q_{N,T,M}$: Traffic volume of mode M on link N in hour T
p_M: Passenger - car - units of mode M
$UC(Q, p)$: Unit costs per PCU
$VOT_{M,N}$: Time - value by mode and country
D: Days per year

The basic methodology towards the definition of congestion costs now is adapted according to the available data in European urban and inter-urban traffic.

2.8.2 Network based congestion modelling

Congestion costs in inter-urban road traffic are determined on the basis of an digitised European road map comprising motorways and rural roads for all western-European countries. The road links are attributed by

- Network information: Length, type of road, number of lanes, gradient and curvature) and
- Traffic data: Volumes of passenger cars and freight vehicles on a average working day.

The traffic data is generated by the IWW inter-urban transport model VACLAV on the basis of UN counting post data for the year 1995. The map below displays a cut-out of the attributed IWW road network. The links are attributed by the Level-of-Service in the peak hours during an ordinary working day.

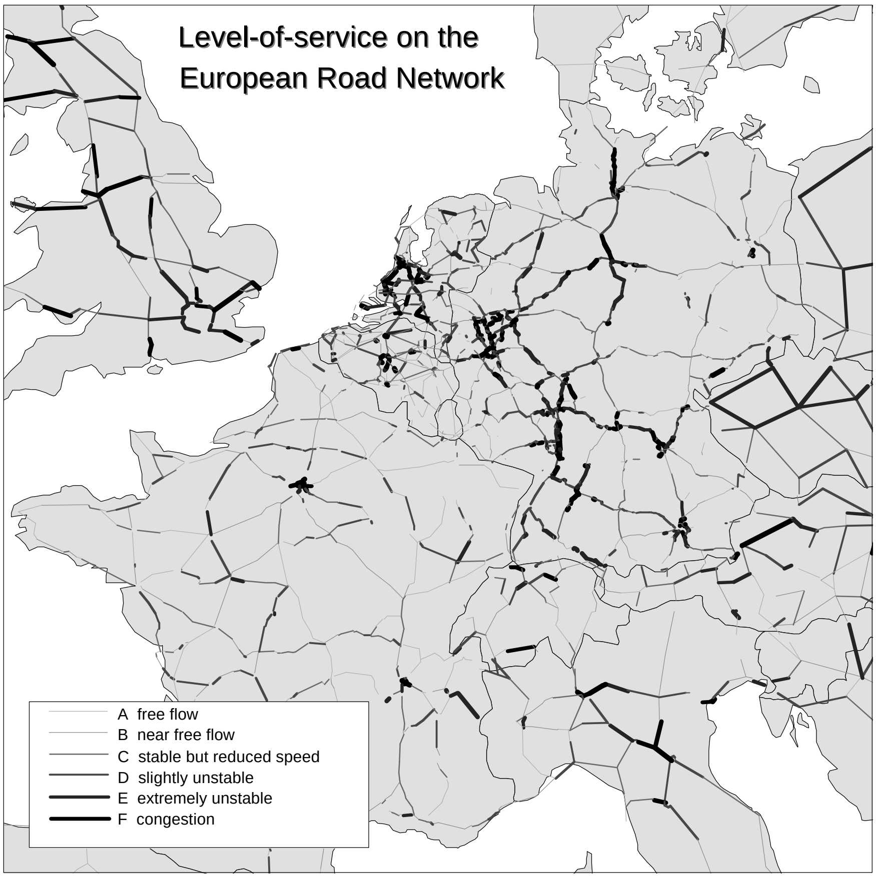

Figure 41: The IWW road network by LOS-conditions (only Central Europe)

Using a standard-deviation of traffic loads over time the average daily traffic was allocated to four characteristic time segments (peak, inter-peak, off-peak, night) according to the following scheme:

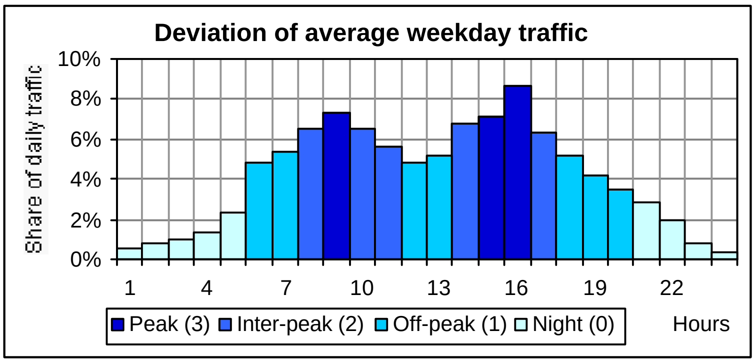

Figure 42: Allocation of hourly traffic to time segments

The results of the network analysis are presented below by annual passenger car and freight vehicle-kilometres per country and traffic condition. The figure shows that there are substantial differences among European countries concerning the share of road traffic affected by congestion. The monetary results of the inter-urban road congestion are presented in chapter 5 of this report.

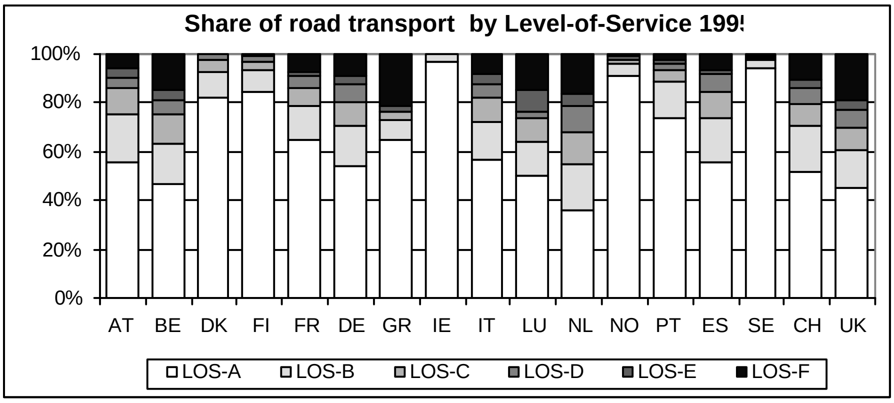

Figure 43: Network results 1995 - LOS-shares by country

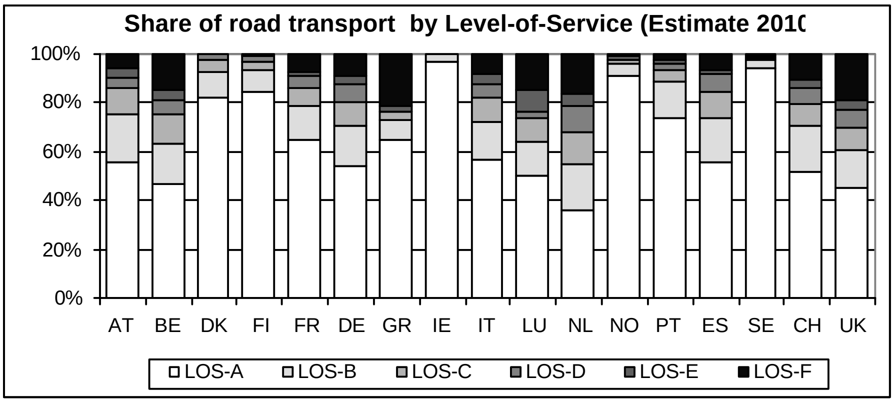

Figure 44: Network results 2010 - LOS-shares by country

By comparing the figures of 1995 and 2010 it is obvious, that the share of traffic suffering from bad LOS-conditions is considerably increasing in nearly every country until 2010.

a) The road network data base

The quantitative data set for calculating inter-urban congestion costs are the specific traffic volumes of passenger cars and heavy duty vehicles by level of service. The results of the IWW road model for 1995 and 2010 are presented in the following tables.

Country	**Passenger cars**						**Heavy duty vehicles**					
	1'000 million vkm, inter-urban traffic						1'000 million vkm, inter-urban traffic					
LOS	A	B	C	D	E	F	A	B	C	D	E	F
Austria	9.5	3.4	1.8	0.6	0.8	1.0	1.2	0.5	0.2	0.1	0.1	0.0
Belgium	9.0	3.3	2.3	1.1	0.7	2.9	1.3	0.5	0.3	0.2	0.1	0.2
Denmark	3.3	0.4	0.2	0.1	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0
Finland	9.0	0.9	0.4	0.2	0.0	0.0	6.4	1.0	0.3	0.2	0.0	0.0
France	83.6	17.7	8.1	6.3	2.4	10.9	8.1	2.3	1.1	0.7	0.3	0.5
Germany	113.9	35.3	20.4	15.4	7.6	19.1	6.5	4.2	2.7	2.0	1.0	1.6
Greece	5.6	0.7	0.3	0.0	0.2	1.8	0.3	0.0	0.0	0.0	0.0	0.0
Ireland	2.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Italy	38.7	10.6	6.6	3.9	2.6	5.7	4.7	2.0	1.5	0.8	0.6	1.2
Luxembourg	0.3	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	12.6	6.7	4.5	3.7	1.8	5.6	1.1	0.9	0.7	0.5	0.3	0.5
Norway	6.6	0.4	0.1	0.0	0.1	0.1	0.7	0.0	0.0	0.0	0.0	0.0
Portugal	5.8	1.2	0.4	0.2	0.1	0.2	0.6	0.1	0.0	0.0	0.0	0.0
Spain	25.9	8.3	4.9	3.4	0.8	2.9	3.8	1.3	0.8	0.5	0.1	0.3
Sweden	15.6	0.6	0.1	0.2	0.0	0.1	2.0	0.1	0.0	0.0	0.0	0.0
Switzerland	8.7	3.1	1.6	1.1	0.5	1.8	0.5	0.2	0.1	0.1	0.0	0.1
UK	25.8	9.1	5.4	4.0	2.5	10.9	3.0	1.4	0.9	0.6	0.5	1.0
Total	**376.0**	**101.9**	**57.1**	**40.3**	**20.3**	**63.0**	**40.4**	**14.5**	**8.7**	**5.8**	**3.0**	**5.5**

Table 140: Annual transport volume of cars and HDVs by country and LOS 1995

Country	Passenger cars						Heavy duty vehicles					
	1'000 million vkm, inter-urban traffic						1'000 million vkm, inter-urban traffic					
LOS	A	B	C	D	E	F	A	B	C	D	E	F
Austria	9.6	3.4	2.1	1.9	0.7	2.2	1.2	0.5	0.3	0.2	0.1	0.2
Belgium	8.7	3.5	2.2	2.2	0.7	4.2	1.3	0.6	0.3	0.3	0.1	0.3
Denmark	3.1	0.7	0.2	0.1	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0
Finland	9.1	1.6	0.4	0.3	0.2	0.1	6.3	1.9	0.4	0.3	0.2	0.1
France	88.2	25.7	14.3	11.7	6.7	31.9	7.8	3.1	1.8	1.6	0.9	2.8
Germany	115.2	34.9	24.6	17.6	10.5	31.9	6.1	3.7	3.2	2.3	1.4	3.3
Greece	6.3	1.3	0.5	0.1	0.3	2.6	0.3	0.0	0.0	0.0	0.0	0.0
Ireland	2.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Italy	39.8	11.6	6.5	7.1	2.9	11.3	4.7	1.9	1.4	1.6	0.6	2.4
Luxembourg	0.3	0.1	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	12.5	5.6	5.3	3.7	2.5	7.6	1.1	0.7	0.8	0.5	0.4	0.8
Norway	7.2	0.9	0.1	0.1	0.0	0.2	0.7	0.1	0.0	0.0	0.0	0.0
Portugal	6.3	1.4	0.7	0.5	0.2	0.5	0.6	0.2	0.1	0.1	0.0	0.1
Spain	25.5	8.7	5.3	3.9	1.0	3.1	3.7	1.3	0.8	0.6	0.2	0.4
Sweden	16.0	0.6	0.2	0.2	0.0	0.1	2.1	0.1	0.0	0.0	0.0	0.0
Switzerland	8.6	3.6	1.6	1.3	0.8	2.6	0.5	0.2	0.1	0.1	0.0	0.1
UK	25.8	9.1	5.7	4.7	2.1	13.3	3.0	1.4	0.9	0.8	0.4	1.4
Total	**384.8**	**112.8**	**69.9**	**55.5**	**28.8**	**111.9**	**39.6**	**15.8**	**10.0**	**8.4**	**4.3**	**11.9**

Table 141: Annual transport volume of cars and HDVs by country and LOS 2010

b) Level-of-Service and unit costs

The Level-of-Service is defined on the basis of the lane occupancy, measured in passenger car units per hour. For each level of service (A to F) a unit value as the average dead-weight-loss in time units is calculated to be applied to the data in table 1 and 2. For motorways and rural roads the following decisive traffic volumes are used:

LOS	Description	Qmin [veh./h,lane]		Decisive Q [veh./h,lane]		Unit costs [h/km]	
		Motorway	Rural	Motorway	Rural	Motorway	Rural
A	Free flow	0	0	400	300	0.0000	0.0000
B	Sight interference	600	500	700	600	0.0004	0.0004
C	Serious interference	800	700	900	800	0.0021	0.0023
D	Very unstable	950	850	1'050	950	0.0057	0.0051
E	Near congestion	1'100	1'000	1'150	1'050	0.0083	0.0065
F	Congestion	1'200	1'100	1'500	1'400	0.0112	0.0079

Table 142: Level-of-Service and unit values

Qmin denotes the traffic volume from which the respective LOS is valid and the "Decisive Q" gives the class average for each LOS-cluster. The unit of the unit costs is "hours per km", which means that the unit costs first need to be multiplied with the value of time to give a monetary figure. The average value of time is calculated by the following table:

Country	**Individual time value**		**Average Occupancy** [Pass. / veh.]			**VOT Passenger** [Euro / veh.-h.]				**VOT Freight** [Euro / veh.-h.]		
	Busin.	Priv.	Car	MC	Bus	Car	MC	Bus	Av.	LDV	HDV	Av.
Austria	19.30	5.79	1.48	1.13	29.97	12.6	6.5	173.6	*13.07*	23.0	42.5	*39.43*
Belgium	20.00	6.00	1.46	1.10	11.57	12.8	6.6	69.4	*12.98*	20.9	38.6	*31.65*
Denmark	20.71	6.21	1.86	1.25	19.96	16.9	7.8	124.0	*17.72*	26.2	48.5	*41.73*
Finland	17.11	5.13	1.40	1.00	12.90	10.5	5.1	66.2	*11.25*	19.2	35.5	*27.78*
France	19.18	5.75	1.86	1.09	18.52	15.7	6.3	106.6	*16.17*	20.8	38.5	*27.19*
Germany	19.72	5.92	1.44	1.00	18.54	12.5	5.9	109.7	*12.93*	23.2	42.9	*37.92*
Greece	11.71	3.51	1.98	1.05	10.73	10.2	3.7	37.7	*10.56*	8.6	15.9	*11.92*
Ireland	16.57	4.97	1.71	1.10	8.45	12.5	5.5	42.0	*12.62*	14.2	26.3	*23.20*
Italy	18.93	5.68	1.88	1.30	16.94	15.7	7.4	96.2	*16.12*	14.9	27.6	*22.58*
Luxembourg	30.13	9.04	1.60	1.10	17.71	21.2	9.9	160.1	*21.92*	33.7	62.3	*56.27*
Netherlands	19.11	5.73	1.63	1.00	22.20	13.7	5.7	127.3	*14.04*	20.0	37.0	*36.85*
Norway	21.81	6.54	1.81	1.12	11.30	17.4	7.4	74.0	*17.94*	26.5	49.1	*36.43*
Portugal	11.98	3.59	2.46	1.35	27.67	13.0	4.8	99.5	*13.79*	8.0	14.8	*11.91*
Spain	13.68	4.11	2.02	1.35	25.18	12.1	5.5	103.4	*12.95*	11.1	20.5	*15.59*
Sweden	17.98	5.39	1.64	1.00	13.21	13.0	5.4	71.3	*13.28*	20.6	38.1	*27.85*
Switzerland	23.86	7.16	1.67	1.11	18.74	17.5	8.0	134.2	*18.14*	33.6	62.2	*46.20*
UK	17.08	5.12	1.66	1.00	8.87	12.4	5.1	45.5	*12.71*	14.8	27.4	*21.63*
Total	**18.76**	**5.63**	**1.74**	**1.12**	**17.21**	**14.4**	**6.3**	**96.8**	***14.83***	**20.0**	**36.9**	***29.48***

Table 143: Value of Time 1995

The value of time 2010 is determined per country multiplication with the GDP growth per capita

c) Results

Country	Passenger cars [million Euro]						Heavy duty vehicles [million Euro]					
LOS	A	B	C	D	E	F	A	B	C	D	E	F
Austria	3	17	51	42	73	117	2	14	43	34	60	36
Belgium	2	17	64	76	68	356	2	13	42	59	44	117
Denmark	1	3	6	11	0	0	1	2	5	8	0	0
Finland	2	4	10	13	4	4	8	23	42	58	20	21
France	29	110	349	479	249	1'473	10	49	149	191	97	259
Germany	31	175	567	1'041	712	2'298	11	127	455	828	570	1'146
Greece	1	3	6	1	16	179	0	0	0	0	0	1
Ireland	1	0	0	0	0	0	0	0	0	0	0	0
Italy	13	65	230	328	302	849	5	36	146	203	208	504
Luxembourg	0	1	3	1	9	19	0	0	1	0	1	1
Netherlands	4	36	135	273	185	740	2	25	107	218	144	372
Norway	3	3	5	1	12	12	1	1	1	0	3	3
Portugal	2	6	10	16	13	22	0	1	2	4	4	5
Spain	7	41	135	231	73	346	3	15	53	87	29	97
Sweden	4	3	3	12	0	11	2	2	1	7	0	8
Switzerland	3	21	61	107	64	306	1	7	18	27	25	46
UK	12	76	254	455	397	2'225	4	31	121	191	195	551
Total	**112**	**563**	**1'938**	**3'479**	**2'585**	**11'178**	**462**	**2'319**	**7'977**	**14'320**	**10'638**	**46'007**

Table 144: Total congestion costs on inter-urban and urban main roads 1995 [million Euro]

Country	Passenger cars [million Euro]						Heavy duty vehicles [million Euro]					
LOS	A	B	C	D	E	F	A	B	C	D	E	F
Austria	3	17	51	42	73	117	2	14	43	34	60	36
Belgium	2	17	64	76	68	356	2	13	42	59	44	117
Denmark	1	3	6	11	0	0	1	2	5	8	0	0
Finland	2	4	10	13	4	4	8	23	42	58	20	21
France	29	110	349	479	249	1'473	10	49	149	191	97	259
Germany	31	175	567	1'041	712	2'298	11	127	455	828	570	1'146
Greece	1	3	6	1	16	179	0	0	0	0	0	1
Ireland	1	0	0	0	0	0	0	0	0	0	0	0
Italy	13	65	230	328	302	849	5	36	146	203	208	504
Luxembourg	0	1	3	1	9	19	0	0	1	0	1	1
Netherlands	4	36	135	273	185	740	2	25	107	218	144	372
Norway	3	3	5	1	12	12	1	1	1	0	3	3
Portugal	2	6	10	16	13	22	0	1	2	4	4	5
Spain	7	41	135	231	73	346	3	15	53	87	29	97
Sweden	4	3	3	12	0	11	2	2	1	7	0	8
Switzerland	3	21	61	107	64	306	1	7	18	27	25	46
UK	12	76	254	455	397	2'225	4	31	121	191	195	551
Total	**112**	**563**	**1'938**	**3'479**	**2'585**	**11'178**	**462**	**2'319**	**7'977**	**14'320**	**10'638**	**46'007**

Table 145: Total congestion costs on inter-urban and urban main roads 2010 [million Euro]

Due different quality levels of the country-specific presentation of road infrastructure within the IWW road network database some adjustments were necessary to the UK and France:

- A comparison of the modelled inter-urban traffic flows to the numbers reported by TRENDS (1999) for all EUR-17 countries justified to factor up the mileage of goods vehicles by 72.5% and the mileage of passenger vehicles by 33.5%. In absence of more detailed information these adjustment factors have been applied equally to all Levels-of-Service.
- 10% of the French inter-urban traffic was shifted from LOS-Levels D, E and F (dense traffic) to less congested traffic situations because the comparison with TRENDS (1999) did not show a over-estimation of inter-urban traffic flows. By the shift of peak traffic to off-peak the urban situations are relaxed and the database is prepared for the estimation of additional inner-urban congestion. The result of this measure is a decrease in total congestion costs by 5.8%.

2.8.3 Adjustment of inner-urban congestion

On an urban level no link-based information is available. Therefore the analysis of traffic situations is based on the decrease in travel speed rather than on the ration of traffic demand to infrastructure capacity. The approach chosen comprises the following working steps:

- Choosing a speed flow diagram for an ordinary urban road (EWS type and an appropriate traffic demand elasticity (η = -0.8) a unit cost function expressing the average dead-weight-loss per PCU-km depending on the road occupancy is estimated.
- By variable a simple transformation the unit cost function is expressed in time-units per kilometre as a function of the actual travel speed relative to free flow. The respective functions used are shown by:

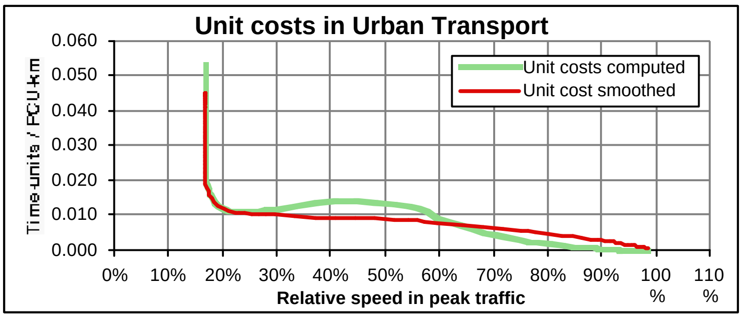

Figure 45: Unit costs by relative speed in urban areas

- From the transport data base derived from TRENDS (1999) the volume of urban traffic per mode and country is derived.
- Based on the hourly deviation of traffic demand used for calculating inter-urban congestion and under the assumption that large cities in average consist of three congested hours per day it is estimated that 20% of urban traffic suffer from congestion. The off-peak hours are assumed to be either congestion-free or to consist of an extremely low demand elasticity.
- On the basis of OECD (1995) it is estimated that the average travel speed in peak hours is about 73% of the travel speed under off-peak conditions. This figure proves no significant dependency on the city size.

The result of this procedure is average European unit costs per vehicle kilometre affected by urban congestion plus the respective traffic volumes. Two difficulties come along with this rough approach, which concern the missing local specification of the cost estimation and possible overlaps between the urban and the inter-urban approach.

Total and average congestion costs in urban and inter-urban traffic by country and means of transport are presented in chapter 3.1.

The following tables present the traffic data based and the results of urban congestion. The underlying unit costs are presented in chapter 2.2 of the main report.

Country	Traffic volume in urban areas 1995 [million vkm]					Urban congestion costs 1995 [1'000 million Euro]				
	Car	MC	Bus	LGV	HGV	Car	MC	Bus	LGV	HGV
Austria	13'807	138	311	526	1'064	0.07	0.00	0.05	0.01	0.05
Belgium	17'238	172	308	1'747	2'540	0.09	0.00	0.02	0.02	0.10
Denmark	12'175	121	475	1'095	1'298	0.09	0.00	0.05	0.02	0.07
Finland	6'013	60	502	782	879	0.03	0.00	0.03	0.01	0.03
France	106'872	1'068	2'383	27'387	12'068	0.71	0.00	0.22	0.36	0.49
Germany	136'569	1'365	2'652	7'434	14'723	0.72	0.00	0.25	0.11	0.67
Greece	11'523	115	140	4'315	1'373	0.05	0.00	0.00	0.02	0.02
Ireland	4'217	42	156	373	202	0.02	0.00	0.01	0.00	0.01
Italy	109'013	1'090	2'525	10'747	10'097	0.72	0.00	0.21	0.10	0.29
Luxembourg	1'267	12	29	27	101	0.01	0.00	0.00	0.00	0.01
Netherlands	22'153	221	337	63	3'246	0.13	0.00	0.04	0.00	0.13
Norway	9'098	90	270	976	465	0.07	0.00	0.02	0.02	0.02
Portugal	7'324	73	184	171	1'320	0.04	0.00	0.02	0.00	0.02
Spain	56'237	562	640	38'014	7'803	0.29	0.00	0.06	0.27	0.17
Sweden	13'346	133	667	2'206	1'470	0.07	0.00	0.04	0.03	0.06
Switzerland	16'642	166	289	1'285	612	0.12	0.00	0.03	0.03	0.04
UK	134'042	1'340	3'813	14'752	8'324	0.71	0.00	0.15	0.14	0.24
EUR 17	**651'796**	**6'517**	**15'122**	**109'636**	**66'508**	**3.95**	**0.01**	**1.17**	**1.14**	**2.43**

Table 146: Urban congestion costs 1995

Country	Traffic volume in urban areas 2010 [million vkm]					Urban congestion costs 2010 [1'000 million Euro]				
	Car	MC	Bus	LGV	HGV	Car	MC	Bus	LGV	HGV
Austria	16'078	160	334	619	1'252	0.22	0.00	0.12	0.02	0.14
Belgium	19'009	190	282	2'006	2'916	0.26	0.00	0.04	0.07	0.30
Denmark	12'431	124	546	1'166	1'382	0.23	0.00	0.15	0.05	0.18
Finland	6'318	63	510	922	1'037	0.07	0.00	0.07	0.03	0.10
France	116'956	1'169	2'514	30'760	13'555	1.92	0.00	0.56	1.00	1.36
Germany	189'291	1'892	3'603	10'259	20'319	2.40	0.01	0.80	0.36	2.21
Greece	14'954	149	128	5'086	1'618	0.16	0.00	0.01	0.07	0.07
Ireland	4'623	46	177	436	236	0.07	0.00	0.02	0.01	0.02
Italy	109'801	1'098	2'657	12'257	11'516	1.87	0.00	0.56	0.30	0.86
Luxembourg	1'516	15	32	28	105	0.03	0.00	0.01	0.00	0.02
Netherlands	23'289	232	358	72	3'731	0.33	0.00	0.09	0.00	0.35
Norway	10'372	117	294	1'142	553	0.19	0.00	0.05	0.05	0.07
Portugal	9'038	90	208	213	1'652	0.14	0.00	0.05	0.00	0.07
Spain	64'698	646	658	45'540	9'348	0.90	0.00	0.16	0.86	0.55
Sweden	13'393	133	662	2'583	1'722	0.18	0.00	0.10	0.08	0.17
Switzerland	18'972	215	315	1'504	728	0.33	0.00	0.08	0.08	0.11
UK	140'225	1'402	3'816	15'976	9'015	1.88	0.00	0.37	0.38	0.67
EUR 17	**770'964**	**7'742**	**17'093**	**130'569**	**80'685**	**11.17**	**0.02**	**3.24**	**3.37**	**7.25**

Table 147: Urban congestion costs 2010

To provide an impression of how dense the IWW traffic networks are in urban areas, the following network extracts are presented. Comparing the networks of Paris to that of London and Berlin the necessity for adjusting the French database due to its dense network representation becomes evident.

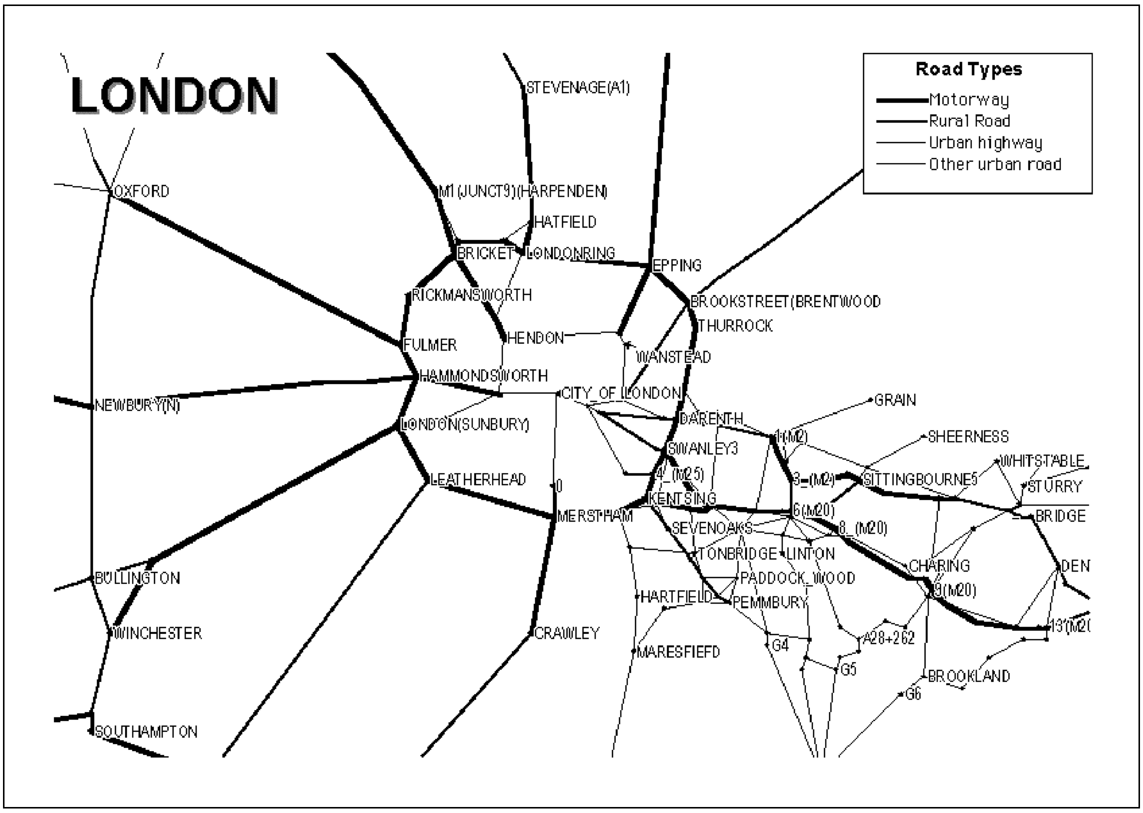

Figure 46: IWW network extraction: London

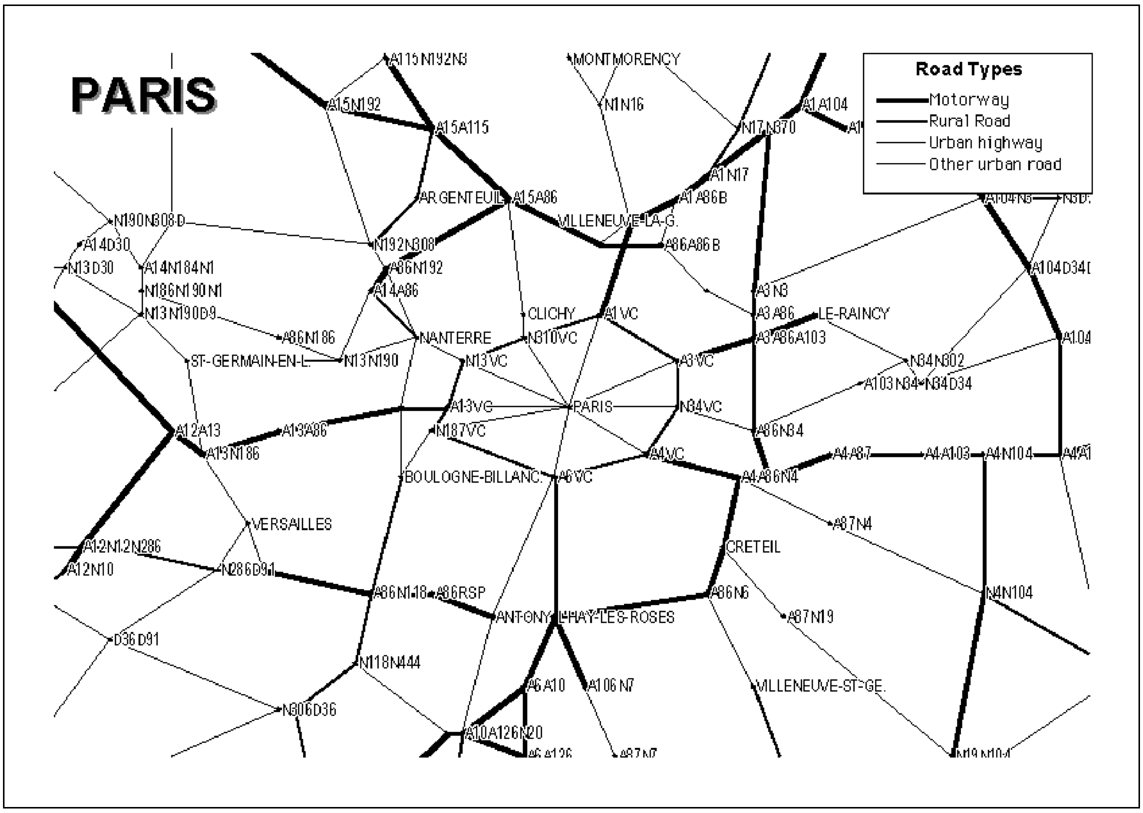

Figure 47: IWW network extraction: Paris

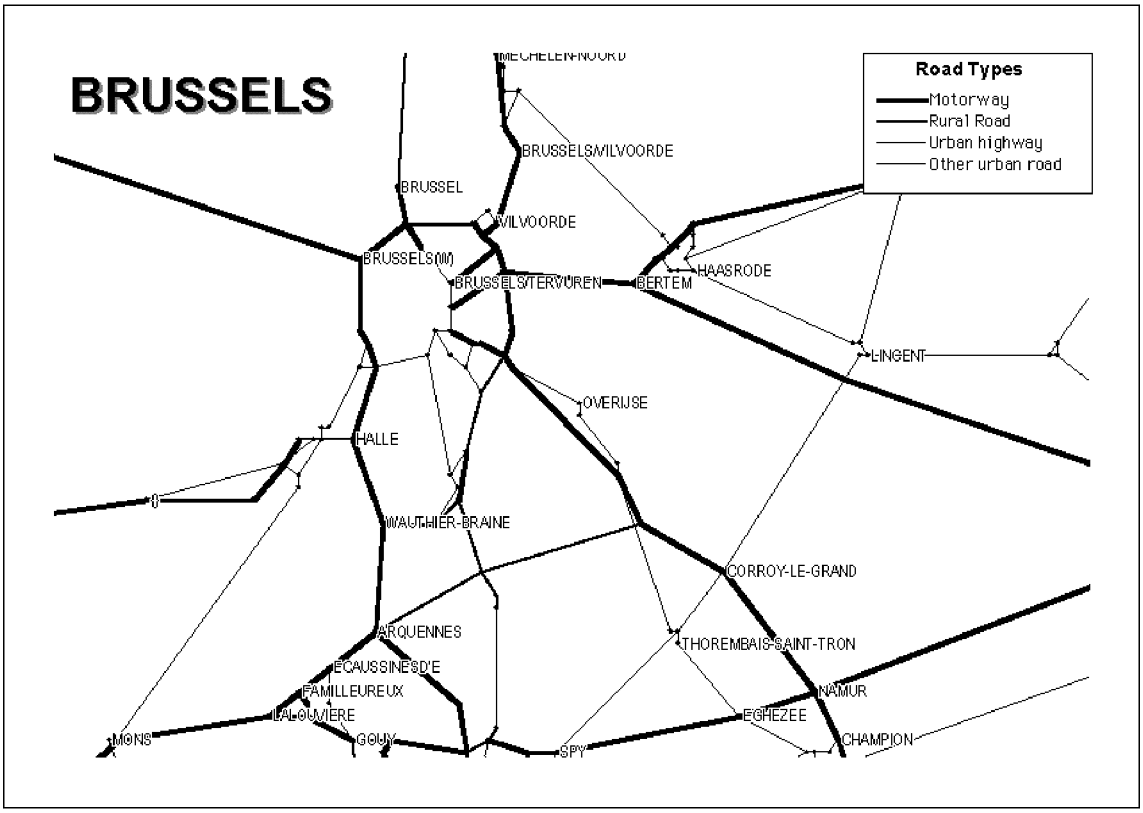

Figure 48: IWW network extraction: Brussels

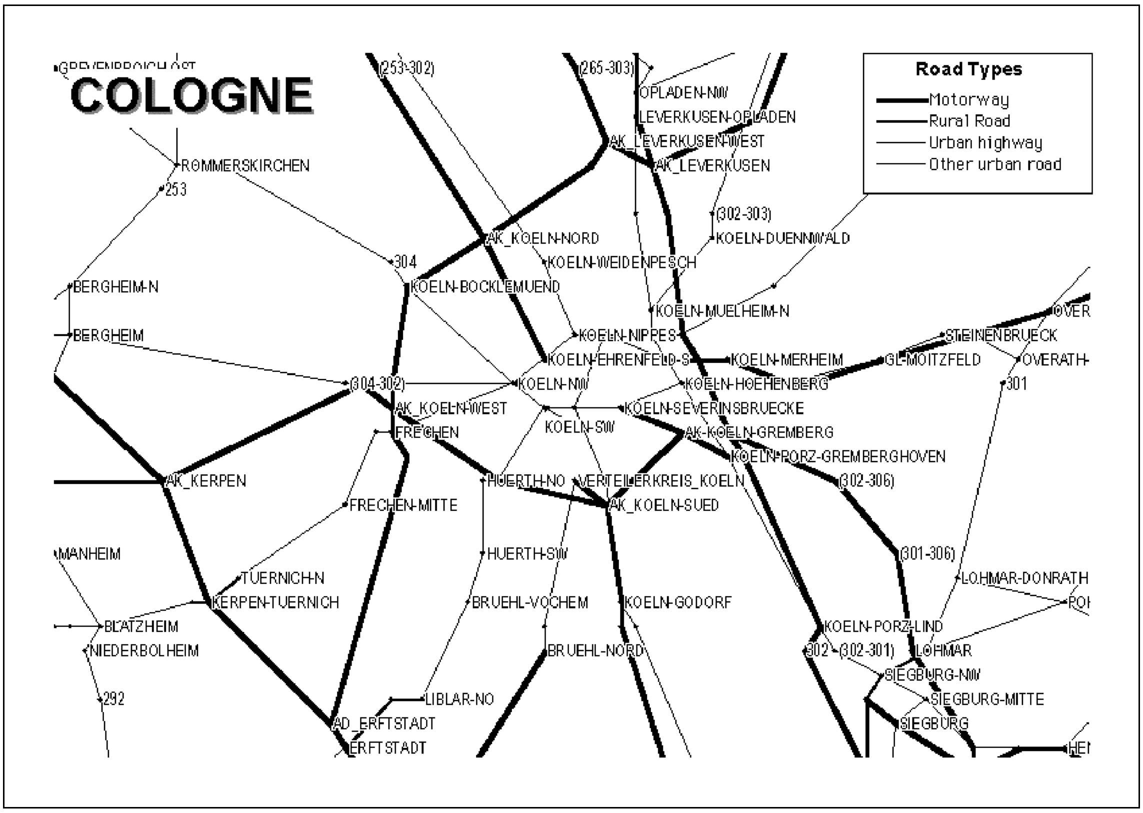

Figure 49: *IWW network extraction: Cologne*

2.9 Corridor estimates

2.9.1 General definitions

The four corridors analysed in this study are each consisting of three main travel alternatives. A number of non-road alternatives include initial and final access by car (passenger corridors) or truck (freight transport). In general comparisons are made between uni-modal road and rail transport and an additional, mostly inter-modal alternative.

Corridor	Mode 1	Mode 2	Mode 3
I: Paris – Vienna (Passenger)	Passenger car	Rail (Euro City)	Mid-distance flight, access by car
II: Paris – Brussels (Passenger)	Passenger car	High speed rail (Thalys)	Short-distance flight (Access by car)
III: Cologne – Milan (Freight)	HDV 28t (CH) HDV 40t (FR)	Combined (container) transport (UCT)	HDV using Rolling Motorway Basle – Chiasso
IV: Rotterdam – Basle (Freight)	HDV 40t	Rail wagon load (direct track access)	Water (direct access)

Table 148: Transport alternatives per corridor

The case studies do not intend to elaborate a complete analysis of all possible travel alternatives along the four corridors and hence a representative type of vehicle is chosen for each mode. Moreover, the loading factors of the representative vehicles are chosen as typical values along the corridors; they are not necessarily in line with the average occupancy rates by mode and country reported in annex 1. An overview of the four corridors and their specific modal characteristics is given by the following table:

Vehicle type	Symbol	DETAILS	LOAD
Passenger car inter-urban	Car	Petrol, Euro-I	1.9
Passenger car urban	Car	Petrol, Euro-I	1.4
Heavy duty vehicle, 28t	L28	Diesel, Euro-I	6.5
Heavy duty vehicle, 32t-40t	L40	Diesel, Euro-I	10.8
Passenger train (EC)	Rail	UCPTE-Mix	248
High speed rail (Thalys)	HSR	UCPTE-Mix	313
Freight train - combined transport	UCT	UCPTE-Mix	529
Freight train - rolling motorway	RMW	UCPTE-Mix	157
Freight train - Wagon load	RWL	UCPTE-Mix	350
Aircraft – short distance	Air		81
Aircraft – medium distance	Air		149
Inland navigation vessel	Water		1139

Table 149: Details of transport modes

The assumptions underlying these load factors are:

- In inter-urban passenger transport by car a vehicle occupancy of 1.9 passengers is assumed for both relevant corridors (I and II). For urban car transport (airport access in corridors I and II) only 1.4 passengers per car are assumed. In both cases an average petrol car (Euro-1 standard) is chosen.
- Passenger rail is presented in the form of traditional rail transport (Euro City) and high speed rail transport (THALYS). The occupancy rates are chosen with 248 passengers (EC) and 313 passengers (THALYS) according to average local conditions. Both trains are assumed to use an UCPTE electricity mix.
- In air passenger transport (corridor I and II) average mid- and short distance aircrafts are chosen, which are occupied with 81 passengers (short distance) and 149 passengers (mid distance). The access by road is assumed to be two times 20 km through urban areas for both corridors.
- In road freight transport (corridors III and IV) and for initial and terminal shipments in combined rail transport (corridor III) standard 32t-40t-HDVs with diesel Euro-1 technology and a payload of 10.8 tons are chosen. Solely in corridor III due to the Swiss 28-t-limit in addition a 28-t lorry with an average loading factor of 6.5 tons is considered.
- In rail freight transport three variants are analysed: combined unaccompanied container transport (UCT) and rolling motorway (RMW) in corridor III and uni-modal wagon load (RWL) for containerised goods in corridor IV. The loading factors chosen are highest (529t) in Trans-Alpine UCT while for a similar train from Rotterdam to Basle an extremely worse rate of 350 t is estimated. The net loading factor of rolling motorway trains is set to 157 t for containerised goods only. Because of the thus less heavy train compositions the emission and climate

change costs per train are only 64% of the UCT-values for RWL and even only 50% for RMW shuttles. The remaining cost components remain constant for all train types.

- In waterborne freight transport an average Rhine vessel with a mean load of 2'280 tons and a share of 50 % empty headings is assumed. The average loading factor hence is 1'138 tons. Initial and terminal shipments by road are not assumed.

As most cost categories are sensitive to environmental characteristics, such as the regional sensitivity, population density, the type and gradient of roads and traffic loads, the corridor sections are classified according to the following features:

Feature	**Details**
Land use: Population density by NUTS-3 regions.	1: Nun built-up area, not sensitive 2: Settlements near transport infrastructure 3: Transport infrastructure through built-up areas 4: Urban area
Road Type: According to the German road investment manual (EWS)	1: Inter-urban Motorway 2: Other rural road 3: Urban motorway 4: Other urban road
Road Gradient: Topological maps.	1: Plain area 2: Mountainous structure
Traffic level (road only): Evaluation of modelled traffic flows on the network links.	1: Relaxed: (< 500 PCU/h, lane) 2: Dense traffic (500 - 900 PCU / h, lane) 3: Congested: (> 900 PCU / h, lane)

Table 150: Characteristics of transport infrastructure

2.9.2 Route definition

The four corridors are defined by route segments of 1 to 10 km length. The basic variables (length, road type, gradients) are taken out of the digitised IWW road and railway networks, while the type of region surrounding each segment is determined by the NUTS-3 region associated to the respective infrastructure. It is clear that a number of attributes are relevant (or available) for the road network only and hence the definition of the rail and air modes contain less information.

Partial Route	NUTS3	Int. name	Dis- tance	Road type	Pop. dens.	Area	Grad.	LOS
Corridor I: Long-distance passenger transport								
Mode 1: Passenger car								
Paris								
Lagny / A4A104N37	FR107	E50	28	4	503	4	1	3
Meaux / CRECY	FR102	E50	19	1	203	2	1	2
Reims	FR221	E50	93	1	7	2	1	1
Châlons	FR213	E50	31	1	7	2	1	1
Metz	FR412	E50	157	1	3	2	1	1
Merlebach	FR413	E50	48	1	16	2	1	1
Hoerdt	FR421	E25	102	1	21	2	1	1
Strasbourg-West	FR421	E25	13	1	21	3	1	3
Strasbourg-Ost	FR421	E52	5	4	21	2	1	3
Autobahn A5/E35	DE134	E52	12	2	212	3	1	1
Karlsruhe	DE124	E52	67	1	287	3	1	3
Stuttgart	DE128	E52	82	1	489	3	1	2
Ulm	DE114	E52	92	1	400	2	2	2
Augsburg	DE27B	E52	81	1	93	2	2	2
Munich-Dachau	DE217	E52	68	1	213	3	2	2
München-Brunnthal	DE21H	E52/A99	39	3	425	3	2	3
Rosenheim	DE21F	E52	59	1	106	2	2	2
Salzburg	DE21M	E52	138	1	107	2	2	1
Linz	AT312	E60	132	1	301	2	2	1
Vienna-West	AT121	E60	166	1	71	3	2	1
Vienna	AT13	E60	10	4	3904	4	0	3
Mode 2: Rail (EC)								
Paris								
Nancy	FR213	-	370	-	7	4	1	-
Strasbourg	FR421	-	149	-	21	3	1	-
Baden-Baden	DE134	-	61	-	212	3	1	-
Karlsruhe	DE124	-	30	-	287	3	1	-
Stuttgart	DE12B	-	82	-	326	3	2	-
Ulm	DE114	-	92	-	400	2	2	-
Augsburg	DE278	-	81	-	158	2	2	-
München-Hbf	DE21C	-	68	-	431	3	2	-
Salzburg	DE21K	-	138	-	159	2	2	-
Attnang-Puchheim	AT315	-	71	-	90	2	2	-
Linz	AT312	-	56	-	301	2	2	-
St. Pölten	AT121	-	130	-	71	2	2	-
Wien	AT123	-	60	-	115	3	2	-
Mode 3: Flight with access by car								
Paris								
Charle-de-Gaulle	FR213	-	20	-	7	-	1	3
Vienna	0	-	1400	-	0	-	-	-
Wien	AT123	-	20	-	115	-	1	3

Table 151: Corridor I: Long-distance passenger transport Paris - Vienna

Partial Route	NUTS3	Int. name	Dis-tance	Road type	Pop. dens.	Area	Grad.	LOS
Corridor II: medium-distance passenger transport Paris - Brussels								
Mode 1: Passenger car								
Paris								
A1A104	FR106	E15/E19	18	1	583	4	1	1
Senlis	FR108	E15/E19	29	1	90	3	1	3
Arsy	FR222	E15/E19	23	1	13	2	1	3
Roye	FR222	E15/E19	35	1	13	2	1	2
Combles	FR223	E15/E19	39	1	9	2	1	2
Havrincourt	FR302	E19	20	1	22	2	1	1
Hordain	FR301	E19	19	1	46	3	1	1
Valenciennes	FR301	E19	17	1	46	3	1	1
Grenze	FR301	E19	17	1	46	3	1	1
Mons / Ville-sur-Heine	BE323	E19	20	1	432	3	1	2
Brussel-Süd	BE325	E19	64	1	331	4	1	2
Brussel	BE1	E19	5	4	5868	4	0	3
Mode 2: High-speed rail (THALYS)								
Paris								
Grenze	FR221	-	200	-	90	2	1	-
Bruxelles	BE11	-	91	-	432	3	1	-
Mode 3: Flight with access by car								
Paris								
Charles d.G.	FR221	-	20	-	583	4	1	1
Brussels Airport		-	300	-	-	-	1	
Bruxelles	FR221	-	20	-	5868	4	1	3

Table 152: Corridor II: Short-distance passenger transport Paris - Brussels

Partial Route	NUTS3	Int. name	Dis-tance	Road type	Pop. dens.	Area	Grad.	LOS
Corridor III: Inter-modal freight transport Cologne - Milan								
Mode 1: Passenger car								
Köln								
Bonn	DEA23	A555	27	1	2383	3	1	1
Koblenz	DEB12	A565/A61/ E31	63	1	161	2	1	2
Mannheim	DEB3B	A61/E31	147	1	203	3	1	2
Karlsruhe	DE123	A5	68	1	381	3	1	3
Offenburg	DE124	A5	71	1	287	3	1	2
Freiburg	DE134	A5	69	1	212	3	2	2
Basel	DE132	A5	70	1	170	3	2	2
Luzern	CH	A2/E35	94	1	172	2	2	1
Göschenen	CH	A2/E35	66	1	172	2	2	1
Bellinzona	CH	A2/E35	74	1	172	2	2	1
Lugano	CH	A2/E35	33	1	172	2	2	1
Como	CH	A9/E35	33	1	172	3	2	1
Milano	IT202	A9/E35	48	1	417	3	2	1
Mode 2: Unaccompanied combined transport (access by road)								
Access by road								
Köln	DEA27	-	50	-	642	3	1	-
Bonn	DEA27	-	34	-	642	3	1	-
Koblenz	DEB12	-	63	-	161	2	1	-
Frankfurt	DEB1A	-	141	-	165	3	1	-
Mannheim	DE716	-	83	-	434	3	1	-
Karlsruhe	DE123	-	62	-	381	3	1	-
Offenburg	DE124	-	72	-	287	3	2	-
Freiburg	DE134	-	63	-	212	3	2	-
Basel	DE132	-	61	-	170	3	2	-
Olten	CH	-	42	-	172	3	2	-
Luzern	CH	-	57	-	172	2	2	-
Bellinzona	CH	-	140	-	172	2	2	-
Lugano	CH	-	33	-	172	2	2	-
(Chiasso)	CH	-	28	-	172	2	2	-
Como	IT202	-	5	-	417	3	2	-
Milano	IT205	-	47	-	1887	3	2	-
Access by road	IT205	-	50	-	1887	3	2	-
Mode 3: Truck with rolling motorway Basle - Chiasso								
Cologne								
Basle (>> road)	DEA27	-	561	-	642	3	1	1
Chiasso (>> rail)	CH	-	320	-	642	2	2	-
Milan (>> road)	IT11	-	50	-	161	3	1	1

Table 153: Corridor III: Inter-modal freight transport Cologne - Milan

Partial Route	NUTS3	Int. name	Dis-tance	Road type	Pop. dens.	Area	Grad.	LOS
Corridor IV: Unimodal freight transport Rotterdam - Basle (no truck access)								
Mode 1: HDV								
Rotterdam								
Grenze	NL411	E19	56	1	453	3	1	3
Antwerpen	BE211	E19	39	1	933	3	1	3
Mechelen	BE211	E19	23	1	933	3	1	3
Bruxelles-Vilvoorde	BE241	E19	28	1	585	3	1	3
Bruxelles-Tervuren	BE241	0	13	3	585	4	1	3
Namur	BE31	E411	44	1	312	2	1	1
Neufchâteau	BE351	E411	93	1	62	2	0	1
Arlon	BE344	E411	37	1	41	2	2	1
Luxembourg	LU	E25	28	1	160	3	2	1
Metz	FR413	E25/A31	63	1	16	2	1	1
Merlebach	FR413	E25/A4	48	1	16	2	0	1
Hoerdt	FR421	E25/A4	102	1	21	3	0	1
Strasbourg	FR421	E25/A4	13	1	21	3	1	3
Dambach-la-Ville	FR421	E25/N83	41	2	21	2	0	2
Houssen	FR422	E25/N83	27	2	20	2	0	3
Mulhouse	FR422	E25/A35	39	1	20	3	1	1
Basel	FR422	E25/A35	35	1	20	3	2	1
Mode 2: Rail Wagon load (direct track connection)								
Rotterdam								
Dordrecht	NL335	-	20	-	994	3	1	-
Roosendaal	NL411	-	38	-	453	3	1	-
Essen	NL411	-	8	-	453	3	1	-
Antwerpen	BE211	-	33	-	933	3	1	-
Mechelen	BE211	-	22	-	933	4	1	-
Bruxelles	BE241	-	26	-	585	2	1	-
Namur	BE31	-	58	-	312	2	1	-
Arlon	BE344	-	137	-	41	2	2	-
Luxembourg	LU	-	28	-	160	3	2	-
Metz	FR413	-	63	-	16	2	1	-
Strasbourg	FR413	-	160	-	16	2	1	-
Mulhouse	FR422	-	107	-	20	3	2	-
Basel								
Mode 3: Inland navigation (direct transhipment)								
Rotterdam								
Basel	FR422	-	730	-	20	2	-	-

Table 154: Corridor IV: Uni-modal freight transport Rotterdam - Basle

3 Country tables

Austria

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	**4'637**	3'883	246	27	*4'155*	76	384	*460*	14	0	8	0	0
Noise	**802**	468	12.4	8	*489*	20	231	*251*	10	10	41	3	0
Air Pollution	**2'863**	1'165	5.1	109	*1'279*	66	1'446	*1'512*	19	27	8	0	18
Climate Change	**2'929**	1'382	11.2	61	*1'454*	76	901	*977*	30	44	391	25	9
Nature & Landscape	**500**	300	2.2	7	*310*	17	145	*162*	3	5	18	1	0
Urban Effects	**185**	104	0.7	3	*107*	6	50	*56*	9	13	0	0	0
Upstream Process	**1'301**	679	4.7	27	*711*	37	416	*459*	17	53	54	3	5
Total	**13'217**	**7'981**	**282**	**242**	***8'505***	**298**	**3'573**	***3'876***	**101**	**151**	**520**	**32**	**32**

Table 155: Total costs per means of transport in Austria (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	51	293	2.1	*46*	1.4	0.7	131	5	*6*	0.0	0.0	0.0
Noise	6	15	0.7	*5*	1.0	3.6	34	3	*3*	0.7	19	0.0
Air Pollution	15	6	8.7	*14*	1.9	0.7	114	18	*18*	2.0	3.4	8.4
Climate Change	18	13	4.9	*16*	3.1	34	131	11	*9*	3.1	179	4.2
Nature & Landscape	4	3	0.6	*3*	0.4	1.6	29	2	*2*	0.4	9	0.0
Urban Effects	1	1	0.2	*1*	0.9	0.0	10	1	*1*	0.9	0.0	0.0
Upstream Process	9	6	2.2	*8*	1.7	4.7	65	6	*5*	3.8	25	2.4
Total	**104**	**336**	**19**	***95***	**10**	**46**	**514**	**44**	***44***	**11**	**234**	**15**

Table 156: Average costs per means of transport in Austria (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	**658**	367	2.3	45	*415*	31	213	*244*
Average Costs [Euro/1000 pkm or tkm]		4.8	2.7	3.6	*4.6*	52.8	2.6	*2.9*

Table 157: Congestion costs in Austria (1995)

Belgium

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	**5'711**	4'705	240	20	*4'966*	262	465	*727*	5	0	13	0	0
Noise	**1'191**	657	14.5	7	*679*	79	324	*403*	35	22	43	8	0
Air Pollution	**5'565**	2'409	8.8	149	*2'567*	376	2'433	*2'809*	46	41	19	4	79
Climate Change	**3'753**	1'767	12.6	52	*1'832*	280	907	*1'187*	39	35	538	100	23
Nature & Landscape	**490**	279	1.7	4	*285*	44	135	*179*	3	3	17	3	0
Urban Effects	**242**	138	0.8	2	*141*	22	66	*88*	7	7	0	0	0
Upstream Process	**2'013**	1'050	5.8	29	*1'085*	167	543	*718*	50	52	76	14	18
Total	**18'964**	**11'006**	**285**	**264**	***11'555***	**1'229**	**4'873**	***6'110***	**185**	**160**	**706**	**129**	**120**

Table 158: Total costs per means of transport in Belgium (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	46	262	5.0	46	0.8	0.7	118	8	12	0.0	0.0	0.0
Noise	6	16	1.8	6	5.2	2.5	36	6	7	3.0	13	0.0
Air Pollution	24	10	36.6	24	6.8	1.1	170	43	48	5.6	5.8	14.1
Climate Change	17	14	12.7	17	5.7	31	126	16	15	4.7	162	4.2
Nature & Landscape	3	2	1.0	3	0.5	0.9	20	2	3	0.4	5	0.0
Urban Effects	1	1	0.5	1	1.0	0.0	10	1	2	0.9	0.0	0.0
Upstream Process	10	6	7.0	10	7.4	4.3	75	10	12	7.2	23	3.2
Total	**108**	**310**	**65**	**108**	**27**	**40**	**554**	**87**	**99**	**22**	**208**	**21**

Table 159: Average costs per means of transport in Belgium (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	1'094	664	3.6	22	*690*	101	303	*404*
Average Costs [Euro/1000 pkm or tkm]		6.5	4	5.4	*6.5*	45.7	5.4	*6.9*

Table 160: Congestion costs in Belgium (1995)

Denmark

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	1'829	1'473	74	27	*1'574*	70	165	*235*	8	0	12	0	0
Noise	395	215	4.3	10	*229*	23	114	*137*	8	3	16	2	0
Air Pollution	2'928	1'158	3.1	225	*1'386*	130	1'272	*1'401*	106	15	17	2	0
Climate Change	2'264	759	5.0	100	*864*	115	565	*681*	67	10	578	64	0
Nature & Landscape	320	163	0.9	11	*175*	23	85	*108*	4	1	29	4	0
Urban Effects	184	102	0.5	7	*110*	14	53	*68*	5	2	0	0	0
Upstream Process	1'042	475	2.2	49	*527*	63	307	*376*	44	7	81	9	0
Total	**8'962**	**4'345**	**90**	**429**	***4'864***	**438**	**2'562**	***3'005***	**242**	**37**	**733**	**81**	**0**

Table 161: Total costs per means of transport in Denmark (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	25	178	2.0	*22*	1.6	0.7	80	3	*5*	0.0	0.0	0.0
Noise	4	10	0.8	*3*	1.7	0.9	26	2	*3*	1.7	4	0.0
Air Pollution	20	7	16.5	*19*	22.2	1.0	148	27	*29*	8.1	4.4	0.0
Climate Change	13	12	7.4	*12*	14.1	34	132	12	*12*	5.1	152	0.0
Nature & Landscape	3	2	0.8	*2*	0.8	1.7	26	2	*2*	0.3	9	0.0
Urban Effects	2	1	0.5	*2*	1.0	0.0	16	1	*1*	1.0	0.0	0.0
Upstream Process	8	5	3.6	*8*	9.1	4.7	72	7	*8*	3.4	21	0.0
Total	**75**	**216**	**32**	***68***	**51**	**43**	**500**	**54**	***60***	**20**	**191**	**0**

Table 162: Average costs per means of transport in Denmark (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	251	105	0.3	45	*151*	22	79	*101*
Average Costs [Euro/1000 pkm or tkm]		1.8	0.7	3.3	*2.1*	25.3	1.6	*2.1*

Table 163: Congestion costs in Denmark (1995)

Finland

Total Costs per Means of Transport (1995) [million Euro / year]		Road								Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	1'081	768	146	20	*934*	57	82	*139*	4	0	5	0	0
Noise	248	104	8.3	7	*120*	17	52	*70*	14	18	25	2	0
Air Pollution	1'432	586	6.1	151	*743*	110	508	*618*	11	30	5	0	25
Climate Change	1'459	543	13.6	94	*650*	114	310	*424*	20	53	276	21	14
Nature & Landscape	347	159	3.4	14	*177*	35	78	*113*	2	6	45	4	0
Urban Effects	127	64	1.4	6	*71*	14	31	*45*	3	8	0	0	0
Upstream Process	634	292	5.6	39	*337*	58	145	*207*	8	33	38	3	8
Total	**5'328**	**2'517**	**185**	**331**	***3'033***	**406**	**1'206**	***1'615***	**63**	**148**	**393**	**30**	**47**

Table 164: Total costs per means of transport in Finland (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	26	163	2.4	*24*	1.3	0.6	61	4	*6*	0.0	0.0	0.0
Noise	4	9	0.9	*3*	4.5	3.3	19	2	*3*	1.9	13	0.0
Air Pollution	20	7	18.3	*19*	3.6	0.7	119	24	*28*	3.1	2.4	7.6
Climate Change	18	15	11.4	*17*	6.4	36	124	15	*13*	5.5	169	4.2
Nature & Landscape	5	4	1.8	*5*	0.7	5.8	38	4	*5*	0.6	31	0.0
Urban Effects	2	2	0.7	*2*	0.8	0.0	15	1	*2*	0.8	0.0	0.0
Upstream Process	10	6	4.8	*10*	2.5	4.9	63	7	*9*	3.5	23	2.3
Total	**85**	**205**	**40**	***79***	**20**	**51**	**440**	**57**	***66***	**15**	**238**	**14**

Table 165: Average costs per means of transport in Finland (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	303	61	0.8	27	*88*	70	145	*215*
Average Costs [Euro/1000 pkm or tkm]		2.1	0.9	3.3	*2.3*	75.7	6.8	*9.7*

Table 166: Congestion costs in Finland (1995)

France

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	23'168	17'369	1'688	157	*19'214*	2'284	1'569	*3'853*	50	0	51	0	0
Noise	7'172	3'823	153.1	92	*4'067*	1'148	1'593	*2'741*	42	42	255	24	0
Air Pollution	18'970	7'865	50.8	957	*8'873*	3'184	6'520	*9'705*	128	140	62	6	57
Climate Change	16'883	7'180	95.7	463	*7'739*	2'985	3'016	*6'001*	67	73	2'679	299	25
Nature & Landscape	4'078	2'077	22.5	67	*2'167*	820	847	*1'667*	25	27	167	24	0
Urban Effects	983	479	5.2	15	*500*	189	195	*384*	55	45	0	0	0
Upstream Process	8'137	3'888	41.1	217	*4'146*	1'597	1'606	*3'246*	134	185	369	41	15
Total	**79'391**	**42'681**	**2'056**	**1'968**	***46'706***	**12'207**	**15'347**	***27'597***	**501**	**512**	**3'584**	**395**	**97**

Table 167: Total costs per means of transport in France (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	32	245	2.7	*32*	0.9	0.7	99	9	*19*	0.0	0.0	0.0
Noise	7	22	1.6	*7*	0.7	3.4	50	9	*13*	0.9	12	0.0
Air Pollution	14	7	16.4	*15*	2.2	0.8	138	35	*47*	2.8	2.9	9.7
Climate Change	13	14	8.0	*13*	1.1	36	129	16	*23*	1.5	147	4.2
Nature & Landscape	4	3	1.2	*4*	0.4	2.2	36	5	*8*	0.6	12	0.0
Urban Effects	1	1	0.3	*1*	0.9	0.0	8	1	*2*	0.9	0.0	0.0
Upstream Process	7	6	3.7	*7*	2.3	4.9	69	9	*16*	3.8	20	2.6
Total	**78**	**299**	**34**	***77***	**8**	**48**	**529**	**84**	***128***	**10**	**193**	**16**

Table 168: Average costs per means of transport in France (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	5'179	3294	29	247	*3571*	768	841	*1609*
Average Costs [Euro/1000 pkm or tkm]		6.1	4.3	4.3	*5.9*	33.3	4.6	*7.8*

Table 169: Congestion costs in France (1995)

Germany

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	43'386	35'359	3'900	268	*39'527*	958	2'763	*3'721*	58	0	80	0	0
Noise	10'021	5'691	265.0	112	*6'068*	331	2'283	*2'614*	403	325	553	59	0
Air Pollution	32'603	15'576	121.3	1'657	*17'354*	1'256	12'257	*13'513*	392	441	115	12	777
Climate Change	27'329	14'766	193.5	663	*15'623*	1'021	5'047	*6'068*	481	541	3'897	452	268
Nature & Landscape	3'343	2'039	25.7	54	*2'119*	155	801	*956*	34	38	156	22	17
Urban Effects	2'363	1'480	18.6	39	*1'538*	113	581	*694*	65	65	0	0	0
Upstream Process	13'425	7'877	86.9	341	*8'305*	583	2'858	*3'471*	302	553	543	63	189
Total	**132'470**	**82'788**	**4'611**	**3'135**	***90'534***	**4'417**	**26'590**	***31'036***	**1'735**	**1'963**	**5'344**	**607**	**1'251**

Table 170: Total costs per means of transport in Germany (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	48	305	3.2	*48*	0.8	0.7	124	9	*12*	0.0	0.0	0.0
Noise	8	21	1.3	*7*	5.9	4.9	43	8	*8*	4.7	19	0.0
Air Pollution	21	9	19.8	*21*	5.7	1.0	162	40	*43*	6.3	3.8	12.1
Climate Change	20	15	7.9	*19*	7.0	35	132	17	*16*	7.8	148	4.2
Nature & Landscape	3	2	0.6	*3*	0.5	1.4	20	3	*3*	0.6	7	0.3
Urban Effects	2	1	0.5	*2*	1.0	0.0	15	2	*2*	0.9	0.0	0.0
Upstream Process	11	7	4.1	*10*	4.4	4.8	75	10	*11*	8.0	21	3.0
Total	**113**	**360**	**38**	***110***	**25**	**48**	**569**	**88**	***96***	**28**	**199**	**20**

Table 171: Average costs per means of transport in Germany (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	9'661	5384	60	302	*5746*	702	3213	*3915*
Average Costs [Euro/1000 pkm or tkm]		7.3	4.7	3.6	*6.9*	90.6	10.6	*12.6*

Table 172: Congestion costs in Germany (1995)

Greece

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	3'162	2'193	257	14	*2'464*	368	323	*691*	3	0	4	0	0
Noise	338	148	7.1	3	*158*	58	97	*155*	5	1	19	1	0
Air Pollution	1'759	578	4.3	40	*622*	287	828	*1'115*	15	3	5	0	0
Climate Change	2'578	966	13.1	32	*1'012*	463	683	*1'146*	12	2	386	21	0
Nature & Landscape	306	117	1.5	3	*121*	61	75	*135*	1	0	45	3	0
Urban Effects	148	67	0.9	2	*69*	35	43	*77*	1	0	0	0	0
Upstream Process	1'001	428	5.1	12	*446*	203	282	*495*	5	1	52	3	0
Total	**9'293**	**4'498**	**289**	**105**	***4'891***	**1'475**	**2'329**	***3'815***	**41**	**7**	**510**	**29**	**0**

Table 173: Total costs per means of transport in Greece (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	33	282	5.1	*35*	2.1	0.4	106	6	*12*	0.0	0.0	0.0
Noise	2	8	0.9	*2*	2.9	1.8	17	2	*3*	4.6	7	0.0
Air Pollution	9	5	14.4	*9*	9.5	0.5	83	16	*20*	8.7	1.7	0.0
Climate Change	15	14	11.7	*14*	7.5	37	134	13	*16*	6.8	146	0.0
Nature & Landscape	2	2	1.0	*2*	0.8	4.3	17	1	*2*	0.8	23	0.0
Urban Effects	1	1	0.6	*1*	0.6	0.0	10	1	*1*	0.6	0.0	0.0
Upstream Process	6	6	4.5	*7*	3.1	5.0	58	6	*9*	1.7	20	0.0
Total	**68**	**318**	**38**	***70***	**26**	**49**	**425**	**45**	***64***	**23**	**196**	**0**

Table 174: Average costs per means of transport in Greece (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	306	249	2.7	7	*258*	24	24	*48*
Average Costs [Euro/1000 pkm or tkm]		3.8	2.9	2.6	*3.7*	7	0.5	*0.9*

Table 175: Congestion costs in Greece (1995)

Ireland

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	1'153	956	60	10	*1'026*	33	86	*119*	1	0	7	0	0
Noise	278	156	4.1	4	*164*	12	68	*80*	9	10	16	1	0
Air Pollution	980	456	1.9	58	*516*	47	389	*435*	14	7	7	0	0
Climate Change	1'226	456	3.9	33	*493*	49	224	*272*	9	5	425	22	0
Nature & Landscape	239	135	1.0	5	*141*	14	57	*71*	1	1	23	1	0
Urban Effects	78	49	0.3	2	*51*	5	21	*26*	1	0	0	0	0
Upstream Process	454	238	1.6	14	*254*	25	107	*134*	4	0	58	3	0
Total	**4'409**	**2'447**	**73**	**125**	***2'645***	**184**	**951**	***1'137***	**40**	**23**	**536**	**28**	**0**

Table 176: Total costs per means of transport in Ireland (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	30	209	5.2	*30*	0.7	0.6	88	4	*6*	0.0	0.0	0.0
Noise	5	14	2.2	*5*	7.0	1.3	32	4	*4*	15.9	6	0.0
Air Pollution	14	7	31.0	*15*	11.1	0.6	125	20	*22*	11.8	3.0	0.0
Climate Change	14	14	17.4	*15*	7.2	35	130	12	*10*	7.6	172	0.0
Nature & Landscape	4	3	2.6	*4*	1.1	1.9	37	3	*4*	1.2	10	0.0
Urban Effects	2	1	0.9	*2*	0.8	0.0	13	1	*1*	0.8	0.0	0.0
Upstream Process	8	6	7.7	*8*	3.2	4.8	67	6	*6*	0.8	23	0.0
Total	**77**	**254**	**67**	***79***	**31**	**44**	**492**	**50**	***53***	**38**	**215**	**0**

Table 177: Average costs per means of transport in Ireland (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	36	22	0.0	4.9	*27*	3.4	5.6	*9*
Average Costs [Euro/1000 pkm or tkm]		0.7	0.2	2.7	*0.8*	9	0.3	*0.5*

Table 178: Congestion costs in Ireland (1995)

Italy

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	23'780	19'254	1'573	173	*21'000*	1'055	1'675	*2'730*	22	0	28	0	0
Noise	5'395	2'848	97.3	67	*3'012*	343	1'216	*1'559*	307	208	290	19	0
Air Pollution	21'413	10'268	51.5	1'167	*11'487*	1'528	8'164	*9'692*	118	73	39	2	1
Climate Change	16'270	8'479	89.3	495	*9'063*	1'352	3'779	*5'132*	258	160	1'536	122	0
Nature & Landscape	1'390	797	7.4	25	*830*	126	333	*459*	11	7	70	7	5
Urban Effects	1'374	809	7.5	26	*842*	128	338	*466*	46	20	0	0	0
Upstream Process	8'422	4'785	39.2	247	*5'071*	742	2'012	*2'792*	210	120	212	17	0
Total	**78'044**	**47'240**	**1'865**	**2'201**	***51'306***	**5'275**	**17'518**	***22'830***	**972**	**587**	**2'175**	**167**	**7**

Table 179: Total costs per means of transport in Italy (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	32	206	3.0	*31*	0.4	0.7	104	7	*11*	0.0	0.0	0.0
Noise	5	13	1.2	*5*	6.2	6.9	34	5	*6*	9.4	25	0.0
Air Pollution	17	7	20.4	*17*	2.4	0.9	151	33	*38*	3.3	3.1	11.0
Climate Change	14	12	8.6	*14*	5.2	37	134	15	*15*	7.2	159	4.2
Nature & Landscape	1	1	0.4	*1*	0.2	1.7	12	1	*2*	0.3	9	51.8
Urban Effects	1	1	0.4	*1*	0.9	0.0	13	1	*2*	0.9	0.0	0.0
Upstream Process	8	5	4.3	*8*	4.2	5.1	73	9	*11*	5.4	22	2.8
Total	**78**	**244**	**38**	***77***	**20**	**52**	**521**	**72**	***84***	**26**	**218**	**70**

Table 180: Average costs per means of transport in Italy (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	4'173	2437	18	220	*2674*	446	1053	*1499*
Average Costs [Euro/1000 pkm or tkm]		4.1	2.3	3.8	*4*	44.1	4.3	*5.9*

Table 181: Congestion costs in Italy (1995)

Luxembourg

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	315	255	12	3	*269*	7	35	*42*	2	0	2	0	0
Noise	43	23	0.4	1	*24*	1	14	*16*	0	0	1	1	0
Air Pollution	383	122	0.5	21	*144*	12	208	*220*	4	7	2	2	5
Climate Change	222	81	0.5	6	*87*	6	61	*67*	2	3	27	34	1
Nature & Landscape	29	13	0.1	0	*13*	1	8	*9*	0	0	3	4	0
Urban Effects	9	5	0.0	0	*5*	0	3	*3*	0	1	0	0	0
Upstream Process	115	50	0.3	4	*54*	4	42	*47*	1	3	4	5	1
Total	**1'117**	**549**	**13**	**34**	***596***	**32**	**371**	***404***	**9**	**13**	**39**	**47**	**7**

Table 182: Total costs per means of transport in Luxembourg (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	47	315	3.6	*44*	7.1	1.1	127	7	*9*	0.0	0.0	0.0
Noise	4	11	0.8	*4*	1.6	0.7	26	3	*3*	0.5	4	0.0
Air Pollution	23	13	29.3	*23*	12.8	1.1	210	44	*46*	13.2	6.0	17.1
Climate Change	15	14	8.3	*14*	5.5	16	113	13	*13*	5.6	85	4.2
Nature & Landscape	2	2	0.6	*2*	0.6	1.7	19	2	*2*	0.6	9	0.0
Urban Effects	1	1	0.2	*1*	1.5	0.0	7	1	*1*	1.4	0.0	0.0
Upstream Process	9	7	5.1	*9*	3.6	2.4	80	9	*11*	5.3	13	3.6
Total	**102**	**362**	**48**	***98***	**33**	**23**	**581**	**79**	***84***	**27**	**117**	**25**

Table 183: Average costs per means of transport in Luxembourg (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	59	44	0.2	4.3	*49*	1	9.4	*10*
Average Costs [Euro/1000 pkm or tkm]		8.2	5	6	*7.9*	18	2	*2.2*

Table 184: Congestion costs in Luxembourg (1995)

Netherlands

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	4'697	3'813	294	21	*4'128*	5	537	*542*	3	0	24	0	0
Noise	1'442	462	15.0	7	*484*	1	322	*323*	34	9	487	105	0
Air Pollution	7'558	2'511	13.2	204	*2'728*	9	4'214	*4'223*	44	4	28	6	525
Climate Change	5'008	1'850	18.1	66	*1'934*	7	1'548	*1'555*	101	9	1'039	225	144
Nature & Landscape	514	253	2.2	5	*260*	1	173	*174*	3	0	34	7	35
Urban Effects	472	266	2.3	5	*274*	1	181	*182*	13	3	0	0	0
Upstream Process	2'503	1'098	8.5	38	*1'144*	4	934	*939*	123	6	144	31	116
Total	**22'193**	**10'253**	**353**	**346**	***10'953***	**28**	**7'909**	**7'937**	**321**	**31**	**1'755**	**374**	**821**

Table 185: Total costs per means of transport in Netherlands (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	34	245	2.1	*34*	0.2	0.7	97	5	*5*	0.0	0.0	0.0
Noise	4	12	0.7	*4*	2.5	14.0	26	3	*3*	2.9	74	0.0
Air Pollution	22	11	20.5	*22*	3.2	0.8	166	36	*36*	1.3	4.0	15.2
Climate Change	17	15	6.6	*16*	7.2	30	133	13	*10*	2.9	158	4.2
Nature & Landscape	2	2	0.5	*2*	0.2	1.0	18	1	*1*	0.1	5	1.0
Urban Effects	2	2	0.5	*2*	0.9	0.0	19	2	*2*	0.9	0.0	0.0
Upstream Process	10	7	3.8	*10*	8.8	4.2	76	9	*8*	1.9	22	3.4
Total	**92**	**294**	**35**	***89***	**23**	**51**	**536**	**68**	***64***	**10**	**262**	**24**

Table 186: Average costs per means of transport in Netherlands (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	2'524	1467	12	50	*1529*	6.6	989	*995*
Average Costs [Euro/1000 pkm or tkm]		13.1	10	5	*12.4*	125.3	8.5	*8.5*

Table 187: Congestion costs in Netherlands (1995)

Norway

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	1'052	855	96	11	*961*	39	38	*77*	4	0	9	0	0
Noise	320	225	11.2	7	*244*	23	48	*71*	0	0	5	0	0
Air Pollution	1'601	764	5.6	114	*884*	110	558	*668*	15	16	17	0	0
Climate Change	1'495	633	9.7	48	*690*	92	221	*313*	9	10	456	17	0
Nature & Landscape	437	244	3.3	11	*258*	32	51	*83*	3	3	85	5	0
Urban Effects	109	74	1.0	3	*78*	10	15	*25*	3	3	0	0	0
Upstream Process	646	357	4.3	24	*385*	52	128	*183*	3	8	64	2	0
Total	**5'660**	**3'152**	**131**	**218**	***3'501***	**358**	**1'059**	***1'421***	**38**	**40**	**636**	**26**	**0**

Table 188: Total costs per means of transport in Norway (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	20	132	2.8	*20*	1.9	0.8	61	4	*8*	0.0	0.0	0.0
Noise	5	15	1.9	*5*	0.1	0.4	36	5	*7*	0.1	1	0.0
Air Pollution	18	8	28.8	*18*	6.4	1.5	173	60	*67*	6.1	3.7	0.0
Climate Change	15	13	12.1	*14*	3.8	42	144	24	*24*	3.6	135	0.0
Nature & Landscape	6	5	2.7	*5*	1.1	7.7	51	5	*8*	1.1	41	0.0
Urban Effects	2	1	0.8	*2*	1.1	0.0	15	2	*3*	1.0	0.0	0.0
Upstream Process	8	6	6.1	*8*	1.5	5.9	81	15	*19*	2.8	19	0.0
Total	**73**	**181**	**55**	***73***	**16**	**58**	**562**	**115**	***136***	**15**	**199**	**0**

Table 189: Average costs per means of transport in Norway (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	166	99	0.6	16	*115*	21	30	*51*
Average Costs [Euro/1000 pkm or tkm]		2.3	0.8	4	*2.4*	32.8	3.2	*5.1*

Table 190: Congestion costs in Norway (1995)

Portugal

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	4'447	3'271	444	31	*3'746*	217	458	*675*	21	0	7	0	0
Noise	474	221	12.7	5	*240*	33	143	*176*	18	12	27	1	0
Air Pollution	1'743	722	6.1	70	*798*	135	770	*905*	20	14	6	0	0
Climate Change	2'319	902	17.7	52	*972*	199	524	*723*	25	18	552	29	0
Nature & Landscape	187	86	1.3	3	*90*	17	54	*71*	1	1	22	1	0
Urban Effects	63	31	0.5	1	*33*	6	20	*26*	3	1	0	0	0
Upstream Process	890	436	7.0	21	*463*	90	233	*326*	14	8	75	4	0
Total	**10'124**	**5'669**	**489**	**183**	***6'341***	**697**	**2'202**	***2'903***	**102**	**54**	**688**	**36**	**0**

Table 191: Total costs per means of transport in Portugal (1995)

Average Costs per Means of Transport (1995)	Average CostsPassenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	35	281	2.7	*35*	4.3	0.4	146	15	*21*	0.0	0.0	0.0
Noise	2	8	0.5	*2*	3.7	1.7	22	5	*5*	6.0	8	0.0
Air Pollution	8	4	6.1	*8*	4.2	0.4	91	25	*28*	7.1	1.8	0.0
Climate Change	10	11	4.5	*9*	5.3	36	133	17	*14*	8.8	160	0.0
Nature & Landscape	1	1	0.2	*1*	0.3	1.4	11	2	*2*	0.5	7	0.0
Urban Effects	0	0	0.1	*0*	0.6	0.0	4	1	*1*	0.6	0.0	0.0
Upstream Process	5	4	1.8	*4*	2.9	4.8	60	8	*9*	4.0	22	0.0
Total	**61**	**310**	**16**	***60***	**21**	**44**	**468**	**71**	***79***	**27**	**198**	**0**

Table 192: Average costs per means of transport in Portugal (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	161	106	1.1	15	*122*	5.4	33	*38*
Average Costs [Euro/1000 pkm or tkm]		1.2	0.7	1.3	*1.2*	3.7	1.1	*1.2*

Table 193: Congestion costs in Portugal (1995)

Spain

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	11'615	8'360	363	60	*8'783*	1'797	991	*2'789*	4	0	40	0	0
Noise	2'433	1'035	18.2	20	*1'073*	506	573	*1'079*	76	60	141	4	0
Air Pollution	9'071	3'177	8.5	245	*3'431*	2'018	3'510	*5'528*	36	36	38	1	0
Climate Change	12'749	4'151	22.0	165	*4'339*	2'760	2'333	*5'094*	81	80	3'072	83	0
Nature & Landscape	1'389	594	2.8	15	*612*	381	322	*703*	6	6	59	2	0
Urban Effects	968	429	2.0	11	*443*	276	233	*509*	10	6	0	0	0
Upstream Process	4'927	1'977	8.8	68	*2'054*	1'275	1'049	*2'360*	39	47	416	11	0
Total	**43'151**	**19'723**	**425**	**584**	***20'733***	**9'013**	**9'012**	***18'061***	**253**	**236**	**3'766**	**102**	**0**

Table 194: Total costs per means of transport in Spain (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	27	185	1.8	*26*	0.3	0.5	92	6	*16*	0.0	0.0	0.0
Noise	3	9	0.6	*3*	4.9	1.8	26	4	*6*	6.0	7	0.0
Air Pollution	10	4	7.4	*10*	2.4	0.5	103	23	*32*	3.6	1.8	0.0
Climate Change	13	11	5.0	*13*	5.3	38	141	15	*20*	8.0	137	0.0
Nature & Landscape	2	1	0.5	*2*	0.4	0.7	19	2	*4*	0.6	4	0.0
Urban Effects	1	1	0.3	*1*	0.7	0.0	14	2	*3*	0.6	0.0	0.0
Upstream Process	6	5	2.0	*6*	2.6	5.2	65	7	*12*	4.7	19	0.0
Total	**64**	**217**	**18**	***61***	**17**	**47**	**459**	**59**	***93***	**24**	**167**	**0**

Table 195: Average costs per means of transport in Spain (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs[million Euro]	1'886	1096	4.5	64	*1164*	435	287	*722*
Average Costs [Euro/1000 pkm or tkm]		3.6	2.3	1.9	*3.4*	22.1	1.9	*4.1*

Table 196: Congestion costs in Spain (1995)

Sweden

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	1'964	1'569	72	22	*1'664*	157	131	*289*	2	0	10	0	0
Noise	328	179	3.4	7	*189*	39	74	*113*	8	9	8	0	0
Air Pollution	2'982	1'460	3.6	213	*1'676*	290	974	*1'265*	8	17	15	1	0
Climate Change	3'125	1'436	7.7	122	*1'565*	374	530	*904*	10	21	594	32	0
Nature & Landscape	635	305	1.6	15	*322*	88	123	*211*	5	10	82	6	0
Urban Effects	217	112	0.6	6	*118*	32	45	*78*	5	16	0	0	0
Upstream Process	1'392	755	3.2	53	*811*	176	261	*444*	11	39	82	4	0
Total	**10'644**	**5'815**	**92**	**438**	***6'346***	**1'158**	**2'139**	***3'304***	**48**	**112**	**791**	**43**	**0**

Table 197: Total costs per means of transport in Sweden (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	19	142	2.0	*18*	0.3	0.7	55	4	*8*	0.0	0.0	0.0
Noise	2	7	0.6	*2*	1.2	0.5	14	2	*3*	0.5	2	0.0
Air Pollution	18	7	19.5	*18*	1.3	1.0	102	31	*37*	0.9	3.1	0.0
Climate Change	18	15	11.1	*17*	1.6	38	131	17	*19*	1.1	158	0.0
Nature & Landscape	4	3	1.4	*3*	0.8	5.3	31	4	*6*	0.5	28	0.0
Urban Effects	1	1	0.5	*1*	0.9	0.0	11	1	2	0.8	0.0	0.0
Upstream Process	9	6	4.9	*9*	1.7	5.3	62	9	*12*	2.1	22	0.0
Total	**72**	**182**	**40**	***69***	**8**	**51**	**405**	**69**	***89***	**6**	**212**	**0**

Table 198: Average costs per means of transport in Sweden (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	248	103	0.3	37	*140*	38	70	*108*
Average Costs [Euro/1000 pkm or tkm]		1.3	0.6	3.4	*1.5*	13.3	2.2	*3.2*

Table 199: Congestion costs in Sweden (1995)

Switzerland

Total Costs per Means of Transport (1995) [million Euro / year]		Road							Rail		Aviation		Water-borne
		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	3'412	2'703	470	20	*3'193*	90	84	*174*	19	0	25	0	0
Noise	980	576	42.1	11	*629*	42	88	*130*	105	67	43	5	0
Air Pollution	2'927	1'568	20.2	169	*1'757*	177	923	*1'100*	23	15	29	3	0
Climate Change	2'641	1'135	26.1	51	*1'213*	119	290	*409*	7	4	912	96	0
Nature & Landscape	438	301	5.9	8	*315*	29	45	*74*	6	4	36	4	0
Urban Effects	111	72	1.4	2	*75*	7	11	*18*	12	7	0	0	0
Upstream Process	1'172	679	12.5	31	*722*	75	192	*271*	26	12	128	13	0
Total	**11'680**	**7'034**	**579**	**291**	***7'903***	**539**	**1'632**	***2'175***	**198**	**109**	**1'173**	**121**	**0**

Table 200: Total costs per means of transport in Switzerland (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	37	244	2.8	*39*	1.4	0.9	107	7	*13*	0.0	0.0	0.0
Noise	8	22	1.6	*8*	7.9	1.6	50	7	*10*	7.7	8	0.0
Air Pollution	21	10	24.0	*21*	1.7	1.1	211	75	*84*	1.7	5.2	0.0
Climate Change	16	14	7.3	*15*	0.5	33	142	24	*24*	0.5	163	0.0
Nature & Landscape	4	3	1.1	*4*	0.4	1.3	34	4	*6*	0.4	7	0.0
Urban Effects	1	1	0.3	*1*	0.9	0.0	8	1	*1*	0.9	0.0	0.0
Upstream Process	9	6	4.3	*9*	1.9	4.7	89	17	*22*	1.4	23	0.0
Total	**96**	**300**	**41**	***96***	**15**	**43**	**643**	**134**	***160***	**13**	**205**	**0**

Table 201: Average costs per means of transport in Switzerland (1995)

Congestion Cost (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs [million Euro]	903	662	11	39	*712*	81	110	*191*
Average Costs [Euro/1000 pkm or tkm]		9.1	5.7	5.5	*8.7*	96.7	9	*14.6*

Table 202: Congestion costs in Switzerland (1995)

United Kingdom

Total Costs per Means of Transport (1995)		Road							Rail		Aviation		Water-borne
[million Euro / year]		Car	MC	Bus	Pass. total	LDV	HDV	Freight total	Pass	Freight	Pass	Freight	Freight
Accidents	20'204	16'872	963	227	*18'062*	1'049	982	*2'031*	28	0	84	0	0
Noise	4'678	2'865	69.6	100	*3'035*	373	896	*1'269*	50	16	286	22	0
Air Pollution	19'544	9'532	34.0	1'524	*11'090*	1'432	6'470	*7'902*	413	46	84	6	2
Climate Change	19'569	8'724	60.5	703	*9'487*	1'445	3'015	*4'460*	331	37	4'847	407	1
Nature & Landscape	1'273	706	4.6	33	*744*	121	216	*337*	21	2	152	14	3
Urban Effects	1'245	791	5.2	37	*834*	135	242	*377*	25	10	0	0	0
Upstream Process	8'440	4'719	26.4	337	*5'082*	749	1'600	*2'389*	223	29	661	55	1
Total	**74'954**	**44'210**	**1'163**	**2'962**	***48'335***	**5'303**	**13'420**	***18'764***	**1'091**	**140**	**6'114**	**504**	**6**

Table 203: Total costs per means of transport in United Kingdom (1995)

Average Costs per Means of Transport (1995)	Average Costs Passenger						Average Costs Freight					
	Road				Rail	Avia-tion	Road			Rail	Avia-tion	Water-borne
	Car	MC	Bus	Total			LDV	HDV	Total			
	Euro / 1000 pkm						Euro / 1000 tkm					
Accidents	33	241	5.4	*33*	0.9	0.6	101	5	*9*	0.0	0.0	0.0
Noise	6	17	2.4	*6*	1.7	2.0	36	4	*6*	1.3	9	0.0
Air Pollution	19	8	36.0	*20*	13.9	0.6	137	30	*35*	3.7	2.5	10.9
Climate Change	17	15	16.6	*17*	11.2	34	139	14	*16*	2.9	171	4.2
Nature & Landscape	1	1	0.8	*1*	0.7	1.1	12	1	*1*	0.2	6	13.2
Urban Effects	2	1	0.9	*2*	0.8	0.0	13	1	*2*	0.8	0.0	0.0
Upstream Process	9	7	8.0	*10*	7.5	4.7	72	8	*11*	2.3	23	2.8
Total	**88**	**291**	**70**	***88***	**37**	**44**	**509**	**63**	***81***	**11**	**211**	**31**

Table 204: Average costs per means of transport in United Kingdom (1995)

Congestion Costs (1995)	Total	Road Passenger				Road Freight		
		Car	MC	Bus	Total	LDV	HDV	Total
Total Costs[million Euro]	5'711	3980	23	234	*4237*	578	896	*1474*
Average Costs [Euro/1000 pkm or tkm]		7.9	5.7	5.5	*7.7*	55.5	4.2	*6.6*

Table 205: Congestion costs in United Kingdom (1995)

4 Members of the advisory board

Gunnar Gustafsson (Chair)	UIC
Gunter Ellwanger (Project manager)	UIC
Snejana Markovic (Secretary)	UIC

Sylvia Schwermer	Umweltbundesamt (UBA)
Beatrice Schell	Transport & Environment
Stephen Perkins	ECMT
Prof. Chris A. Nash	University of Leeds
Stein Hansen	Nordic Consulting Group
Tom Howes	European Commission DG Transport
Prof. Emile Quinet	Conseil general des ponts et chausées
Peter Wiederkehr	OECD
Prof. Lars Hansson	Lund University
Prof. Olav Hohmeyer	University of Flensburg
Karl-Otto Schallaböck	Wuppertal Institut

Glossary

Accident insurance Voluntary or mandated insurance against the risks of accidents (property and health). The premia serve to (partly) internalise external costs.

Accident rate Accident rates describe the probability of an accident per 1'000 vehicle kilometres.

Average costs Total costs in a period, divided by the quantity (out-put) produced/consumed in that period. Long term average costs include a share of fixed costs (e.g. costs associated with expansion of existing infra-structure).

Barrier effect Separation of adjacent areas due to road or rail infrastructure investments; negative impact on human beings (e.g. recreation), or on flora and fauna (e.g. constriction of habitat).

Contingent valuation method → Valuation technique which asks people directly how much they are willing to pay/to accept for improving/deteriorating environmental quality. Method is based on the → stated preference approach; it is the only method that allows the estimation of → existence value. The values obtained are compared with other opportunities, in order to make visible a budget restriction.

Cost-effectiveness Seeks to minimise the costs of achieving a given (e.g. environmental) objective/target. This principle is a → "second-best" efficiency criterion, often used when a full cost-benefit analysis is not feasible.

CO_2 Carbon dioxide is a major greenhouse gas i.e. it contributes to the climate change.

Decibel (dB(A)) Decibel (dB) is a measure for the intensity of sound energy. According to the characteristic of human ears the relationship between sound energy and dB is logarithmic. Several filters have been defined to achieve a better adaptation of dB measurements and the loudness impression of human beings. The most commonly used type of filter is the (A) filter.

Defensive expenditures → Valuation technique wherein a value for environmental quality is inferred from people's (voluntary) expenditures aimed at improving their situation.

Dose-response-functions Functions showing the connection between a specific concentration and its specific effects. They are especially used for the measurements of air pollution impacts. For example health: Impacts on mortality due to specific air pollution concentrations.

Efficiency Refers to the efficient allocation of scarce resources. At the margin, resources should be used by the individual who is willing to pay the most for them (i.e. where marginal social cost equals marginal social benefit).

Elasticity Proportional change in demand in response to a price increase or decrease (price elasticity); or reaction in total demand after an increase/decrease in income (income elasticity).

Environmental effectiveness Effect on the environment that a given policy response generates. This criterion ignores the economic costs that may result from implementing the policy.

Existence value Economic value which people attribute to something purely for its existence (no consumption is fore-seen); can only be estimated via the → contingent valuation method.

Externality (external cost) Economic cost not normally taken into account in markets and in the decisions made by market players.

Fixed cost Cost which are not depending on the traffic volume (in the short run).

(Full) fuel cycle Complete fuel cycle; comprising discovery, depletion (mining), processing, transport and use of an energy resource.

Free-flow situation Traffic situation without congestion, used as a reference level. Usually an Off-Peak-Situation can be used for urban traffic.

GDP (= Gross Domestic Product). The GDP is the sum of all goods and services produced within a country and a year. GDP per capita can be regarded as the relative economic power of a country per inhabitant.

HC/VOC Hydrocarbons / Volatile Organic Compounds contribute to ozone formation. Some like benzene, butadiene and benzo-a-pyrene have been found to have impacts on public health.

HDV Heavy duty vehicles (Road trucks) above 3,5 tonne gross weight.

Hedonic pricing → Valuation technique which infers a value for environmental quality from rent or property price differentials.

Human value (loss) Value attributed to human life in excess of the average economic output produced by an individual (e.g. grief, pain, etc.). –> VSL

Internalisation Incorporation of an externality into the market decision making process through pricing or regulatory intervention. In the narrow sense internalisation is implemented by charging the polluters with the damage costs of the pollution generated by them, the corresponding damage costs resp. according to the polluter pays principle.

LDV Light duty vehicles (Vans up to 3,5 tonnes gross weight).

Life-cycle based approach An approach, where up- and downstream processes of transport services are included (i.e. vehicle production and disposal, fuel cycles of the electricity production etc.).

Marginal costs Costs related to a small increment in demand (e.g. an extra vehicle-kilometre driven). Long-term marginal costs include the capacity expansion needed to service increased traffic demands.

MC Motorcycle

NO_x Nitrogen oxides, which are formed primarily by fuel combustion and contribute to the formation of acid rain. They also combine with hydrocarbons in the presence of sunlight to form ozone.

Opportunity costs Costs which arise when a particular project restricts alternative uses of a scarce resource (e.g. land-use of infrastructure prevents an alternative use, such as recreation). The size of an opportunity cost is the value of a resource in its most productive alternative use.

Option value Value of keeping open the possibility of consuming a good/service at some time in the future.

PCU (= Passenger Car Units) PCU is used in order to standardise vehicles in relation to a passenger car. Speed and lengths differentials are most common. Within this study they are used for the allocation of different costs (e.g. nature and landscape, urban effects, congestion).

pkm Passenger kilometre

PM Particulate matter. Fine particulate (PM_{10} with a diameter of less than 10 µm) can contribute to the chronic and acute respiratory disease and premature mortality, as they are small enough to be inhaled into the lungs. Larger particles decrease visibility and increase fouling.

Polluter-pays-principle Political/economic principle which stipulates that the user should pay the full social cost (including environmental costs) of his/her activity.

Precombustion Production, storage and transportation of energy for its final use.

Prevention approach → Valuation technique for estimating externalities whereby the costs of preventing damage are used as a proxy for the cost of the damage itself for society.

Productivity Output divided by the inputs needed to produce that output in value terms.

Public good Good/service for which property rights are not defined. Without government intervention, environmental goods (e.g. clean air) are usually treated as public.

Progressivity/Regressivity Term to describe the impact of government policy on income distributions. Progressive/regressive effects occur when poor households spend a smaller/larger proportion of their income for a particular measure (e.g. a tax) than do richer households.

Purchasing power parity (= PPP) The purchasing power parity describes the amount of goods or services which can be bought in a particular country compared to a reference country. The PPP necessarily must be expressed relative to a particular currency.

Revealed preference → Valuation technique wherein consumers. choices are revealed in the marketplace (e.g. by the purchase of a good).

Risk approach → Valuation technique for estimating externalities whereby external costs inferred from premia for risk factors (e.g. the cost of insurance, or of risk diversification).

Risk value Monetary value for pain, grief and suffering of an average transport victim, mainly used for the estimation of accident fatalities.

Shadow Prices Shadow price is the marginal opportunity cost of the use of a resource (i.e. the loss of benefits caused if this resource cannot be used the next best purpose).

Social costs The sum total of internal and → external costs.

Social cost benefit analysis Systematic estimation of all costs and benefits of a project that are relevant to society. Includes both → technological externalities and → pecuniary externalities, as long as the latter are not merely redistribution of income.

SO_2 Sulphur dioxide contributes to the formation of sulphate aerosols and is the primary pollutant in the formation of acid rain. It can also cause respiratory system damage in humans.

Speed-flow function A mathematical or graphical relationship between the flow on a particular road, and the speed of that traffic flow. As traffic flows increase, traffic speeds eventually fall.

Stated preference → Valuation technique wherein monetary estimates are derived from hypothetical statements by individuals about their preferences. The typical method used is a questionnaire approach (e.g. → contingent valuation method).

Technological Externality External effect that is not actively or voluntarily processed through markets, which results in economic inefficiencies. This occurs when some firm or individual uses an asset without paying for it. Technically they occur where one productive activity changes the amount of output or welfare which can be produced by some other activity using any given amount of resources. Negative technological externalities reduce the amount of output or welfare which an economy can produce with any given allocation of inputs.

tkm Tonne kilometre

Traffic mode Category of means of transport (road, rail, aviation, shipping, etc.).

Traffic volume Measure for traffic activity which can be expressed in vehicle-kilometres, or in passenger/tonne kilometres.

UCPTE (Union pour la coordination de la production et du transport de l'éléctricité)
International mix of electricity production, varying slightly every year. The mix used for the forecast 2010 is based on:
50% fossil fuels
15% hydro generation
35% nuclear generation.

Unit costs Costs per unit of service or goods provided (e.g. traffic volume).

(User) charge Charge imposed on the user of a good (e.g. road infrastructure), often linked to the costs generated by his or her use.

Utility (Private) Private benefit received by an individual due to his/her consumption of a good or service, or by the existence of that good/service.

Utility (Social) The aggregate of private utilities in an economy.

Valuation Process of estimating the economic value of a certain quantity of a transport good/service; generally expressed in monetary terms.

Value of statistical life (=VSL) The value of statistical life is a methodology to find a monetary pendant to a killed or injured human being. VSL is the → opportunity costs of a saved human life.

Variable costs (→ Fixed costs) Full costs can be subdivided into fixed costs and variable costs. Fixed costs remain constant with varying use of a transport system (e.g. supplier- or capital costs for road and rail networks or administrative costs). The expression "fixed" in the way it is used in the Real Cost Scheme means "fixed in the short run" (without consideration of new infrastructure), as in the long run also infrastructure supply costs vary with the traffic demand, that is in the long run all costs can be made variable. Main relations of variable costs are kilometres driven or the amount of vehicles (e.g. crossing a specific section).

Vkm, Vehicle-kilometre One kilometre travelled by a single vehicle.

Willingness to pay (= WTP). The willingness (or ability) of people to pay for the abolishment, reduction or reception of a particular matter can be estimated by two ways: (1) by → stated preference surveys and by → hedonic pricing methods.

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