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External and infrastructure costs of road and rail traffic

analysing European studies

Report

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Summary

Background and aim
In 1998 the European Commission established important principles for the pricing of transport in its White Paper 'Fair Payment for Infrastructure Use'. The Commission said that, in principle, users of all transport modes should be charged for the marginal external and infrastructure costs they cause. This principle was reinforced in the 2001 White Paper 'European transport policy for 2010: time to decide'.

Since 1998 numerous studies have been published translating the principle of 'marginal social cost' (MSC) pricing or 'efficient' pricing into concrete figures for different types of vehicles.

At first sight, these studies appear to differ significantly in both approach and final figures; there is, moreover, a lack of transparency as to the causes of these differences. This is hampering the development of policy at the European level and in the Member States: if economists cannot agree on figures and methodology, how can politicians ever use the data they come up with as a solid basis for their ideas on pricing policies?

Against this background the Dutch Ministry of Transport commissioned CE to undertake an analysis of five important European studies presenting figures on 'optimal' prices for different modes of transport. These five studies were:
- ECMT, *Efficient Transport for Europe; policies for the internalisation of external costs*, Paris, 1998;
- CE Delft, *Efficient prices for transport; estimating the social costs of vehicle use*, Delft, 1999;
- INFRAS/IWW, *External costs of transport, accident, environmental and congestion costs of transport in Western Europe*, Zürich / Karlsruhe, 2000;
- TRENEN, several publications on the input for the TRENEN model, among which Borger, B. de *et al.*, *Reforming Transport Pricing in the European Union*, Edward Elgar, Cheltenham, UK, 2001, and Mayeres *et al.*, *The external costs of transport*, Leuven, 2001;
- UNITE, UNIfication of accounts and marginal costs for Transport Efficiency, *several deliverables* 2000-2003.

The main purposes of the present study are:
- to identify the most important differences between the studies;
- to formulate a discussion agenda for narrowing these differences.

Conclusions on principal differences
One of the main conclusions of our analysis is that the inter-study differences can be largely explained by a) differences in 'statistics' (risk figures, emission figures) and b) differences in normative choices that have more to do with transport policy than with economics. Purely economic questions, such as valuation of pollutants, risks etc., play only a minor role. These conclusions are briefly elaborated below.

'Statistical' differences: straightforward, but important
The first category of differences stems from the use of different statistical figures, emission factors, accident rates, purchasing power parities, etc. These differences are the domain of statisticians and technicians.

This category of differences, although rather straightforward and obvious, appears to be quite important in explaining the differences between studies. For example, accident rates vary by more than a factor of 10 across member States and road types. Emission factors may also vary by a factor of 10 or more, depending on the emission class of the vehicle.

'Valuation' differences: surprisingly small
The second category of differences stems from differences in financial valuation of tonnes of CO_2-emissions, fatalities, et cetera, given the same normative choices (see next category). These differences are the domain of economists.
Differences between valuations then appear to be surprisingly small, differing in the case of fatalities by only about 15% and in the case of individual emissions by several dozen per cent.

'Normative' differences: important issues for policy makers
A final category of differences stems from different normative choices with respect to transport and environment policy. These differences are the domain of neither economists nor technicians, but of policy makers.

Primary differences in normative choices include:
- On marginal infrastructure costs: CE Delft and ECMT assess full maintenance and upkeep costs and then allocate these to different vehicle categories. TRENEN and UNITE assess the short-term extra damage costs of extra traffic on a given piece of infrastructure.
- On marginal accident risks: here there are similar differences between studies. ECMT, CE Delft, INFRAS/IWW and TRENEN take as their basis average accident risks per vehicle type and per type of infrastructure. Based on a Swiss and Swedish case study, UNITE draws the conclusion that extra traffic causes other traffic participants to driver more safely, so that extra traffic in effect makes roads safer. The so-called *risk elasticity* is 0 in the ECMT, CE Delft, INFRAS/IWW and TRENEN studies and less than 0 in UNITE.
- On internal vs. external accident costs: TRENEN and UNITE consider the own risk of traffic participants as internal costs, ECMT, CE Delft and INFRAS//IWW as external costs.

Table 1 Summary of differences in normative choices made in the five studies

Issue	ECMT 1998	CE Delft 1999	INFRAS/IWW 2000	TRENEN 2001	UNITE 2003
Infrastructure costs	variable	variable	not assessed	marginal	marginal
Accident risk elasticity	0	0	0	0	< 0
Own accident risk	external	external	external	internalised	internalised
CO_2-reduction target	EU 1990 stabilisation	NL Kyoto compliance	transport emissions -50% 1990-2030	damage costs	EU Kyoto compliance

A discussion agenda for developing pricing policies

Given the differences described in the previous section the question now is how to translate the results from empirical studies into concrete pricing policies. For this purpose, we have prepared a discussion agenda for policy makers working on the issue.

Infrastructure costs: what are marginal costs?

As indicated, the reviewed studies differ in the approaches taken to marginal infrastructure costs. All studies agree:

- that SUNK costs of infrastructure construction should not be passed on to users, as these costs are 'gone forever';
- that short-term marginal costs should be charged to users.

The principal difference concerns whether or not the intermediate category of infrastructure costs – the fixed (but NOT sunk!) upkeep and maintenance costs – should be charged to infrastructure users. The TRENEN and UNITE say no, the ECMT CE Delft studies say yes.

The strict short-term marginal cost approach, although often favoured for its capacity to optimise use of a given piece of infrastructure, leaves open the question how to decide on keeping infrastructure open for use. It may well be argued that this decision is best based on the willingness to pay of users instead of the willingness to pay of the relevant authority[1].

This situation can be compared with a production line in a factory. The decision whether to keep the line open and productive does not depend on sunk costs, which are bygone, but on the question whether total exploitation costs can be covered by the revenues from its products.

Here lies a clear choice for policy makers and clearly an item for discussion.

Accident risks: what are marginal costs?

The second point of discussion concerns accident risks. In principle, this is the same issue as described above. UNITE takes the approach that extra traffic on a given piece of infrastructure generally makes that infrastructure relatively safer[2] because traffic participants adjust their behaviour. Consequently, the marginal accident costs reported by UNITE are very low.

ECMT, CE Delft, INFRAS/IWW and TRENEN implicitly assume that relative risk is independent of traffic flow and thus in fact allocate average risks.

The first approach has the drawback of excluding from the analysis the costs of the behavioural adjustment leading to the reduced risks[3]. In addition, the methodology relies heavily on data that are difficult to acquire.

The second approach may be theoretically less satisfactory, but this can only be confirmed after an analysis of the impact of the risk-avoiding behaviour.

Accident risks: internal or external costs?

A second difference with respect to accident costs concerns the issue of which costs are to be considered external and which internal.

UNITE and TRENEN take the approach that people internalise the risk they impose on *themselves* when entering a traffic flow, but not the risk they impose on *others*. The other studies assume that all risks, whether for users or for others, are external. This is an item that is not easily decided upon.

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1 Another way of formulating this idea is: who pays the marginal costs of the first user of a certain piece of infrastructure?

2 Based on Swiss and Swedish case studies. Earlier case studies show more mixed results.

3 For example: more cars on a road may imply fewer pedestrians crossing a street, or longer waiting times for them, in order to avoid accidents. The costs borne by these pedestrians should obviously be included in a marginal risk charge for the car drivers.

The first approach is more libertarian. Strict application implies that governments should not put any efforts into, say, improving seat belt utilisation, because people can judge the risk they are running themselves and therefore decide for themselves whether to belt up or not.
The second approach is more paternalistic. Strict application implies that people assign an equal value to risks imposed on themselves and on others. This is also certainly not the case, given the discussion on cigarette smoking, which often focuses on the health impact smoking has on others, while the impact on the smoker's own well-being is far more profound.
The truth will probably lie somewhere in the middle. A possible solution could be to consider all risks external, but attach different values to a statistical life for internal and external risks.

Clarity about climate change objectives and mechanisms
Our study showed that the value assigned to emissions of greenhouse gases like CO_2 depends very much on the climate policy targets adopted and the mechanisms envisaged for achieving these targets.
For example, the highest CO_2 shadow price in the five studies is € 135 per tonne CO_2, in the INFRAS/IWW study. This value results from both a highly ambitious reduction target (-50% between 1990 and 2030) and a rather inflexible reduction mechanism (namely to be achieved by measures in the EU transport sector). Less ambitious targets and full application of the flexible mechanisms of the Kyoto Protocol[4] would obviously lead to lower shadow prices, as valuations applied in the four other studies show.

[4] In other words: emission trading, Joint Implementation (JI) and the Clean Development Mechanism (CDM).

1 Introduction

Traffic brings with it external costs: costs to society, such as that embodied in damage to the environment and human health, which are not currently included in transport prices. As long as external costs are not ‘internalised’ via pricing policy, social welfare is sub-optimal

Information on the external costs of traffic is vital if a sensible and effective transport pricing policy is to be developed. After all, the magnitude of these external costs determines the optimum charge level. Quantification of external costs has proved to be a thorny problem, however. Over the last few years a number of European studies have been published reporting estimates of the external costs of traffic.

It has proved very hard to compare the results of these studies, which differ in the assumptions and methodologies adopted, apply to different geographical areas are vary in their presentation of results. The debate on transport and infrastructure charging in the EU would thus benefit greatly from a transparent overview of the results of these studies and an explanation of their main differences.

The present study was commissioned by the Dutch Ministry of Transport, Public Works and Water Management with the aim of investigating the main underlying causes of these differences. Which methodological choices have a significant influence on results? By comparing results for several specific cases – covering different modes, fuels, etc. – the principal discrepancies have been identified. The main underlying methodological differences have been assessed for the cost categories air pollution, climate change, accidents, noise and congestion.

2 Studies investigated and analytical approach

2.1 Studies investigated

As a first step we selected five studies that have, or have had, a significant influence in the debate on transport pricing policy in Europe or in selected Member States over the last five years. These studies are described in the following sections.

2.1.1 INFRAS/IWW 2000

In 2000 the Swiss consultancy INFRAS and IWW from the University Karlsruhe in Germany published the study "External Costs of Transport; Accident, Environmental and Congestion Costs in Western Europe". The study is an update and extension of a former study on external costs in the year 1995 at the request of the UIC (Union Internationale des Chemins de Fer)[5]. Detailed results are given for the base year 1995 and a rough prognosis for 2010, using emission forecasts from TRENDS. Cost categories are assessed for all EU member states, plus Switzerland and Norway, with some functional and regional differentiation. Road, rail, air and waterborne transport are taken into consideration, with (several) passenger modes, except for waterborne, as well as freight. There are two output data sets: total and average (per person- or vehicle-kilometre) costs per country; and marginal costs per traffic situation (European average). Congestion costs are treated as a separate issue throughout the study. The aim of the study was primarily to develop a method for bottom-up allocation of environmental externalities.

2.1.2 CE Delft 1999

In 1999, the Dutch consultancy CE Delft performed the study "Efficient prices for transport; estimating the social costs of vehicle use", commissioned by the Dutch Ministry of Transport. CE investigated the external costs of traffic in the Netherlands for the base year 2002. The aim was to develop a Dutch position on the common framework proposed in the 1998 White Paper “Fair Payment for Infrastructure Use”. Marginal social external costs of accidents, airborne emissions, noise nuisance and congestion were quantified, as well as infrastructure costs, for various modes and means of transport. The external costs were compared to current user charges. An indication was also given of anticipated initial price changes following internalisation. Congestion was treated as a separate issue throughout the report.

2.1.3 ECMT 1998

In 1998, the ECMT (European Conference of Ministers of Transport) published the report “Efficient Transport for Europe; Policies for Internalisation of External Costs". The report is a compilation of studies for the base year 2000. The aim of the report was to evaluate which methods of internalisation are most appropriate and what improvements are needed with a view to developing transport policy options. Hence, the report gives an extensive assessment of the methodologies used in major studies and arrives at “best

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5 INFRAS/IWW, 1995, External Effects of Transport, Zürich/Karlsruhe.

estimates" that are often very similar to the pricings of the other studies treated in the current report.

2.1.4 TRENEN / ExternE 2001

In 1991 the European Commission launched the (ongoing) ExternE project in collaboration with the US Department of Energy. This project is the first comprehensive attempt to use a consistent 'bottom-up' methodology to evaluate the external costs associated with a range of different fuel cycles. One element of the ExternE project was the study "External costs of transport in ExternE" (Bickel *et al.*, 1997), which assessed the costs of energy-related environmental impacts of traffic for the base year 1995. The only impact categories included were air pollution and climate change, albeit that a third category "up- and downstream" is listed. This category covers air pollution and climate change due to fuel production and power generation, construction and maintenance of infrastructure and production, maintenance and scrapping of vehicles. Shadow prices (ECU per kg gas emitted) for the various pollutants are found using atmospheric transport models, including the formation of secondary pollutants (such as O_3), dose-response functions and eventually valuation of "years of life lost", crop losses, etc. Damages due to climate change are assessed with two models (FUND, ECU).

The TRENEN model, developed by the Catholic University of Leuven *et al.*, uses the methodology of the ExternE project as far as financial valuation of air emissions is concerned.
The objective of the TRENEN model is to assess pricing reform in transportation and application thereof in the European Union. It is funded by the European Commission and co-ordinated by CES-KULeuven. The TRENEN model includes estimates of the external costs of congestion, air pollution (including climate change), accidents, noise and road damage. Costs are calculated for a range of transport modes: cars, buses, trams, metro, trucks, (passenger and freight) rail and inland navigation. The publication "Reforming Transport Pricing in the European Union" (De Borger and Proost, 2001) presents results for the case study Belgium and for the transport situation as of 2005, assuming no change in policy.

2.1.5 UNITE 2003

UNITE is part of the European Union's Fifth RTD Framework Programme (1998-2002). It builds on previous European research such as the Concerted Action on Transport Pricing Research Integration (CAPRI) and the High Level Group on Infrastructure Charging. At the empirical level, projects such as ExternE and QUITS (environment) and TRENEN and PETS have provided valuable evidence on the nature and valuation of costs.

The purpose of UNITE is to develop answers to the following policy questions:
1 How should the structure and level of charges for infrastructure use be calculated?
2 What financial and social cost coverage considerations are relevant for calculating charges, and what are current levels of cost coverage?
3 How can fair charging be promoted between and within modes while avoiding discrimination among users from different nationalities?

In the framework of the study at hand, the first question is especially relevant.

UNITE will lead to some dozens of deliverables of which some have already been published, others have been received from contractors, and some were not yet available at the time of publication of this report.

2.1.6 White Paper 'European Transport policy for 2010'

Finally, we cross-checked the results of the five studies cited with the White Paper of the European Commission entitled "European transport policy for 2010: time to decide". This White Paper indicates possible transport policies that will be able to reconcile the ever-growing demand for mobility with public opinion that calls for better control and quality. Also, existing transport policies should be adapted to the new concepts of sustainable development. To these ends, it proposes some 60 specific measures to be implemented by the Commission during this decade, ranging from road transport pricing to revitalisation of other modes. A framework directive (2003) will establish the principles of infrastructure charging and a pricing structure for all modes. Road safety is considered to be a major issue.

In the White Paper there is no emphasis on actual numerical results, though an indication is provided of the range of external costs for heavy good vehicles, compiled from several European studies including several 4th & 5th framework projects: PETS, UNITE, RECORDIT. The idea was to have a very broad range reflecting extreme estimates too, in order to be inclusive. We have included a brief discussion of these estimates.

2.2 Analytical approach

To analyse the methodologies and results of the five studies the following procedure was adopted.

First, we filtered the results of the studies to make them as comparable as possible. For example, we endeavoured to compare identical (use-dependent) costs of identical effects, in identical countries or regions, identical vehicles and in identical units (per vehicle-kilometre). In this way the various results were cleared as far as possible of obvious differences.

Second, we identified factors explaining the differences remaining after this filtering process.

Third, we elaborated on differences that imply a normative choice made by researchers.

3 Filtering the studies

In this chapter we describe the ‘filtering’ process applied to the five cited studies, the purpose of which was to create a starting point in which the studies were as comparable as possible.

3.1 Summary of technical starting point of the studies

All five studies typically differentiate in terms of fuel, technology, car size, type of freight transport, area type and time, but differ in the way they do so. The studies cover different countries, moreover. All studies differentiate between cars, trucks and rail, but there the similarities end. In Table 2 we have structured the differences between the various studies.

Table 2 Technical summary of the studies

	INFRAS/IWW	ECMT	CE	TRENEN/ExternE	UNITE
Fuel	petrol diesel	petrol diesel	petrol diesel LPG	petrol diesel	petrol diesel
Technology	petrol: Before Euro Euro 1 Euro 3 diesel: Euro 1	-	before Euro Euro 1 (cars/vans) Euro 2 (lorries) Euro 3	1 standards 2005 technology, standard fuel efficiency 2 improved emission technology, standard fuel efficiency 3 standard 2005 technology, improved fuel efficiency	Euro2
Car size	-	-	-	small large	average
Type of freight transport	Light-duty vehicle (van) Heavy-duty vehicle (3.5-7.5 tonnes) Heavy-duty vehicle (32-40 tonnes)	-	Van solo lorry (<12 tonne) solo lorry (>12 tonne) articulated lorry	van lorry (3.5 - 16 tonne) lorry (>16 tonne) articulated lorry (>16 tonne)	different per case study
Area type	air pollution: urban and interurban noise: urban, rural and suburban climate change: urban, rural and highway congestion: urban, rural and motorway accidents: no differentiation	-	within built-up area outside built-up area	urban (e.g. Amsterdam, Stuttgart, Barnsley) interregional (e.g. Stuttgart-Mannheim, Tiel drive)	urban extra-urban motorways (different per case study)
Time	noise: sparse and dense traffic, night and day congestion: sparse and dense traffic and congestion	-	congestion: peak, off-peak	peak off-peak	peak off-peak
Country	EU	EU	The Netherlands	Belgium (example for EU)	all EU countries, depending on case study

Within the categories distinguished the results differ widely. Particle emissions, for example, an important component of external costs, differ by up to a factor 100 across different types of cars (technology and fuel use). Noise-related external costs per vehicle-kilometre may differ by over a factor 100 between suburban and urban areas. As far as possible, however, we have tried to present results for comparable cases.

3.2 Cost type: marginal external and infrastructure costs

Many different cost items are mentioned in the various studies: marginal costs, average costs, full costs, internal costs, external costs, social costs, user costs, taxes, charges, et cetera.

In the present study we are specifically interested in marginal external costs and in infrastructure costs. As of 1998, marginal external and infrastructure costs are the lead focus of EU pricing policy and it was these that were therefore selected for analysis.

3.3 Cost *presentation*: per vehicle kilometre

The studies differ in the units employed to express the external costs of transport. Most frequently, marginal external costs are given in Euro per *person*- and *tonne*-kilometre. Most of the time *total* annual external costs are presented for each mode of transport. The least used unit is Euro per *vehicle*-kilometre.

Give the express aim of the studies, this is rather remarkable: all the studies examined were designed to provide input for pricing policies, which will generally take *vehicle*-kilometres as their point of departure, not *person*- or *tonne*-kilometres. The presentation of results in Euro per *person*-kilometre as well as the presentation of *total* costs is therefore of little relevance for designing pricing policy. At most, it provides insight into the economic (and therefore political) relevance of the external costs.

In the next chapter we have therefore attempted to translate all results to marginal external costs per *vehicle*-kilometre. Unfortunately, this exercise is complicated by the fact that to translate person- or tonne-kilometres to vehicle-kilometres we need occupancy rates and load factors, which are not always reported in the studies or again differ when they are.

3.4 Cost *categories:* five items included

Second, we filtered the studies with respect to the cost categories compared, comparing only those categories common to the majority of studies, viz.:
1. Safety risks.
2. Air pollution.
3. Climate change.
4. Noise (not taken into account by TRENEN outside urban areas).
5. Infrastructure (not taken into account by INFRAS/IWW, and TRENEN with the exception of heavy lorries).

This implies that we did not consider a number of cost categories that a minority of studies tries to quantify, of which congestion is probably the most frequently cited. This implies that the presented costs should be considered minimum estimates. A few cost items that have been omitted here are discussed briefly below.

Congestion
The cost category ‘congestion’ is intrinsically different from the others and, as such, if it is treated at all it is as a separate issue. Although the White Paper mentions a range of congestion costs for lorries (2.7 - 9.3 €ct/vkm), only the CE and the INFRAS/IWW studies derive actual values for marginal external congestion costs. Results, valuation and methodology are summarised in the following table. For freight transport, the resulting costs per vehicle-kilometre are approximately twice those for private cars in both studies.

Table 3 Costs and valuation of congestion (passenger cars)

	€/vkm	€/hour	Origin
CE		~7.5	Proost 1999
	< 1.52		Based on marginal extension costs and optimal levy
INFRAS		21.4 (business) 5.35 (private)	European average from PETS (1998). Adjusted for countries by weighted income per capita. Business : private = 80:20
	< 3.10		Speed-flow functions for different types of situations
TRENEN		~7.5	Proost 1999
	< 1.8		Based on marginal extension costs and optimal levy

Up- and downstream processes
INFRAS/IWW takes into account additional external effects resulting from up- and downstream processes. This following processes are distinguished: energy production (precombustion), vehicle production and maintenance, and infrastructure construction and maintenance. ExternE also includes up- and downstream processes.

From the point of view of pricing policy it is questionable, however, whether these additional external effects should be taken into account. For pricing policy to be efficient, the costs considered must be internalised for the party being responsible and able to take mitigation measures. Internalising costs somewhere down the product chain will result only in an incentive to reduce the overall volume of transport, with other options like use of cleaner technologies not being addressed.

Nature and urban effects
Only INFRAS/IWW includes the cost categories “Nature & Landscape” and “Urban effects”. These were therefore omitted from our analysis.

3.5 Type of fuel

All studies provide a good indication of the type of fuel used by each specific vehicle. As different fuels have different environmental impacts, we also filtered the studies with respect to the type of fuel used.

3.6 Location: Dutch urban / extra-urban situations

For most of the studies except the UNITE study it proved possible to consider the values assigned to costs for the Dutch situation, with a distinction being made between urban and extra-urban environments. However, precision on this point was often lacking. The UNITE study included no relevant case studies for the Netherlands. The figures presented by the ECMT study do not differentiate between countries. Sometimes 'urban' relates to typical urban figures, while in other cases a specific city like Amsterdam is mentioned. The same goes for 'extra-urban'. We were therefore only partly able to filter the results with respect to location.

3.7 Road vehicle emission class: Euro2 if possible

In the case of road vehicle emissions, European legislation has been made progressively more stringent over the past decade. The so-called emission class of the vehicle is very relevant for its external costs, as an advanced-technology vehicle emits only a fraction of the air pollutants emitted by an old vehicle. Despite this fact, though, some studies do not explicitly mention the emission class. Where it is reported, we have tried to stay as close as possible to the ’Euro2’ emission class, i.e. vehicles constructed between 1997 and 2000. On this point we were only **partly** able to filter the results.

3.8 Vehicle size: comparable load capacity if possible

In the case of freight transport, especially, it is important to strictly define vehicle size, as there are major differences between a small lorry or train and a large one. Wherever possible we have attempted to base ourselves on results applying to identical load capacities. For road, we distinguished a ’small' lorry (typically up to 16t GVW) and a 'large' lorry (typically 40t GVW). Because virtually all studies used different vehicle definitions, however, we were only **partly** able to do so.

4 Filtered results of the studies

In this chapter, we present the results of the five studies, corrected as well as possible for the factors mentioned in Section 3.2, i.e. the region and types of vehicles and technologies to which the figures apply.

4.1 Petrol passenger car

For passenger cars all five sources give information on extra-urban traffic. In the case of INFRAS/IWW two different extra-urban cases could even be constructed.

Table 4 Marginal external and infrastructure costs of a **petrol** passenger car in the Netherlands in a **rural** situation, according to five studies (€ct/vkm)

Cost category	INFRAS/IWW		ECMT	CE	TRENEN	UNITE low	UNITE high
Technology	Euro1		Euro3	Euro1	Euro2	Euro2	Euro2
Location	rural	motorway / densely pop./ suburban	rural	outside built-up area	Tiel drive		
1. Accidents	7.2	1.3	**3.2	1.5	***4.6	****0.3	****1.6
2. Air pollution	*0.1	0.4	*0.1	0.3	0.2	0.1	0.4
3. Climate change	2.1	3.8	**0.9	1.0	0.3	0.3	0.4
4. Noise	*0.0	0.0	*0.3	0.2	0.0	0	0.1
Total (1-4)	**9.4**	**5.5**	**4.5**	**3.0**	**5.2**	**0.8**	**2.5**
5. Infrastructure			2.2	1.7	0.0	0.4	0.5
Total (1-5)			**7.7**	**4.7**	**5.2**	**1.2**	**3.0**
6. Up- & downstream							

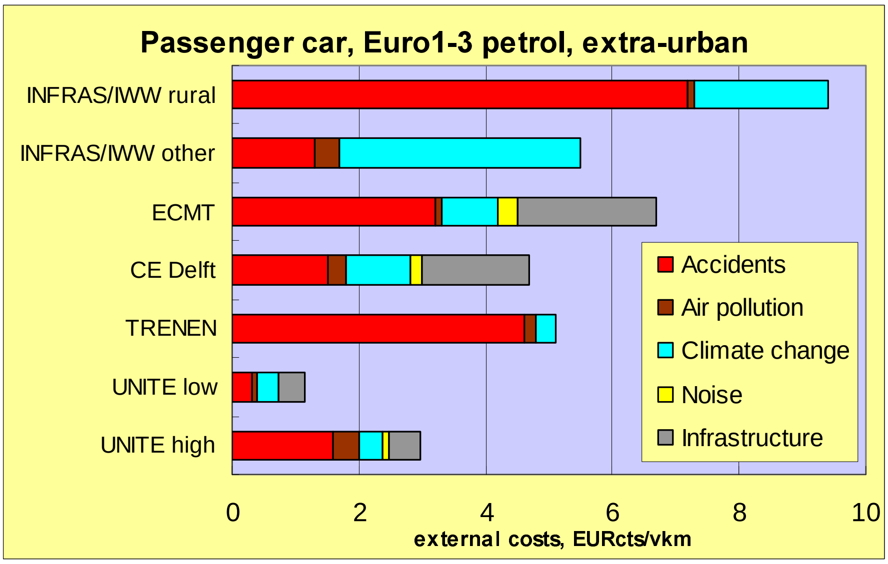
* EU average values

** Average values rural / urban

*** Belgium interregional

**** In the variant in which the accident risk of the causer of the accident is assumed to be internalised (i.e. victim risks are not)

Figure 1 Marginal external and infrastructure costs of a **petrol** passenger car in the Netherlands in a **rural** situation, according to five studies (€ct/vkm)



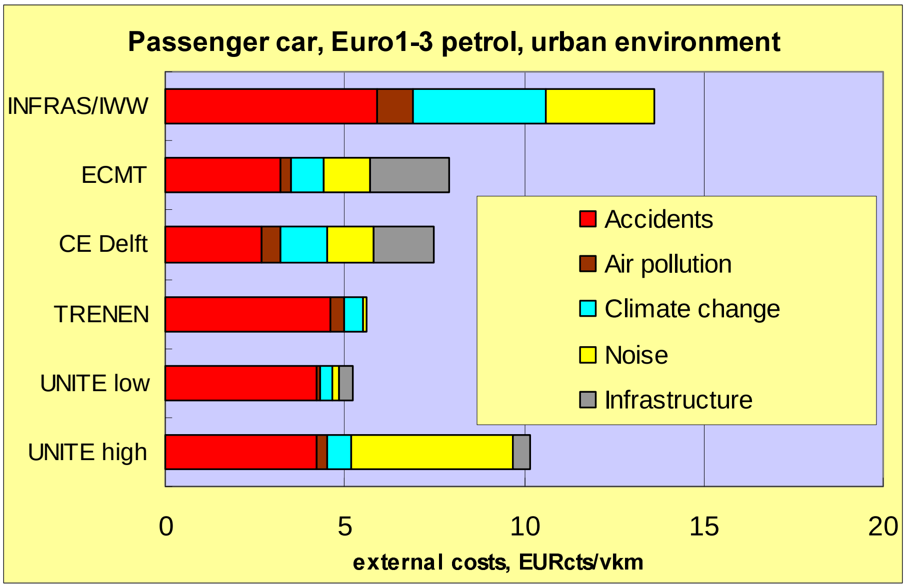
It can be seen that the five estimates are quite close, given the fact that the two INFRAS/IWW figures should be averaged for a final 'extra-urban' result. Values of external costs are in the range of 3-6 €ct per vehicle-km, except the lower bound estimate of the UNITE study, which is only 1 €ct per vkm. Marginal infrastructure costs vary from 0 €ct (TRENEN) via 0.4-0.5 €ct (UNITE) to roughly 2 €ct per km (CE Delft and ECMT).

Table 5 Marginal external and infrastructure costs of a **petrol** passenger car in the Netherlands in an **urban** situation, according to five studies (€ct/vkm)

Cost category	INFRAS/IWW	ECMT	CE	TRENEN Amsterdam	UNITE low	UNITE high
Technology	Euro1	Euro3	Euro1	Euro2	Euro2	Euro2
Location	urban	urban	within built-up area	Amsterdam	various	various
1. Accidents	5.9	**3.2	2.7	***4.6	****4.2	****4.2
2. Air pollution	*1.0	*0.3	0.5	0.4	0.1	0.3
3. Climate change	3.7	**0.9	1.3	0.5	0,4	0.7
4. Noise	*3.0	*1.3	1.3	0.1	0.2	4.5
Total (1-4)	**9.9**	**5.7**	**5.8**	**5.6**	**4.9**	**9.7**
5. Infrastructure		2.2	1.7		0.4	0.5
Total (1-5)		**7.9**	**7.5**	**5.6**	**5.3**	**10.2**
6. Up- & downstream	1.1					

* EU average values
** Average values rural / urban
*** Belgium interregional
**** In the variant in which the accident risk of the causer of the accident is assumed internalised (i.e. victim risks are not)

Figure 2 Marginal external and infrastructure costs of a **petrol** passenger car in the Netherlands in an **urban** situation, according to five studies (€ct/vkm)



It can be seen that the marginal external and infrastructure costs generally fall in the range of 5-13 €ct per vehicle-km (excluding congestion). It should be noted that values become lower if the UNITE accident costs are taken to assume that all accident risks of traffic participants are internalised in their decisions.

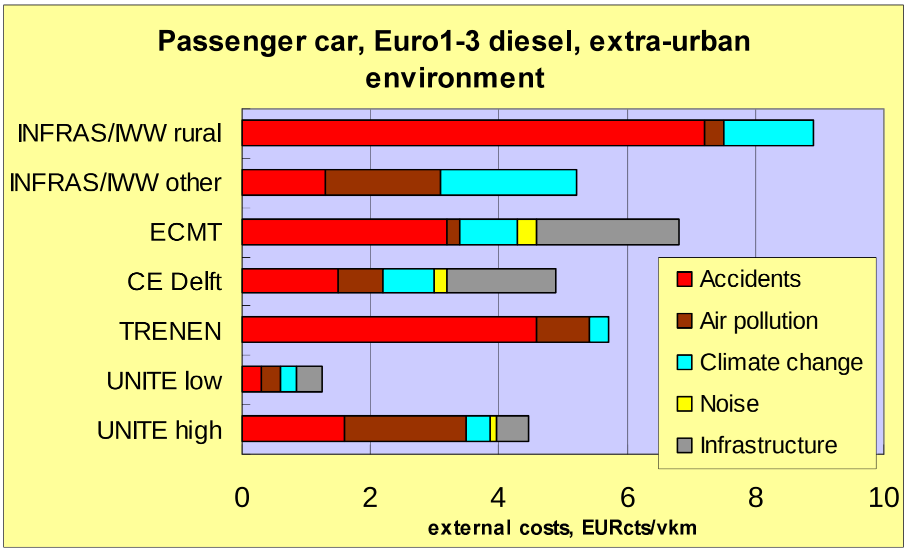
4.2 Diesel passenger car

Table 6 Marginal external and infrastructure costs of a **diesel** passenger car in the Netherlands in a **rural** situation, according to five studies (€ct/vkm)

Cost category	INFRAS/IWW		ECMT	CE	TRENEN	UNITE	UNITE
Technology	Euro1		Euro3	Euro1	Euro2	low	high
Location	rural	motorway / densely pop./ suburban	rural	outside built-up area	Tiel drive	various	various
1. Accidents	7.2	1.3	**3.2	1.5	***4.6	****0.3	****1.6
2. Air pollution	*0.3	*1.8	*0.2	0.7	0.8	0.3	1.9
3. Climate change	1.4	2.1	**0.9	0.8	0.3	0.3	0.4
4. Noise	*0.0	*0.0	*0.3	0.2	0.0	0	0.1
Total (1-4)	**8.9**	**5.3**	**4.5**	**3.2**	**5.7**	**0.9**	**4.0**
5. Infrastructure			2.2	1.7	0.0	0.4	0.5
Total (1-5)			**7.7**	**4.9**	**6.3**	**1.3**	**4.5**
6. Up- & downstream							

* EU average values
** Average values rural / urban
*** Belgium interregional
**** In the variant in which the accident risk of the causer of the accident is assumed internalised (i.e. victim risks are not)

Figure 3 Marginal external and infrastructure costs of a **diesel** passenger car in the Netherlands in a **rural** situation, according to five studies (€ct/vkm)



It can be seen that the five estimates are quite close, given the fact that the two INFRAS/IWW figures should be averaged for a final 'extra-urban' result. External cost values are all in the range of 3-6 €ct per vehicle-km, except the UNITE lower bound estimate which is roughly 1 to 2 €ct per vehicle-km. Infrastructure costs vary from 0 €ct (TRENEN) via 0.4-0.5 €ct to 2 €ct (CE Delft and ECMT).

Table 7 Marginal external and infrastructure costs of a **diesel** passenger car in the Netherlands in an **urban** situation, according to five studies (€ct/vkm)

Cost category	INFRAS/IWW	ECMT	CE	TRENEN	UNITE low	UNITE high
technology	Euro1	Euro3	Euro1	Euro2	Euro2	Euro2
location	urban	urban	within built-up areas	Amsterdam	various	various
1. Accidents	5.9	**3.2	2.7	***4.6	****4.2	****4.2
2. Air pollution	*2.6	*0.9	2.9	2.0	0.7	1.5
3. Climate change	2.6	**0.9	1.1	0.4	0.3	0.4
4. Noise	*3.0	*1.3	1.3	0.1	0.2	4.5
Total (1-4)	**14.2**	**6.3**	**8.0**	**7.1**	**5.4**	**10.6**
5. Infrastructure		2.2	1.7	0.0	0.4	0.5
Total (1-4)		**8.5**	**9.7**	**7.1**	**5.8**	**11.1**
6. Up- & downstream	1.1					

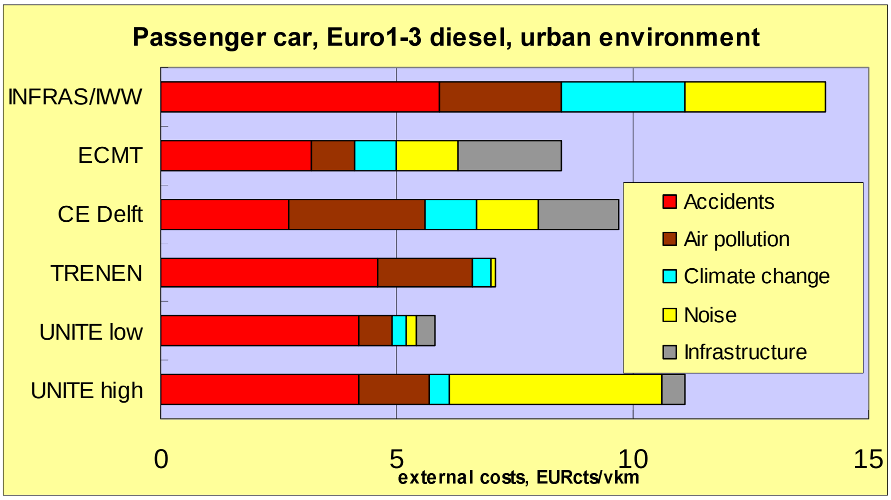
* EU average values

** Average values rural / urban

*** Belgium interregional

**** In the variant in which the accident risk of the causer of the accident is assumed internalised (i.e. victim risks are not)

Figure 4 Marginal external and infrastructure costs of a **diesel** passenger car in the Netherlands in an **urban** situation, according to five studies (€ct/vkm)



It can be seen that the marginal external and infrastructure costs generally fall in the range of 5-13 €ct per vehicle-km (excluding congestion). It should be noted that values become lower if the UNITE accident costs are taken to assume that all accident risks of traffic participants are internalised in their decisions.

4.3 Lorry (Heavy Goods Vehicle)

Data on freight transport are even more scattered than those on passenger cars. First, freight has been less extensively studied. Second, lorries differ much more in size and thus emissions, infrastructure load, etc. than passenger cars. An analytical advantage, however is that they all run on diesel. We therefore split up the figures for lorries as far as possible into those for light and heavy lorries, and again for the urban and rural situation. Not all the studies had all the figures; nevertheless the next four tables could be decently filled.

4.3.1 Light lorry

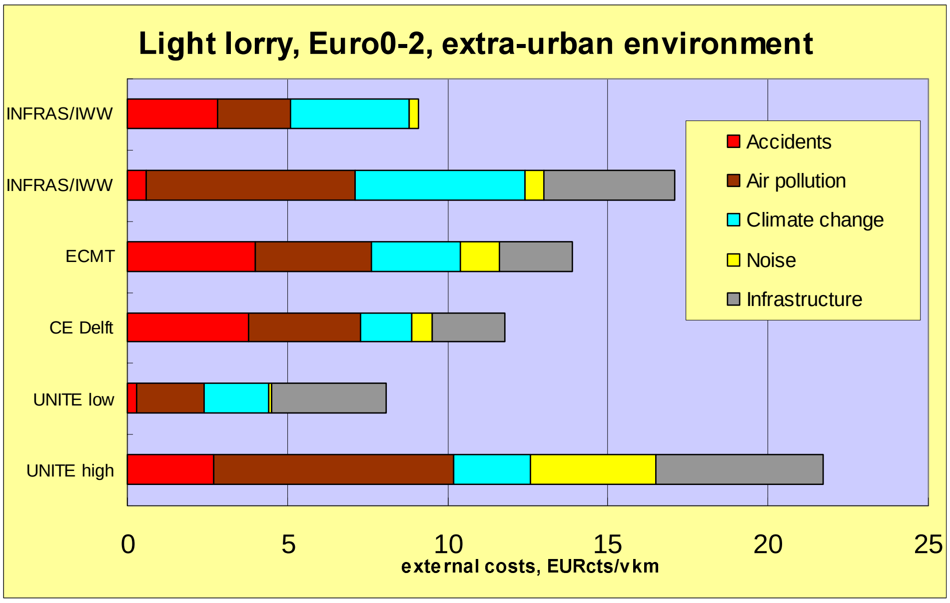
Table 8 Marginal external and infrastructure costs of a **light lorry** in the Netherlands in a **rural** situation, according to four studies (€ct/vkm)

Cost category	INFRAS/IWW		ECMT	CE	UNITE low	UNITE high
size (in tonnes GVW)	3.5-7.5		avg. van / lorry	3.5 - 12	various	up to 42
load (t)	1.9		3	1.6		
technology	Euro0		Euro3	Euro2	Euro2	Euro2
location	rural	motorway / densely pop.		outside built-up areas	various	various
1. Accidents	2.8	0.6	**4.0	3.8	0.3	2.7
2. Air pollution	*2.3	*6.5	*3.6	2.1	2.1	7.5
3. Climate change	3.7	5.3	**2.8	1.6	2	2.4
4. Noise	*0.3	*0.6	*1.2	0.6	0.1	3.9
Total (1-4)	**9.1**	**13.0**	**11.6**	**8.1**	**4.5**	**16.5**
5. Infrastructure			4.1	2.3	3.6	5.2
Total (1-5)			**15.7**	**10.4**	**8.1**	**21.7**
6. Up- & downstream	4.9					

* EU average values

** Average values rural / urban

Figure 5 Marginal external and infrastructure costs of a **light lorry** in the Netherlands in a **rural** situation, according to four studies (€ct/vkm)



It can be seen that the resultant external cost values fall in the range of 5-15 €ct per vehicle-km. Marginal infrastructure costs vary for 2 to 5 €ct per vehicle-km.

INFRAS/IWW is particularly high on air pollution and climate change. Motorways are much safer than other extra-urban roads.

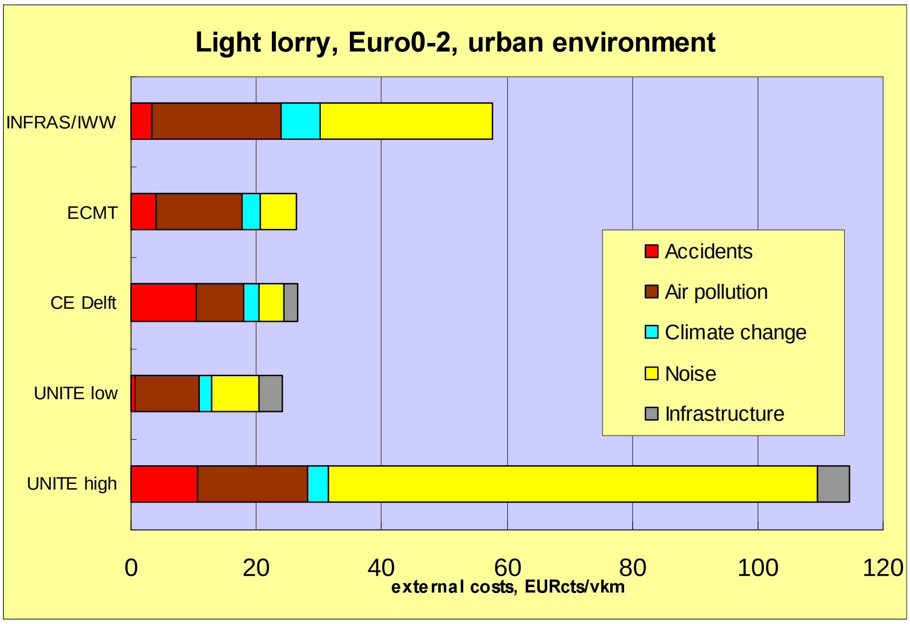
Table 9 Marginal external and infrastructure costs of a **light lorry** in the Netherlands in an **urban** situation, according to four studies (€ct/vkm)

Cost category	INFRAS/IWW	ECMT	CE	UNITE low	UNITE high
size (in tonnes GVW)	3.5-7.5	avg. van / lorry	3.5-12	various	various
Load (tonnes)	1.9	3	1.6		
technology	Euro1	Euro0	Euro0	Euro2	Euro2
location	urban	urban	within built-up areas	urban	urban
1. Accidents	3.4	**4.0	10.4	0.6	10.7
2. Air pollution	*20.5	*13.8	7.6	10.2	17.5
3. Climate change	6.3	**2.8	2.4	2	3.3
4. Noise	*27.4	*5.8	4.0	7.7	78
Total (1-4)	**57.6**	**26.4**	**23.4**	**20.5**	**110**
5. Infrastructure		4.1	2.3	3.5	5.2
Total (1-5)		**30.5**	**25.7**	**24**	**115**
6. Up- & downstream	4.9				

* EU average values

** average values rural / urban

Figure 6 Marginal external and infrastructure costs of a **light lorry** in the Netherlands in an **urban** situation, according to four studies (€ct/vkm)



In this case the differences between the studies are more remarkable, especially in absolute terms. The absolute outlier in upward terms is the UNITE estimate of freight transport by night in Stuttgart, which leads to exceptionally high noise costs. A minimum of 20-25 €ct seems a good estimate.

4.3.2 Heavy lorry

The next table is particularly relevant from an EU policy point of view, as this category concerns international transport (heavy lorries) on large corridors (non-urban).

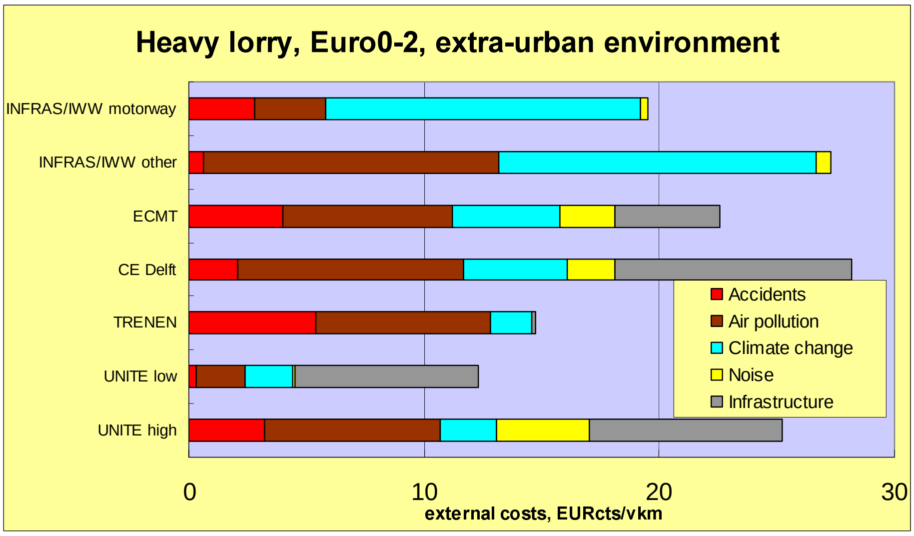
Table 10 Marginal external and infrastructure costs of a **heavy lorry** in the Netherlands in a **rural** situation, according to five studies (€ct/vkm)

Cost category	INFRAS/IWW		ECMT	CE	TRENEN Belgium interregional	UNITE low	UNITE high
size (tonnes GVW)	32-40		avg. lorry	articulated	articulated	up to 42	up to 42
load (tonnes)	15		6	12	11.3		
technology	Euro1		Euro0	Euro0	Euro2	Euro2	Euro2
location	rural / extra-urban	motorway / densely pop	rural	within built-up areas		various extra-urban	various extra-urban
1. Accidents	2.8	0.6	**4.0	2.1	5.4	0.3	3.2
2. Air pollution	*3.0	*12.6	*7.2	9.6	7.4	2.1	7.5
3. Climate change	13.4	13.5	**4.6	4.4	1.8	2	2.4
4. Noise	*0.3	*0.6	*2.3	2	0	0,1	3.9
Total (1-4)	**19.5**	**27.3**	**18.1**	**18.1**	**14.6**	**4.5**	**17.0**
5. Infrastructure			4.5	10.1	0.1	7.8	8.2
Total (1-5)			**22.6**	**28.2**	**14.7**	**12.3**	**25.2**
6. Up- & downstream	4.9						

* EU average values

** Average values rural / urban

Figure 7 Marginal external and infrastructure costs of a **heavy lorry** in the Netherlands in a **rural** situation, according to five studies (€ct/vkm)



It can be seen that the resulting *external* cost values fall mostly in the range of 15-20 €ct per vehicle-km. Exceptions include the UNITE lower value of 5 €ct per vkm and the INFRAS/IWW upper value of 27 €ct per vkm. *Infrastructure* costs range from 0.1 to 10 €ct per kilometre.

INFRAS/IWW is particularly high on air pollution and climate change. Motorways are much safer than other extra-urban roads.

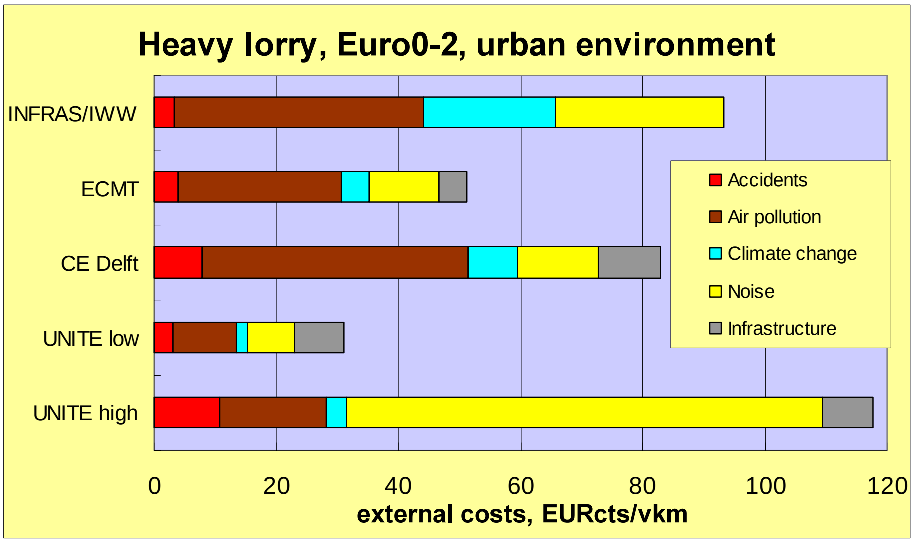
Table 11 Marginal external and infrastructure costs of a **heavy lorry** in the Netherlands in an **urban** situation, according to four studies (€ct/vkm)

Cost category	INFRAS/IWW	ECMT	CE	UNITE low	UNITE high
size (tonnes GVW)	32-40	avg. truck		up to 42	up to 42
load (tonnes)	15	6	12		
technology	Euro1	Euro0	Euro0	Euro2	Euro2
location	urban		inside built-up areas	diverse urban	diverse urban
1. Accidents	3.4	**4.0	7.8	3.2	10.7
2. Air pollution	*40.8	*26.7	43.6	10.2	17.5
3. Climate change	21.6	**4.6	8.0	2	3.3
4. Noise	*27.4	*11.3	13.4	7.7	78
Total (1-4)	**93.2**	**46.6**	**71.9**	23.1	109
5. Infrastructure		4.5	10.1	7.9	8.2
Total (1-5)		**51.2**	**82.0**	**31**	**117**
6. Up- & downstream	4.9				

* EU average values
** Average values rural / urban

In this case the differences between studies are more remarkable, especially in absolute terms. The primary differences include the higher INFRAS/IWW estimates of noise and climate change.

Figure 8 Marginal external and infrastructure costs of a **heavy lorry** in the Netherlands in an **urban** situation, according to four studies (€ct/vkm)



4.3.3 Comparison with EC's White Paper estimates

The European Commission's White Paper “European Transport Policy for 2010: time to decide” (EC, 2001) contains estimates of the marginal external and infrastructure costs of a heavy goods vehicle travelling on a motorway with little traffic outside an urban area. We compared the White Paper estimates with the values found in this study; the results in shown in Table 12.

Table 12 Comparison between range of marginal external and infrastructure costs per vehicle-km found in this study and figures reported in European Commission's White Paper "European Transport Policy for 2010: time to decide" (2001)

Cost item	White Paper ranges (motorway, little traffic)	Ranges found in this study (as far as possible adjusted to motorways)
1. Accidents	0.2-2.6	0.3-5.4
2. Air pollution	2.3-15	2.1-12.6
3. Climate change	0.2-1.54	1.6-13.5
4. Noise	0.7-4	0.1-2.3
Total 1-4	**3.5-23**	**4-44**
5. Infrastructure	2.1-3.3	2.3-10
Total 1-5	**6-26**	**6-54**
6. Congestion	2.7-9.3	-
Total	8-36	

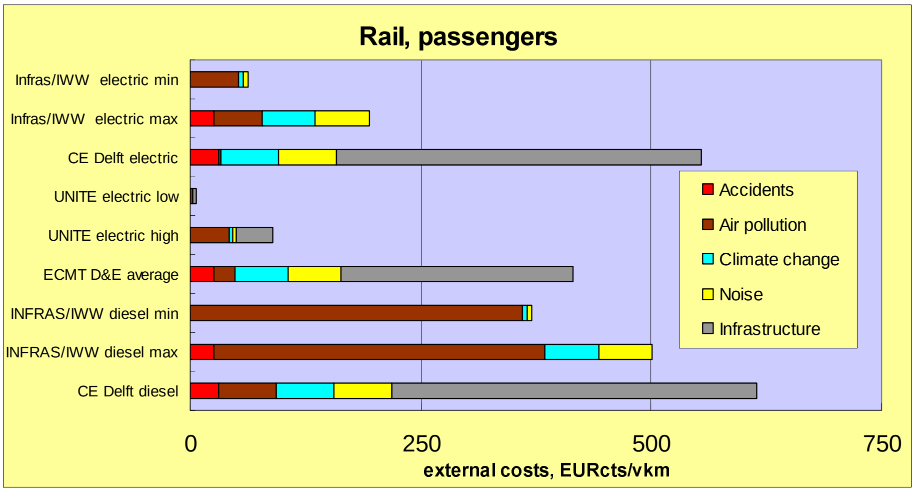
As can be seen, the ranges reported in the White Paper are generally in approximate agreement with those of the present review. The White Paper, however, omits the most extreme values from its estimates, notably the INFRAS/IWW climate change costs and the CE/UNITE heavy lorry infrastructure costs. This largely explains the White Paper upper estimate of 36 €ct per vehicle-km, which is rather modest compared with our upper estimates.

4.4 Passenger train

Table 13 Marginal external and infrastructure costs of a passenger train running on electricity and diesel according to five studies (€ct per train-kilometre)

Cost category	INFRAS/IWW ranges	CE	ECMT	INFRAS/IWW ranges	CE	UNITE low	UNITE high
Location	EU	NL	EU	EU	NL		
running on …	**electricity**	**electricity**	**87%el.,13%D**	**diesel**	**diesel**	**electric**	**electric**
no. of pass. carried	130	130	126	130	130		
1. Accidents	0 - 25	31	25	0-25	31	small	small
2. Air pollution	53	2	24	360	62	2.5	42
3. Climate change	105	21	32	134	24	0.2	17
4. Noise	5 - 58	63	57	5-58	63	0,0	4
Total (1-4)	**163 - 241**	**117**	**138**	**499-577**	**180**	**3**	**63**
5. Infrastructure	--	396	252		396	3.5	39
Total (1-5)		**513**	**390**		**576**	**6**	**102**
6. Up- & down-stream	28 - 245			28-245			

Figure 9 Marginal external and infrastructure costs of a passenger train running on electricity and diesel according to five studies (€ct per train-kilometre)



It can be seen that two factors dominate the outcome for passenger transport by rail:

- whether or not marginal *infrastructure* costs are taken into account and how marginal costs are defined. If marginal costs are taken to be the costs of maintenance and upkeep (as ECMT and CE do) then they dominate the cost figure with € 2.5 to 4 per train-km. If a strictly short-term definition of marginal cost is adopted, as in the UNITE study, the cost figures decrease substantially;
- the question whether electrical or *diesel* traction is used. Diesel traction approximately doubles external costs.

INFRAS/IWW reports substantially higher values with respect to climate change and air pollution. The other values are largely comparable.

Without infrastructure costs, most of the values for the *electrically* powered train range from about € 1 to 2 per train-km, depending mainly on train size and location. The UNITE maximum estimate is only € 1, however. Diesel-powered trains add € 0.5 to 3 to this figure, mainly because of air pollution costs. Infrastructure costs add about € 2-4 according to the ECMT and CE studies and a maximum of only € 0.4 according to UNITE.

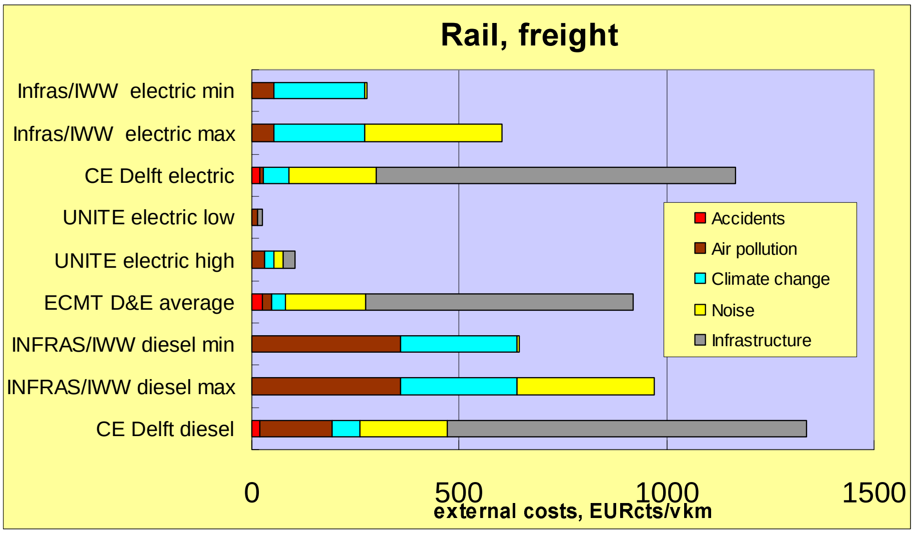
4.5 Freight train

Table 14 summarises the results of the INFRAS/IWW, ECMT and CE studies with respect to freight trains.

Table 14 Marginal external and infrastructure costs of freight transport by rail (€ct per train-kilometre)

Cost category	INFRAS / IWW ranges	CE	ECMT	INFRAS / IWW ranges	CE	UNITE low	UNITE high
Location	EU	NL	EU	EU	NL		
running on …	**electricity**	**electricity**	**76%el., 24%D**	**diesel**	**diesel**	**electric**	**electric**
tonnes load	285		323	285			
1. Accidents	0	19	25	0	19	small	small
2. Air pollution	53	8	24	360	174	14.8	32
3. Climate change	220	62	32	279	67	0.2	21
4. Noise	5-331	211	194	5-331	211	0.3	22
Total (1-4)	**278 - 644**	**300**	**275**	**604 - 970**	**471**	**15**	**75**
5. Infrastructure	--	866	646	--	866	9	29
Total (1-5)		**1,166**	**921**		**1,337**	**24**	**104**
6. Up- & down-stream	11-33			11-33			

Figure 10 Marginal external and infrastructure costs of freight transport by rail (€ct per train-kilometre)



It can be seen that again *diesel* traction and *infrastructure* costs dominate the cost picture. Owing to the high weight of freight trains, infrastructure costs are even more dominant here than in the case of passenger rail.

INFRAS/IWW gives substantially higher values with respect to climate change and air pollution. The other values are largely comparable.

Without infrastructure costs most of the values for the *electrically* powered train range from about € 3 to 6 per train-km, depending mainly on train size and location. The UNITE maximum estimate is only € 1, however. Diesel-powered trains add approximately € 1 to 4 to this figure, mainly because of air pollution costs. Infrastructure costs add about € 6-8 according to the ECMT and CE studies and at most only € 0.3 according to UNITE.

4.6 Conclusion

From the review of results presented a number of conclusions can be drawn:

- Disregarding the results of the UNITE study, the upper and lower results of the studies considered do not generally differ by more than a factor 2 if comparable situations and vehicles are considered. Many of the results differ by no more than several dozen per cent. To a large extent the differences between the results of these studies can be explained fairly straightforwardly as being due to such factors as differences in fuel, technology, location and/or country. Nevertheless, differences remain. These are explored in the next chapter.
- The UNITE cost estimates for passenger cars and rail transport are generally substantially lower than those of the other studies. Remarkably, the UNITE results for *road freight* transport are quite close to the other estimates. The explanation follows in the next chapter.
- Although it sounds odd, differences in estimates of *infrastructure* costs are just as large as those for *external* costs. In other words: there is as much agreement on infrastructure costs as there is on external costs. This might be explained by the research effort devoted to the valuation of external costs, which has brought about greater consensus among estimates.

5 Explaining remaining differences

5.1 Differences in statistics

In part, the remaining differences between the studies can be attributed to differences in input data. Essential data in this respect include load factors, annual number of vehicle-kilometres, emission factors, number of road accidents, et cetera. Sometimes the differences are due to differences in the base year; in other cases different studies use different numbers for exactly the same variable.

As an example Table 15 shows the annual number of vehicle-kilometres reported in the various studies for the Netherlands.

Table 15 Annual number of passenger car kilometres (vkm) in the Netherlands according to four studies

Study	year	vkm (million)
ECMT	1991	77,800
TRENEN (see ExternE)	1993	88,362
INFRAS/IWW	1995	68,566
CE	2002	100,275

Although the ECMT, ExternE and CE Delft statistics can be reconciled if one allows for growth in transport demand between 1991 and 2002, the data used by INFRAS/IWW clearly stand out.

Another example of different statistics being used is the total number of transport accidents. For example, ECMT cites a figure of 1,479 for casualties for the Netherlands in 1991, fairly high in comparison with the 1,203 reported by INFRAS/IWW and the data of the Dutch Bureau of Statistics for 1995. The differences in both annual accidents and annual kilometres largely explains the differences in marginal external costs due to accidents in the various studies.

Table 16 gives an indication of the degree to which accident figures differ.

Table 16 Number of fatalities and serious injuries attributed to cars and trucks in four studies per billion vehicle-kilometres

	fatalities		severe injuries		remarks
	extra-urban	urban	extra-urban	urban	
Cars					
INFRAS/IWW	3 (motorway) 16 (other)	17	35 (motorway) 180 (other)	200	Netherlands 1995, approximate figure
ECMT	24	24	120	120	EU 1991
CE	13 (average) 3 (motorway) 19 (other)	8	50	146	Netherlands 1995-1997
TRENEN	17	18		96	Belgium 1990
heavy lorries					
INFRAS/IWW	3 (motorway) 16 (other)	12	17 (motorway) 72 (other)	86	Netherlands 1995, approximate figure
ECMT	24	24	120	120	EU 1991
CE	13 (average) 6 (motorway) 46 (other)	48	34 (average) 13 (motorway) 140 (other)	124	Netherlands 1995-1997
TRENEN	17	41	147	290	Belgium 1990

It can be seen that accident risk rates can vary by up to a factor of 8 within the extra-urban and urban environment, depending on exactly what type of road and region is considered and what accident statistics are used.

It should be remarked that most of the studies proved to be rather untransparent when it came to tracing the values of input and output data. Most of them lack a clear summary of emission factors and load factors. Unfortunately, therefore we were **not** able to correct the results for these differences.

The fact that there is such a spread in the results of these external cost studies makes it even more important that the reader be able to retrace the analysis.

5.2 Differences in normative choices

A second, and very crucial, category of differences stems from the different normative choices made in the studies. These normative choices generally go beyond the economists' domain; they are typically the policy makers'.

5.2.1 Infrastructure: who pays fixed maintenance costs?

Infrastructure costs are external as well as environmental costs, since users do not take infrastructure costs into account when deciding whether or not to make use of the infrastructure. Infrastructure costs are treated quite differently in the various studies, however.

INFRAS/IWW does not include infrastructure costs.

ECMT's philosophy is that users should be charged short-term marginal costs in situations without congestion and long-term marginal costs (full infrastructure costs) when there is congestion. Short-term marginal costs are estimated at 50% of full infrastructure costs. These estimates are based on limited data regarding fixed and variable infrastructure costs. Consequently the short-term marginal costs can in fact be considered variable costs: all the costs of road maintenance and upkeep.

CE takes into account the variable infrastructure costs, such as those for infrastructure maintenance and upkeep, policing, administration and traffic management. From the point of view of efficient pricing, fixed infrastructure costs such as construction costs should not be passed on. As the infrastructure has already been built, charges would lead to sub-optimal usage. CE does report average infrastructure costs, however, for policy makers wishing to take cost coverage rather than efficiency as their point of departure for pricing policy.

TRENEN takes marginal infrastructure costs into account for heavy lorries only, it being assumed that other vehicles scarcely contribute to road damage. The marginal infrastructure costs for heavy road vehicles are a factor 70 lower than the CE estimates (0.14 €ct vs. 10.1 €ct).

Finally, UNITE also estimates marginal infrastructure costs on the basis of a number of case studies. These case studies are based either on econometric analyses (ex-post explanations of relationships between maintenance costs and infrastructure use) or engineering analyses (‘bottom-up’ calculations of road maintenance costs).

In brief, UNITE uses proxies for short-term marginal costs, CE takes a rather somewhat broader approach (variable infrastructure maintenance and upkeep costs), ECMT states marginal costs but seems in practice to work with variable costs, and TRENEN scarcely takes infrastructure costs into account at all.

5.2.2 Safety risks: can we estimate marginal costs?

An important methodological difference between the studies is the way in which marginal accident costs are derived.

With respect to *marginal* costs, all studies except UNITE take – implicitly or explicitly – marginal costs equal to average cost. UNITE works with the so-called 'risk elasticity' approach, in which the safety impact of addition of one extra vehicle to traffic flow is assessed. UNITE comes to the conclusion that the risk elasticity is usually below 0. According to UNITE this implies that extra traffic makes roads safer and that marginal accident costs are therefore lower than average accident costs[6]. This would lead to the conclusion that in some cases accident charges may even be negative, implying that these users should in fact be subsidised.

5.2.3 Safety risks: internal or external costs?

With respect to *external* costs, there is a significant debate as to whether traffic participants have internalised their own safety risk when entering a traffic flow, or only the risk that they might *cause* an accident.

Again, UNITE takes an anomalous approach by running two variants: one in which the internal risk of all transport participants is internalised, and one in

[6] Other studies come to less outspoken conclusions on this point; see for example the report of the expert advisors to the High Level Group on Infrastructure Charging on estimating accident costs.

which only the risk of causing an accident is internalised (i.e. being the victim of an accident is not). In the UNITE final overview reports, mostly only the variant is presented in which the risk of the victim is internalised. All other studies consider both internal and external risks as external costs.

5.2.4 Climate change: reduction targets and mechanisms

The most important greenhouse gas emissions are those of CO_2. As vehicle CO_2-emission is linked directly to fuel used, fuel consumption figures are generally used as an input for calculating CO_2-emissions.

The five studies differ widely in their *monetary valuation* of CO_2-emissions. See Table 17.

Table 17 Monetary valuation of climate change

	€/tonne CO_2	Origin
ECMT	50	marginal prevention costs of measures implemented within the EU to stabilise European CO_2-emissions at 1990 levels
CE Delft	50 (15-100)	marginal prevention costs to reduce Dutch CO_2-emissions by 6% relative to 1990 by 2008-2012 (50% of reduction outside the Netherlands via Kyoto mechanisms)
INFRAS/IWW	135 (70-200)	marginal prevention costs of "reduction of European transport CO_2-emissions of 50% relative to 1990 until 2030"
TRENEN (ExternE)	25	upper value of the IPCC range for marginal damage costs of CO_2-emissions (IPCC assessment 1995)
UNITE	20	marginal abatement costs for the EU to achieve Kyoto target

As can be seen from the table, different points of departure can lead to substantial differences in monetary valuations. With the exception of TRENEN (ExternE), all studies give a monetary valuation of CO_2-emissions on the basis of the marginal costs of achieving a certain reduction target. While CE, ECMT and UNITE take 'political' targets for emission reduction to arrive at a cost estimate of € 50 per tonne CO_2, INFRAS/IWW arrive at more than double this value by using a much more stringent 'scientific' target for emission reduction.

This again shows that normative choices, namely the greenhouse gas emission reduction target adopted and the permitted mechanisms for reducing them (inside transport sector? indifferent to what sector?) have a decisive influence on the valuation of CO_2-emissions. The more stringent the target, and the less flexible the ways it may be achieved, the higher the valuation of vehicle CO_2-emissions.

5.3 Differences in valuation (economics)

The last category of possible differences deals with differences in the valuation of external effects, once normative choices have been corrected for.

5.3.1 Safety risks: monetary valuation

The following table shows the different monetary values reported for safety risks. CE gives a value for the Netherlands only, while INFRAS/IWW does not give a value for the EU as a whole. For this reason, all values are given for the Netherlands to enable comparison.

Table 18 Monetary valuation of mortality and morbidity in the five studies for the case of the Netherlands

	€/fatality	€/injury	Origin
INFRAS/IWW	1,704,984	138,445 ("severe") 15,053 ("slight")	Survey of scientific (primary) literature, such as willingness-to-pay studies
ECMT	1,470,000 (EU: 1,500,000)	196,000 ("serious") (EU: 200,000)	Based on official values adopted in the five European countries where non-material damage is included in cost estimates of traffic accident fatalities
CE	1,346,000	109,000 ("registered hospitalisation")	Primarily based on official estimates for costs of traffic accident fatalities in European countries
TRENEN	126,882	306,631 ("serious")	only net output loss, ambulance costs, police and medical costs
UNITE	1,500,000	480,000 (permanent) 135,000 (temporary)	Survey of scientific (primary) literature, such as willingness-to-pay studies

The monetary valuations given by TRENEN are noteworthy in comparison with the other studies. TRENEN assumes that the utility loss of the victim for himself and his relatives and friends are already internalised in the transport users' decision process. The result is a very low monetary valuation of mortality in comparison to the other studies. On the other hand, their value for morbidity is high. It is composed of the same values as for mortality, but in this case the discounted consumption is not subtracted from the output loss.

TRENEN is the only study in which the 'cold-blooded costs' predominate in the accident cost calculation. In most other studies society's willingness to pay for avoiding accident risks (the so-called 'risk value') is the most important component of external accident costs.

Apart from TRENEN, which makes a different normative choice, the valuations used differ by only several dozens per cent.

5.3.2 Environment: valuation of air pollution

The external costs due to air pollution are by far the most difficult to compare across the different studies. The studies use completely different methodologies to ascribe monetary values to the emissions.
CE and ECMT use shadow prices to ascribe monetary values to the emissions directly. These shadow prices are derived from estimates of both the costs to reduce emissions to a given political target and of emission-related damage.
INFRAS/IWW takes estimates by the World Health Organisation for the total external costs of transport emissions and divides these costs over the various transport categories on the basis of total emissions and emission factors ('top-down' calculation). As a result, the implicit valuations of each pollutant are not to be found in the study.
ExternE, on which TRENEN is based, and UNITE both calculate the actual health effects in specific transport situations 'bottom-up', using the Impact Pathway Approach, and assigns monetary values to these effects. In Ex-

ternE the result is that external costs per vehicle-kilometre depend very much on the specific situation. In a densely populated area like the conglomeration of Paris the external costs per vehicle kilometre are much higher than those in a less densely populated area such as Amsterdam.
The differences between these three approaches are so fundamental that the differences in results cannot be explained within the scope of the present study.

Finally, it should be mentioned that the external costs due to particulate emissions are featuring ever more prominently in total estimates of the external costs of pollution. In recent years more information has become available on the harmful effects of these small-particle emissions, leading to higher cost estimates. In the INFRAS/IWW, TRENEN and UNITE studies the overall cost estimates for air pollution are dominated by particulates.

Table 19 Monetary valuation of NO_x-emissions

	€/kg	€/kg	Origin
	Rural area	Urban area	
INFRAS/IWW			Not retraceable
ECMT	4	8	Differentiation of 5 €/kg, in turn a plausible average of available studies using prevention as well as damage costs
CE	5	7	Prevention costs based on emission reduction ceilings for 2010: 120 ktonne NO_X and 117 ktonne HC
TRENEN (ExternE)	5	5	Damage cost estimate for Amsterdam and Tiel drive

As can be seen, NO_X-emissions are valued very similarly in the TRENEN, CE Delft and ECMT studies, varying by only a few dozen per cent.

Table 20 Monetary valuation of particulate (PM_{10}) emissions

	€/kg	€/kg	Origin
	Rural area	urban area	
INFRAS/IWW	-	-	Not retraceable
ECMT	0	70	Marginal prevention costs for “reducing PM_{10}-emissions in urban areas”
CE	20	150	Based on damage costs in urban areas and rural areas (IVM 1997, Kageson 1998)
TRENEN (ExternE)	155	304	Damage cost estimate for Tiel drive and Amsterdam respectively
UNITE	3-27	98-227	Helsinki, Stuttgart and Berlin

It can be seen that in the valuation of PM_{10}-emissions ECMT has the lowest estimates, TRENEN the highest. The implicit values used by INFRAS/IWW are probably even higher, given the consistently higher air pollution results they report.

5.3.3 Environment: valuation of noise

External costs due to noise generally contribute only a minor fraction of the total external costs of transport. In addition, there are only limited differences between the figures reported in the various studies. We shall therefore not elaborate on this issue.

5.3.4 Summary

Summarising, the remaining differences in the valuation of external effects – accidents, air pollution, climate change – are relatively minor *once normative choices have been made* on whether safety risks are internal or external, what emission reduction targets to use, et cetera.

5.4 Review of results

This chapter shows that the remaining differences between the studies can be explained primarily by two factors:
- differences in statistics and input values for risk rates, emission factors, et cetera;
- differences in normative choices with respect to infrastructure costs, accident costs and climate change targets.

The studies also differ in the values assigned to external effects (casualties, emissions, etc.), but these can be explained primarily by differences in normative choices, as described above. Once there is agreement on these normative choices, differences in valuation are no more than a few dozen per cent.

6 A discussion agenda

6.1 Normative choices

The analysis of the previous chapters has shown that the differences between the results of marginal external and infrastructure cost studies are smaller than a quick scan of their results would suggest. Thoroughly filtering the results for presentation, cost types, vehicle types, region and vehicle emission classes reveals that the studies do not generally differ in their estimates of external costs by more than a factor 2.

Nevertheless, it is desirable that the remaining differences between studies seeking to specifically quantify external costs be further diminished, to achieve greater clarity on the magnitude and structure of the external costs of different transport modes and vehicle types.

Contrary to what is often thought, the primary cause of the remaining differences in marginal external and infrastructure cost estimates is **not** disagreement among economists about the valuation of negative impacts.

It is, rather, the **normative choices** underlying the valuations, risk estimates and infrastructure cost estimates that largely determine the remaining differences. Four such normative choices are discussed below.

6.2 Infrastructure costs: fixed maintenance costs?

Oddly enough, the previous chapters show that the uncertainty regarding marginal infrastructure costs, the only 'tough' economic costs involved in the analysis, is about the same size as the uncertainty regarding external costs. Particularly in the case of road freight and rail transport, this gives rise to substantial differences in cost estimates.

The primary question is whether strictly short-term marginal infrastructure costs should serve as a pricing basis (UNITE, TRENEN), or a broader approach based on total upkeep and maintenance costs taken (ECMT, CE).

The pivotal issue for discussion is therefore who is to pay for *the fixed costs of maintenance and upkeep*. These costs fall 'in between' sunk infrastructure investment costs – on which there is relatively broad agreement that these should *not* be collected though user charges – and short-term marginal costs – on which there is broad agreement that these *should* be charged to users.

Although these costs are fixed – i.e. independent of traffic volume – they are not sunk, as they can theoretically be stopped at any time by closing down the infrastructure. Examples include season-dependent maintenance, roadside maintenance, et cetera. These costs are related to the decision of the road operator whether or not to keep the infrastructure open for use.

On the one hand, it is often argued that short-term marginal costs are superior in welfare-economic terms: only a short-term marginal cost approach ensures that everyone pays the right price at the right time and leads to optimal infrastructure capacity utilisation. Higher prices would deter people from using the infrastructure who would be willing to pay for their marginal costs and would therefore cause a loss of welfare.

On the other hand, an important question in welfare terms is what would be the best yardstick for deciding whether or not to keep a given section of infrastructure open for use. It might be argued that it is reasonable that the users' willingness to pay is the best yardstick for this decision.

This is clearly a point for discussion, for both economists and policy makers.

6.3 Safety risks: what risks are internalised?

The first important discussion item relating to safety risks is: what safety costs are to be taken as external?

TRENEN and UNITE argue that individual transport participants have already internalised their own risk when deciding to get on the street. INFRAS/IWW, ECMT and CE also deem these costs external.

The first approach is more libertarian. Strict application implies that governments should not devote any effort to, say, legislation for seat belts, crash testing, et cetera, because people can judge the risk they run themselves. Consequently, it would be up to the person concerned to decide whether or not to belt up, put their children in children's safety seats or buy cars fulfilling safety requirements. In other words, governments are to some extent inclined to protect their citizens from the consequences of their own decisions.

This leads us to the second approach, which is more paternalistic. Strict application implies that people and governments assign an equal value to risks imposed on themselves and on others. This is also certainly not the case. Governments permit numerous activities involving a clear danger to participants, such as mountaineering or car racing, but they are far less permissive when it comes to activities that harm others. An good example is policy on cigarette smoking, which often focuses on the health impact of smoking on others, while the impact on the smoker's own well-being is far more profound.

The truth will probably lie somewhere in the middle. A possible solution could be to consider all risks external, but attach different values to a statistical life for internal and external risks.

6.4 Safety risks: can marginal costs be estimated?

The second question regarding the costs of safety risks is whether the marginal costs are different from the average costs. The INFRAS/IWW, ECMT, CE and TRENEN studies all assume, either implicitly or explicitly, that the average and marginal costs are equal.
UNITE, however, argues that addition of one extra vehicle to a road may alter accident risks, thus making marginal accident costs different from average costs. Empirical analysis in the UNITE framework shows a so-called 'risk elasticity' of less than 0, i.e. the busier the road the safer it is (relatively speaking), i.e. marginal costs are lower than average costs.
The UNITE approach implies that the entry of a new vehicle, in itself a new risk factor, on the road could be subsidised, as it makes other users behave more carefully.
Again, both approaches have their pros and cons.

Regarding the average cost approach, it is clear that this is only a proxy for the real marginal cost to society of an extra vehicle.

Regarding the marginal cost approach as applied in UNITE, one could argue that the safer traffic induced by the extra vehicles comes at a price. Extra traffic will:

- force motorists to drive slower and take more care;
- force pedestrians not to cross the street (barrier effect) or wait longer at traffic lights;
- force authorities to introduce extra safety measures such as traffic lights, zebra crossings, a ban on cyclists and pedestrians using the infrastructure, et cetera.

The UNITE authors classify such measures under the heading of ‘risk avoiding behaviour’, on which item no quantitative information yet exists. Consequently, this aspect is not quantified by UNITE. One could therefore argue that this short-term marginal cost approach is not of much use as long as the risk avoiding behaviour aspect is not quantified too.

Again, there is a choice to be made as to whether the strictly short-term marginal cost approach, limited to accidents only and omitting the risk avoiding behaviour, is the way to go.

6.5 Climate change: choices on reduction targets and mechanisms

We have seen that most studies, except TRENEN/ExternE, base their valuation of CO_2-emissions on the marginal prevention costs of achieving a certain future CO_2-reduction target. Our analysis also shows that if reduction targets do not differ too radically, neither do the calculated marginal prevention costs.

In other words, the valuation of CO_2-emissions depends primarily on normative choices regarding emission reduction targets and permitted abatement mechanisms.

This also poses a clear challenge to policy makers: to devise a climate change policy that is transparent with respect to its objectives, use of flexible mechanisms and acceptable costs.

Finally, an important – and quite straightforward – factor that explains a substantial part of the remaining inter-study differences is the fact that different studies use different risk rates, emission factors, transport statistics and so on. These 'statistical' differences lead to a recommendation to seek continued improvement of technical and statistical baseline data.

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