CE
Solutions for
environment,
economy and
technology

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

The price of transport

Overview of the social costs of transport

Delft, December 2004

Authors: J.P.L. (Joost) Vermeulen (CE)
B.H. (Bart) Boon (CE)
H.P. (Huib) van Essen (CE)
L.C. (Eelco) den Boer (CE)
J.M.W. (Jos) Dings (CE)
F.R. (Frank) Bruinsma (VU)
M.J. (Mark) Koetse (VU)

vrije Universiteit amsterdam

Publication Data

Bibliographical data:
J.P.L. (Joost) Vermeulen, B.H. (Bart) Boon, H.P. (Huib) van Essen, L.C. (Eelco) den Boer, J.M.W. (Jos) Dings, F.R. (Frank) Bruinsma, M.J. (Mark) Koetse
The price of transport - Overview of the social costs of transport
Delft, CE, 2004

Keywords: Traffic / Transport / Costs / Social factors / Infrastructure / Safety / Emissions / Noise nuisance / Land take / Congestion / Taxes / Subsidies

Publication number: 04.4850.40

CE-publications are available from www.ce.nl

Commissioned by: Dutch Ministry of Transport, Public Works and Water Management (Directorate for Passenger Transport)

Translation to English by Mr Nigel Harle, funded by the European Conference of Ministers of Transport (ECMT) and the Dutch Ministry of Transport, Public Works and Water Management (Directorate for Corporate Management and Strategies).

Further information on this study can be obtained from the contact person Joost Vermeulen or Huib van Essen.

CE

Solutions for environment, economy and technology

CE is an independent research and consultancy organisation specialised in developing structural and innovative solutions to environmental problems. CE's solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

CE Transform

Visions for sustainable development

The business unit CE Transform provides advice and support to business and government in implementing changes towards sustainable development.

For the latest information on CE check out our website: www.ce.nl.

This report is printed on 100% recycled paper.

Contents

Summary

Background
The Dutch Ministry of Transport, Public Works and Water Management is currently preparing a key policy paper on transport and mobility issues and in this context the ministry's Directorate for Passenger Transport commissioned CE to review the social costs of the principal modes of transportation used in the Netherlands today.

Among the principal elements of these costs are those of infrastructure maintenance and operation. Calculation of these costs and their allocation across transport modes has been the subject of an Interdepartmental Policy Study with the working title 'Charging freight transport for infrastructure use'. This IPS study was carried out in parallel to the present study, allowing us to incorporate the results here.

Besides the costs of infrastructure maintenance and operation, there is a wider array of external costs which - for reasons stemming from welfare-theoretical and/or 'fairness' principles - deserve to be passed on in the pricing of transport and mobility.

In 1999 our institute carried out a similar, extensive study of the external costs and infrastructure costs associated with passenger and freight transport entitled 'Efficient prices for transport' [CE, 1999]. The present report, which can be seen as an update of the 1999 report, has been prepared in collaboration with the Free University of Amsterdam.

Aim of this study
The main aim of this study is to provide insight into the social costs of the various modes of transport in use in the Netherlands. To this end we have established:
- The specific cost items to be included.
- The respective magnitude of these costs.
- The share of the costs borne by the transport sector itself, via taxes and charges.
- The extent to which existing payment structures are keyed to cost drivers[1].

The study addresses all the main categories of road and rail transport (both passenger and freight) and inland shipping (freight only).

The results of this study will provide policy-makers with a useful tool for assessing how these costs might best be passed on to the various user categories. The methodology for cost allocation will be one of the factors determining the structure and level of any price incentives established.

---

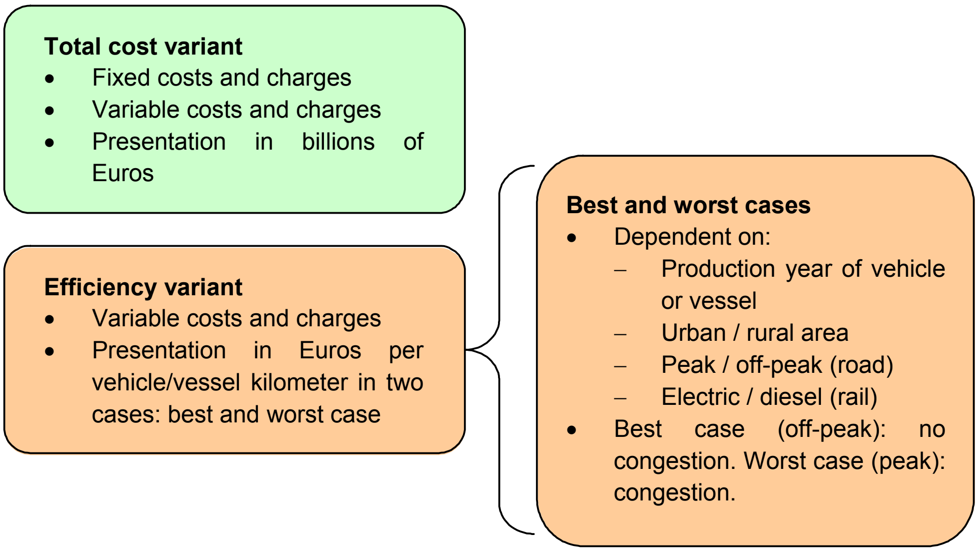
[1] Shedding light on whether current charging structures create an incentive for transport behaviour desirable from the perspective of optimum social welfare.

Two calculation methods

In this study we have inventoried the social costs of transport using two variant methods, rooted in two alternative principles for allocating costs to the parties involved (shown schematically in figure 1):

1. The first approach proceeds from the ‘fairness’ principle, taking as its point of departure that every mode of transport should be confronted with the sum total of social costs to which it gives rise: the total cost variant. This means that both variable and fixed costs are allocated to users.
2. The second approach employs pricing policy as a means to optimise social welfare, by charging all variable costs to users: the efficiency variant. Because the precise level of these costs depends strongly on a variety of real-world parameters of the transport mode in question, in this variant we distinguish a best and a worst case, defining the former (latter) as that in which there is least (greatest) difference between variable costs and the variable charges actually paid.

figure 1 Two calculation methods: total cost variant and efficiency variant, with best and worst cases for the latter



Total cost variant
- Fixed costs and charges
- Variable costs and charges
- Presentation in billions of Euros

Efficiency variant
- Variable costs and charges
- Presentation in Euros per vehicle/vessel kilometer in two cases: best and worst case

Best and worst cases
- Dependent on:
  - Production year of vehicle or vessel
  - Urban / rural area
  - Peak / off-peak (road)
  - Electric / diesel (rail)
- Best case (off-peak): no congestion. Worst case (peak): congestion.

The difference between these two variants lies mainly in the cost items for infrastructure renewal and the fixed costs of its maintenance and operation.

For each of the transport modes investigated, the best and worst cases are summarised in table 1 and table 2. In each case the following cost factors were taken into account, as appropriate:

- *Production year of vehicle or vessel*: for a given fuel type, old vehicles/vessels have significantly higher per-kilometre emissions of air pollutants than new (particularly in the case of road), the result of progressively more stringent European emission standards.
- *Urban/rural*: in the urban environment, the kilometre-indexed external costs of air pollutant emissions, noise and accidents are higher than in rural areas. For health damage and noise nuisance, this is because a greater number of

people are exposed. In the specific case of road transport, accidents are relatively more frequent (per km) in urban areas.

- *Peak/off-peak* (road only): in peak traffic, vehicle hours are lost in traffic jams, while in off-peak periods we have assumed zero congestion. This distinction has only been made for road transport, i.e. we take there to be *no* congestion on the rail network or inland waterways.
- *Electric/diesel* (rail only): the air pollutant emission profile of diesel locomotives is very different from that of their electrically driven counterparts. As there is also wide variation within this latter category, related mainly to train weight (and thus energy use), we have here calculated with two extremes.
- *Large/small vessel* (shipping only): large vessels burn more fuel per kilometre than small vessels and emissions are therefore higher. Energy consumption also depends on load factor, river flow and direction, vessel speed and engine age.

table 1 Definitions of best and worst cases for passenger transport and light goods vehicles (LGV, i.e. vans)

Vehicle type	Best case	Worst case
Car, petrol	Rural, off-peak, 2002 model	Urban, peak, 1993 model
Car, diesel	Rural, off-peak, 2002 model	Urban, peak, 1993 model
Car, LPG	Rural, off-peak, 2002 model	Urban, peak, 1993 model
Bus (town/district)	Rural, off-peak, 2002 model	Urban, off-peak, 1993 model
Rail	Local service (*Sprinter*), 250 seats, rural	Intercity (*Regiorunner*), 1200 seats, urban
	Local service (diesel, *DM 90*), 125 seats, rural	
LGV	Rural, off-peak, 2002 model	Urban, peak, 1993 model

table 2 Definitions of best and worst cases for freight transport (HGV = heavy goods vehicle)

Vehicle type	Best case	Worst case
HGV, 3.5-12 tonne	Rural, off-peak, 2002 model	Urban, peak, 1993 model
HGV >12 tonne, single-unit truck	Rural, off-peak, 2002 model	Urban, peak, 1993 model
HGV >12 tonne, tractor-(semi)trailer combination	Rural, off-peak, 2002 model	Urban, peak, 1993 model
Rail	Non-bulk service, electric, empty, 80 km/h	Bulk service, diesel, 1,700 tonne load, 80 km/h
Inland shipping	‘Spits’ barge (*M1*, 350 tonne, smallest inland vessel), empty, downstream, 15 km/h, year 2000 engine	Quadruple pushed barge unit (*BII-4*, 8,000 tonne) fully laden, upstream, 10 km/h, 1990 engine

Scope

Reference year

All the data used for our quantitative analysis are for the year 2002, with two exceptions:

1 The costs of road infrastructure maintenance and operation, which are based on the government's 'Basic Maintenance' programme, as described in [DWW, 2002].

2 The costs of rail infrastructure maintenance and operation, which are based on the 'standard cost' approach for keeping the infrastructure at its present level of upkeep; we have used the 'standard costs' for 2004, converting these to 2002 prices.

In the case of both road and rail, then, we have used a form of 'standard costs', i.e. the estimated costs of an optimum maintenance regime. In both cases these figures exceed actual expenditure in 2002: by about 8% for road and about 20% for rail[2].

Cost elements and charges considered

Our analysis encompasses the following cost items:

- The costs of infrastructure building.
- The costs of infrastructure maintenance and operation (M/O) and infrastructure renewal, in the former case distinguishing variable and fixed costs.
- The costs of land take, distinguishing direct and indirect land take costs and parking costs.
- The external costs of traffic accidents.
- The external costs of climate emissions (CO_2).
- The external costs of other air pollutant emissions (NO_X, PM_{10}, HC, SO_2).
- The external costs of noise nuisance.
- The external costs of road traffic congestion.

Our analysis includes the following taxes and charges[3]:

- Vehicle Circulation Tax (VCT, for all road vehicles).
- Passenger Car and Motorcycle Purchase Tax (VPT).
- The 'Eurovignette'.
- Parking dues.
- Charge for rail infrastructure use.
- Harbour and fairway dues[4].
- Fuel excise duty.
- Regulatory Energy Charge (REC).

We consider the following subsidies and exemptions:

- Public transport operating subsidies.
- Special VAT rates.

---

[2] In the aforementioned IPS study 'Charging freight transport for infrastructure use', the standard costs for road and railway maintenance were scaled down to actual 2002 expenditures. The calculations in the present report proceed from the standard costs, however, with no scaling down.

[3] Value Added Tax (VAT) has been ignored.

[4] Subsequently referred to simply as 'harbour dues', these being by far the largest item.

In this study we do *not* consider the social costs of:

- Visual intrusion.
- Habitat fragmentation.
- Barrier effects.
- Scarcity costs (rail only).

There is presently too little (methodological) information available for these four items to be quantified and assigned an appropriate value.

Vehicle categories

The study covers the following categories of passenger transport vehicle:

- Passenger car, petrol.
- Passenger car, diesel.
- Passenger car, LPG.
- Motorcycle.
- Moped / scooter[5].
- Local / district bus.
- Long-distance coach.
- Train, electric.
- Train, diesel.

The study covers the following categories of freight transport vehicle:

- Heavy goods vehicle (HGV), 3.5-12 tonne.
- HGV >12 tonne, single-unit truck.
- HGV >12 tonne, tractor-trailer or -semitrailer combination (i.e. rigid or articulated).
- Inland shipping vessel.
- Train, electric.
- Train, diesel.

Vans, or light goods vehicles (LGV), have been included as a separate category, as they are used for both freight and passenger transport:

- LGV, diesel.

Differences from the 1999 CE study

Additions to the 1999 CE study

The 1999 study has been augmented in two important ways, to include:

- The costs of land take.
- The costs of parking and revenue from parking dues.

---

[5] Motorcycles and mopeds/scooters are included in the 'total cost' variant only. As these vehicle categories were added in a later phase of the study, there was no time to define best and worst cases for inclusion in calculations.

Methodological improvements

Relative to the 1999 study the following methodological improvements have been made:

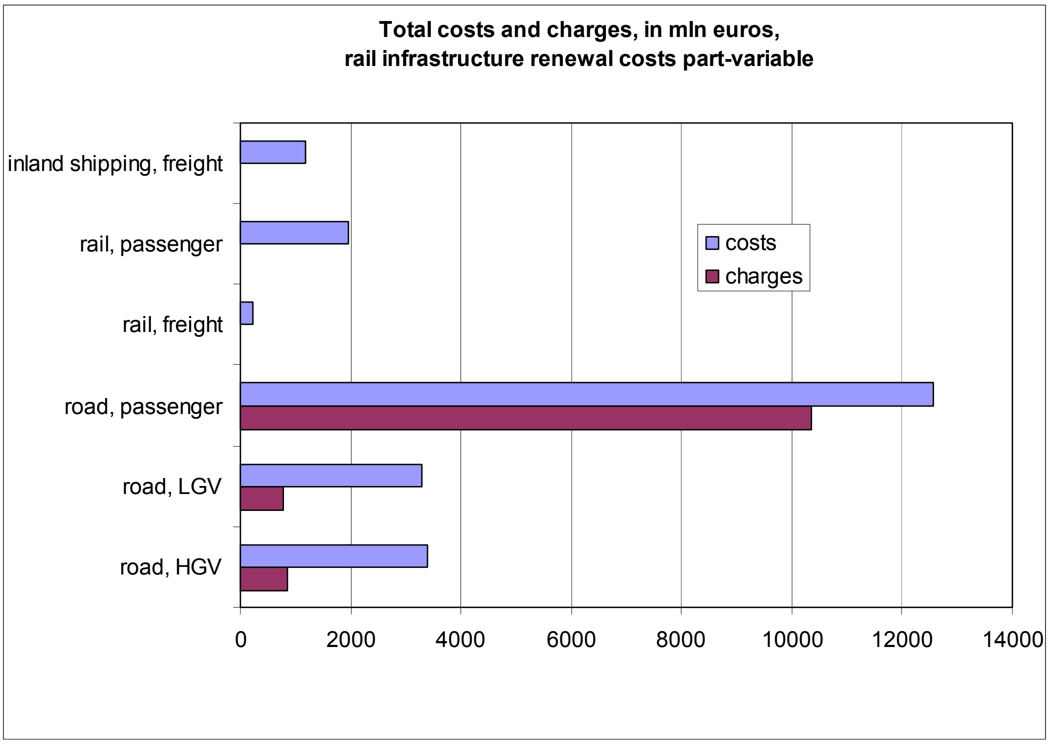
- *Allocation of infrastructure costs* (construction, but particularly M/O) has been handled differently. We now follow the method used in the aforementioned IPS study. For the cost of rail infrastructure renewal, we also present a second variant in which this item is taken as 100% fixed (in the IPS method these costs are assumed part-variable).
- *Congestion costs*, although included in the 1999 study, have also been treated differently. We now distinguish, in the *efficiency variant*, a worst and a best case (with and without congestion). After all, it is more efficient, for society as a whole, to allocate the external costs of congestion (always variable) to the party causing them. In the *total cost variant* we have ignored congestion costs, because this variant proceeds from the 'fairness' principle and *confronts every mode of transport with the sum total of the social costs to which it gives rise.* The social costs of congestion caused by road users are also borne by this group as a whole, however.
- Although the reference year (2002) remains the same as in the 1999 study, we were now in a position to use *actual costs* and empirical data rather than estimates. For example, we have used government expenditure reports rather than budgets as well as new accident statistics, computed new cost figures for noise nuisance, tracked down the latest traffic volume statistics for the various vehicle categories and employed more up-to-date emission data.

Results and conclusions, total cost variant

General

1 In 2002 the total social costs of domestic transportation in the Netherlands, *excluding* aviation, ocean shipping, recreational shipping, high-speed rail, cycling and walking, amounted to approx. € 22.5 billion. Over half this figure (about 55%) is due to passenger transport by road, followed by HGV (i.e. road freight) and LGV (both approx. 15%), rail passenger transport (approx. 9%), inland shipping (5%) and rail freight (approx. 1%). Note that *these figures do not cover all social costs*, in particular those associated with the habitat fragmentation, barrier effects and visual intrusion due to transport infrastructure (figure 2).

figure 2 Total social costs and user charges, principal categories of passenger and freight transport (€ mln/year)



2 There is not a single category of transport, road, rail or shipping, that is fully charged for all the social costs to which it gives rise. The only potential exception are petrol-driven passenger cars, for which we calculate that the estimated social costs are approximately covered by the user charges paid. Note again, however, that not all social costs were included in the quantitative analysis (see conclusion 1). Note also that the share of petrol-driven vehicles in the passenger car fleet has been declining in recent years and that of diesel vehicles increasing (figure 3 to figure 8).

3 For all the transport modes considered, fixed social costs exceed fixed user charges, with the possible exception of petrol and diesel passenger cars. This does not necessarily mean the fixed charges for these vehicle categories are presently too high, as the social costs of fragmentation, barrier effects and visual intrusion have not yet been factored in. Only after realistic figures have been worked out for these items can it be calculated whether or not current fixed charges are too high and should be reduced for considerations of welfare optimisation (figure 3 to figure 8).

figure 3 Total social costs and user charges, passenger road transport (€ mln/year)[6]

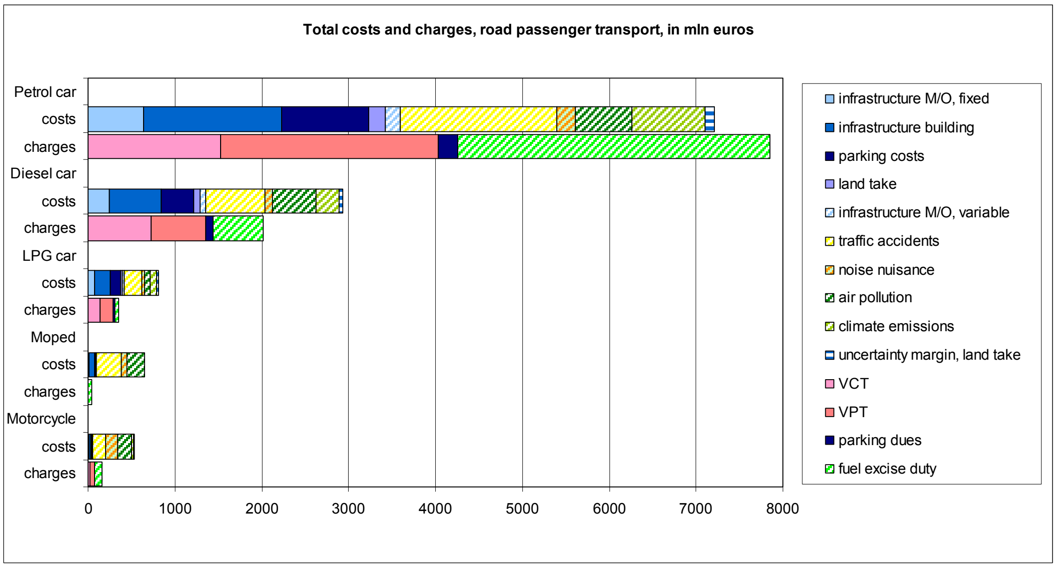
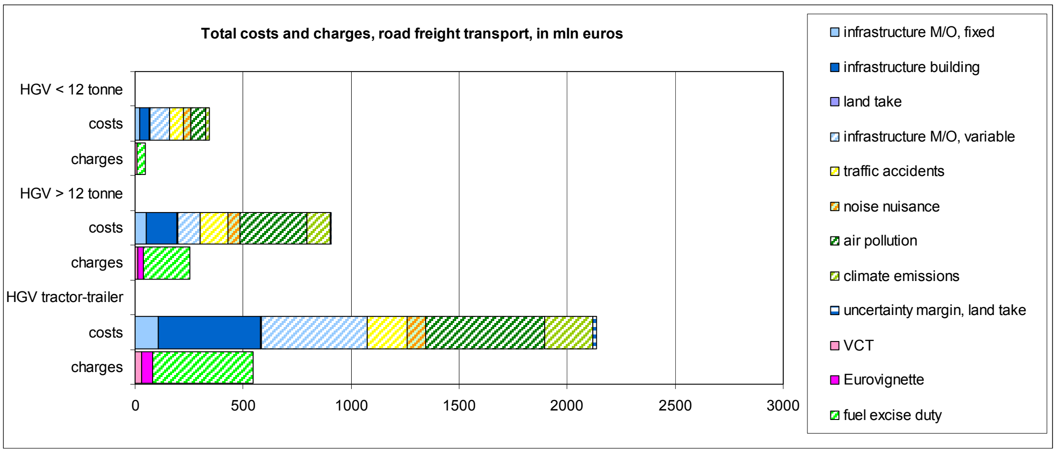


figure 4 Total social costs and user charges, three categories of HGV (€ mln/year)



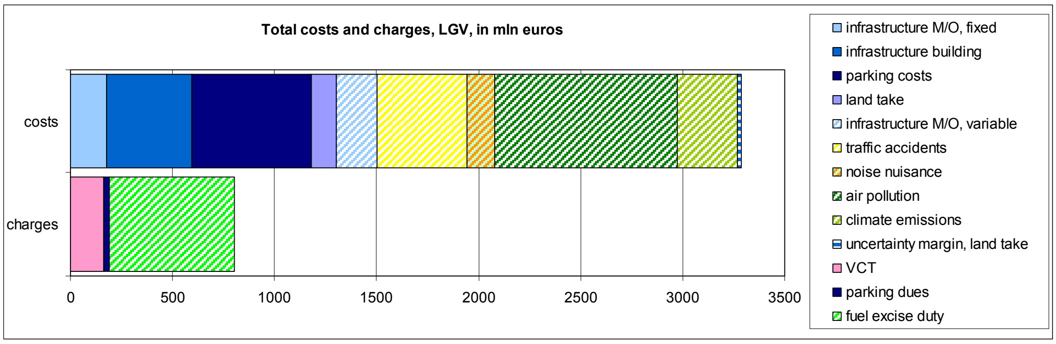
Road transport

4 In 2002 the total social costs attributable to transportation by LGV (vans) approximately equalled those of domestic road freight carriage by HGV (trucks); given the steady growth of the Dutch LGV fleet, they are now (2004) probably greater. In transport and environmental policy circles, however, there appears to be relatively little interest in LGVs (figure 2 and figure 5).

---

[6] In all the figures, solid colours indicate *fixed* costs or charges, hatched colours *variable* costs or charges.

figure 5 Total social costs and user charges, LGV (€ mln/year)



Rail transport

5 With rail transport, the fixed costs of infrastructure (M/O and renewal) predominate. In the case of passenger rail these account for about 75% of total social costs (not shown here; see main report), in the case of freight for over half these costs. Taking the costs of infrastructure renewal as fixed (current Transport ministry practice) or (part-)variable (IPS variant; see above) does not significantly affect this picture (figure 6 and figure 7).

figure 6 Total social costs and user charges, rail freight transport (€ mln/year; costs of infrastructure renewal assumed part-variable)

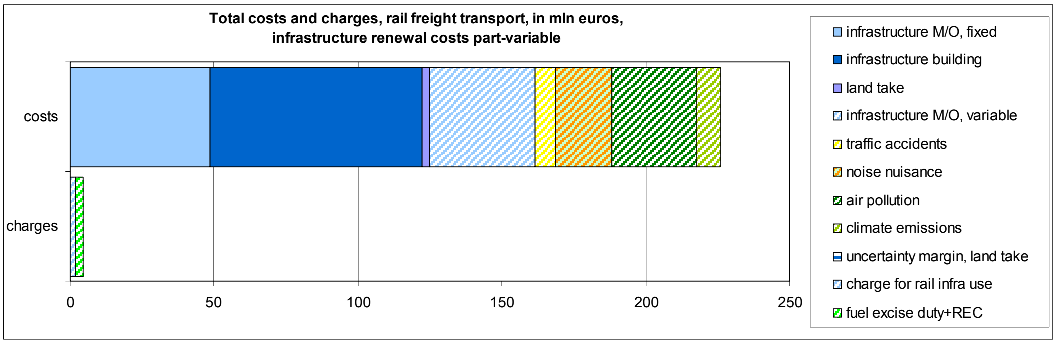
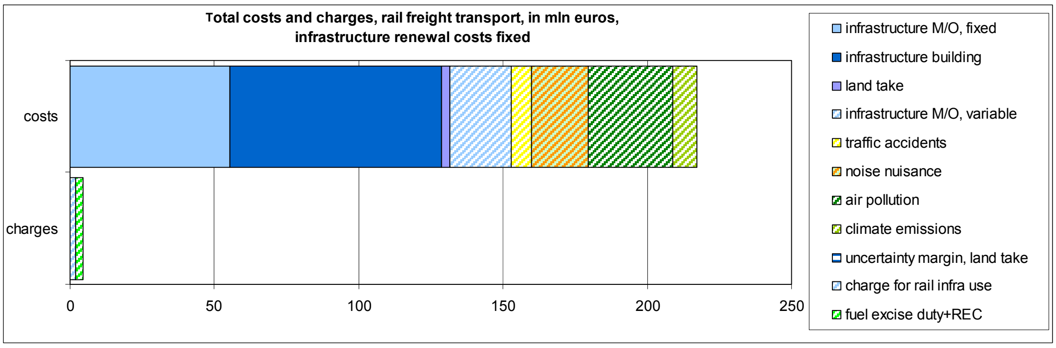


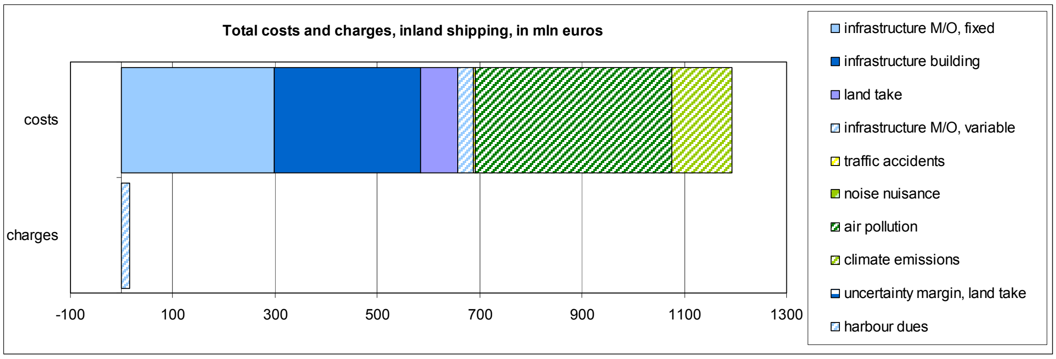
figure 7 Total social costs and user charges, rail freight transport (€ mln/year; costs of infrastructure renewal assumed fixed)



Inland shipping

6 For inland shipping, the fixed costs of infrastructure (M/O and renewal) account for about 50% of total social costs. Compared with rail freight transport, though, variable M/O costs are proportionally lower, consisting almost entirely of the costs of pollutant emissions (climate and other) (figure 8).

figure 8 Total social costs and user charges, inland shipping (€ mln/year)



Results and conclusions, efficiency variant

General

7 For all transport modes considered, with the exception of 'best case' petrol-driven passenger cars, current variable charges are lower than variable social costs. This means that for all these categories of vehicle and vessel, full allocation of variable social costs will lead to an increase in variable costs.

8 A comparison of the results of this study with those of earlier European studies on these issues shows good agreement for all vehicle categories, for both best and worst cases (as detailed in annex L).

Road transport

9 For virtually no category of road vehicle do variable charges cover variable social costs, even if congestion costs are assumed to be zero (these exceeding all other items by far; see, for example figure 10 and figure 12).

10 In the case of passenger cars, besides congestion costs the main variable costs are those associated with accidents and air pollution. However, in the best case (new vehicle, rural) the latter cost item is already significantly lower than in the worst case (10 years old, urban), an improvement due mainly to the introduction of progressively tighter EU standards for NO_X and fine particle emissions over the intervening 10 years. There is far less difference with respect to CO_2 emissions, for which no European emission standards are (yet) in force (figure 9 and figure 10).

11 Petrol-driven cars are the only means of transport for which variable charges are not definitely lower than variable costs. If the costs of congestion are included, however, variable charges come to cover only about 12% of variable costs. Ignoring congestion, even in the worst case (10 year-old petrol-driven car, urban environment) variable charges prove to cover only

just over half the variable costs. Thus, the conclusion that petrol passenger cars ‘pay their way’ in terms of social costs is not generally valid, applying only to certain categories of vehicle in an uncongested situation (figure 9 and figure 10).

figure 9 Variable social costs and user charges, passenger car transport, best case (€ct/vehicle kilometre)

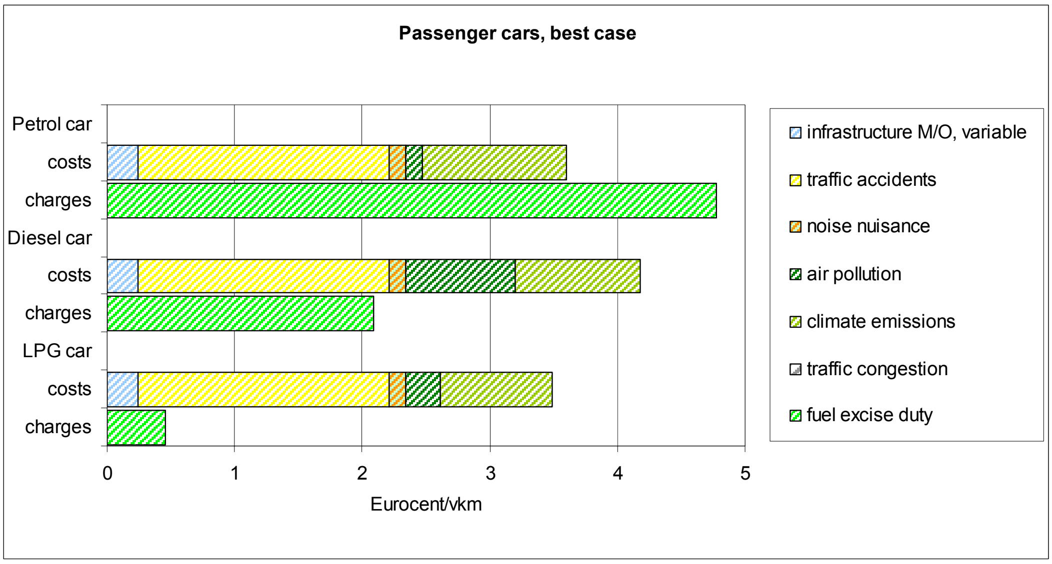
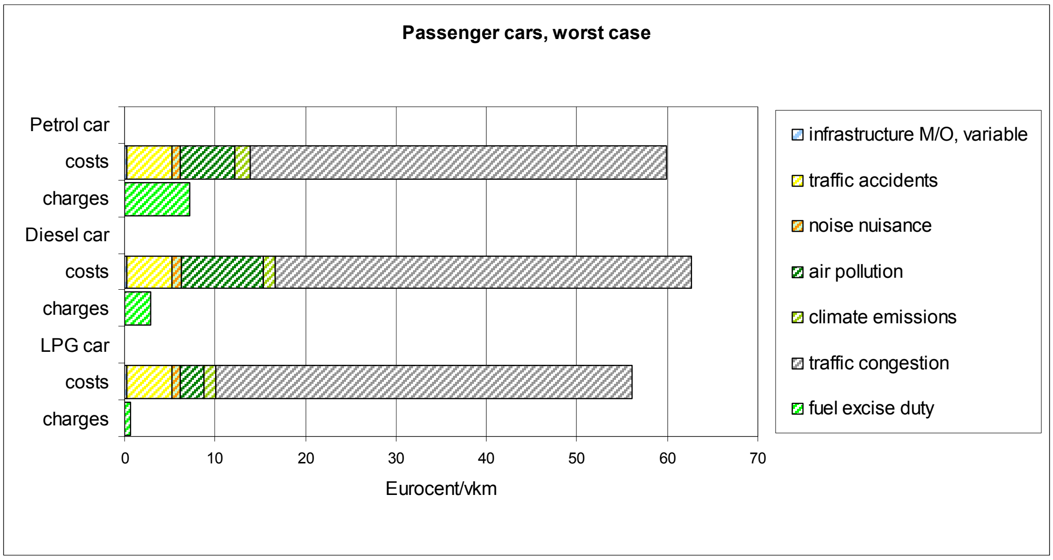


figure 10 Variable social costs and user charges, passenger car transport, worst case (€ct/vehicle kilometre)



12 In the case of diesel and LPG passenger cars and diesel LGV, variable charges (currently, only fuel excise duty) cover between 50% (diesel car, best case) and 1% (LPG car, worst case) of variable costs. Due allocation of these latter costs will therefore bring user charges for diesel and LPG vehicles more in line with those for petrol vehicles.

13 In the present situation, variable charges for passenger cars are not structurally, directly related to the cost drivers in question. In particular, the influence of such factors as vehicle emission class, safety and noise level, as well as journey time and location - all of which are major factors determining overall variable costs - is not currently reflected in the cost structure at all (figure 9 and figure 10).

14 For the various categories of HGV the situation is fairly similar, with variable charges covering about half to a quarter of variable costs. Coverage is greatest for tractor-(semi)trailer combinations, as these make most use of motorways, where the costs of accidents, air emissions and noise are lowest, in relative terms, and pay the most excise duty per kilometre driven (figure 11 and figure 12).

figure 11 Variable social costs and user charges, HGV, best case (€ct/vehicle kilometre)

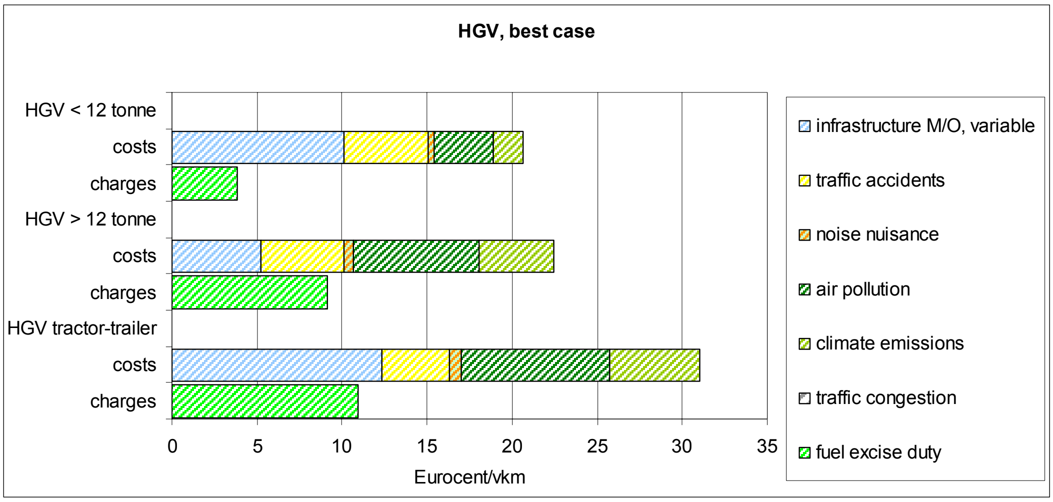
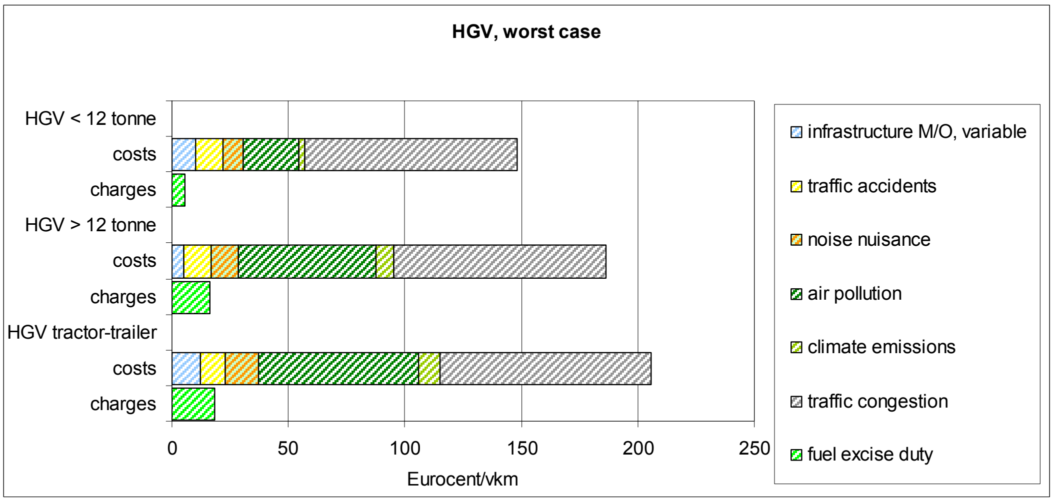


figure 12 Variable social costs and user charges, HGV, worst case (€ct/vehicle kilometre)



Rail transport

15 With rail transport, both passenger and freight, variable costs can vary enormously, depending on aggregate train weight, type of traction and urban vs. rural. In all cases, though, variable charges (and particularly those paid for infrastructure use) are only a mere fraction of variable costs. Increasing both the capacity and utilisation of the existing rail grid provides a means of achieving greater coverage of variable costs via the infrastructure charge at only a fairly minor increase in cost per passenger or tonne kilometre (figure 13 to figure 18).

16 In the case of passenger rail, the variable costs of infrastructure maintenance and operation account for 60-65% of total variable costs, if renewal costs are assumed part-variable (see figure 13). If the costs of infrastructure renewal are taken entirely fixed, the figure still exceeds 50% (figure 14). In the case of rail freight, the variable costs of maintenance and operation still figure prominently, but here air pollution (due to the relatively high share of diesel traction) and noise nuisance also both contribute significantly, particularly in the worst case (figure 15 to figure 18).

figure 13 Variable social costs and user charges, rail passenger transport (electric), best and worst case (€ct/train kilometre; costs of infrastructure renewal assumed part-variable)

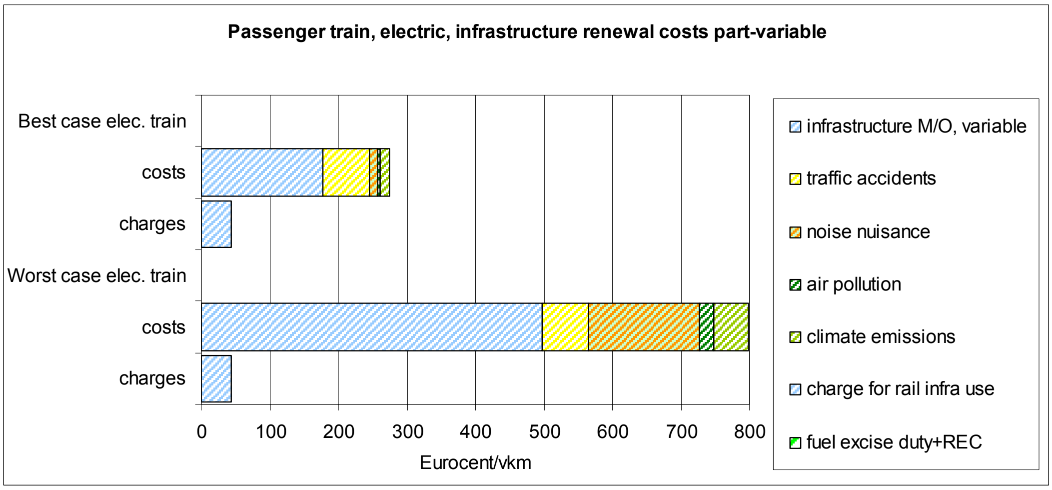


figure 14 Variable social costs and user charges, rail passenger transport (electric), best and worst case (€ct/train kilometre; costs of infrastructure renewal assumed fixed)

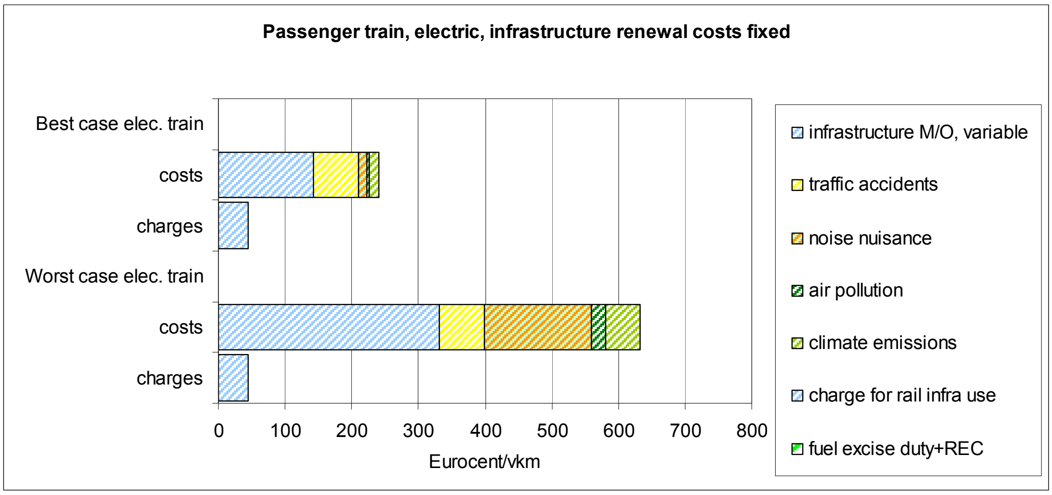


figure 15 Variable social costs and user charges, rail freight transport, best case (€ct/train kilometre; costs of infrastructure renewal assumed part-variable)

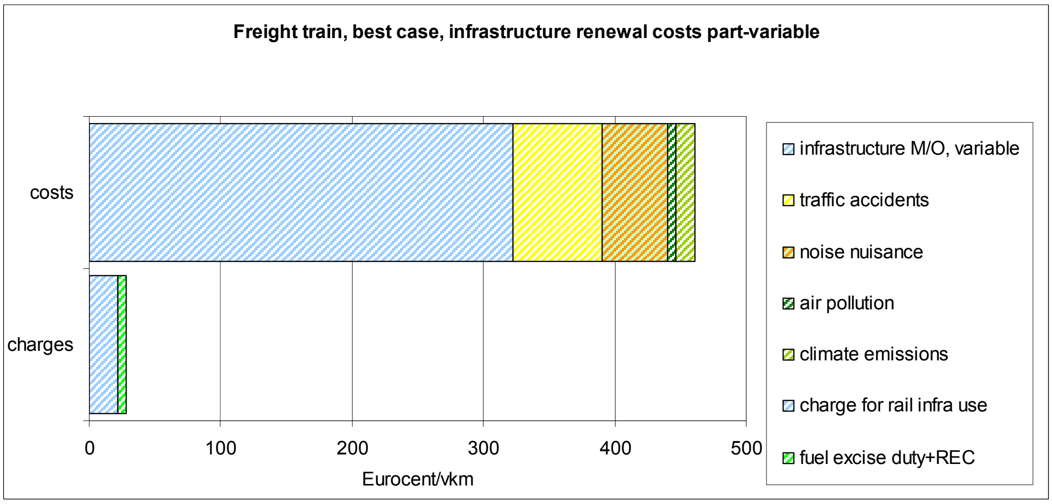


figure 16 Variable social costs and user charges, rail freight transport, best case (€ct/train kilometre; costs of infrastructure renewal assumed fixed)

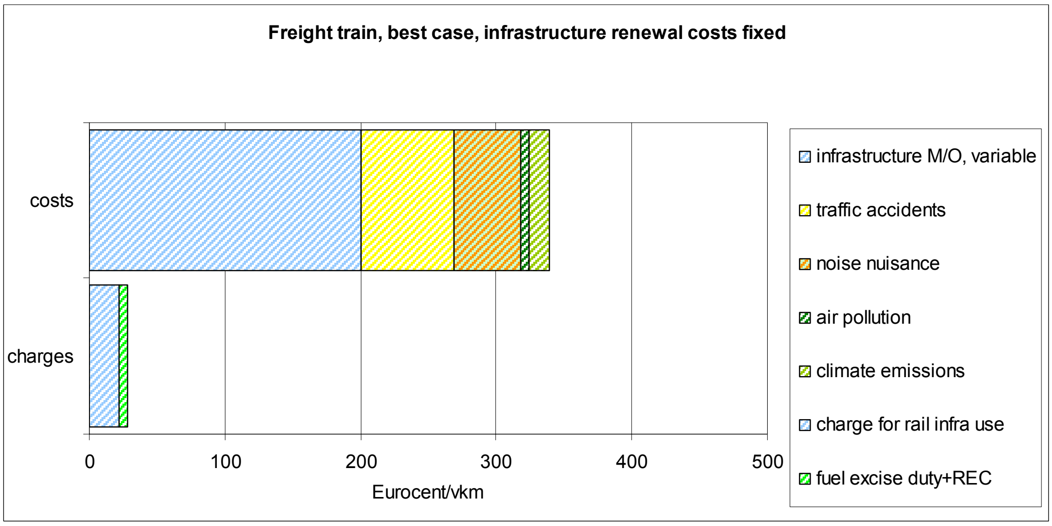


figure 17 Variable social costs and user charges, rail freight transport, worst case (€ct/train kilometre; costs of infrastructure renewal assumed part-variable)

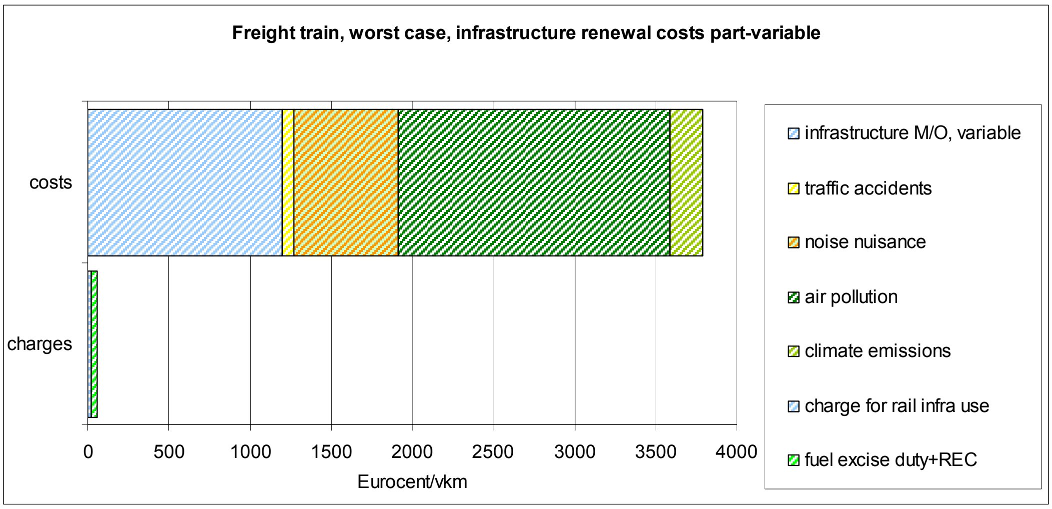
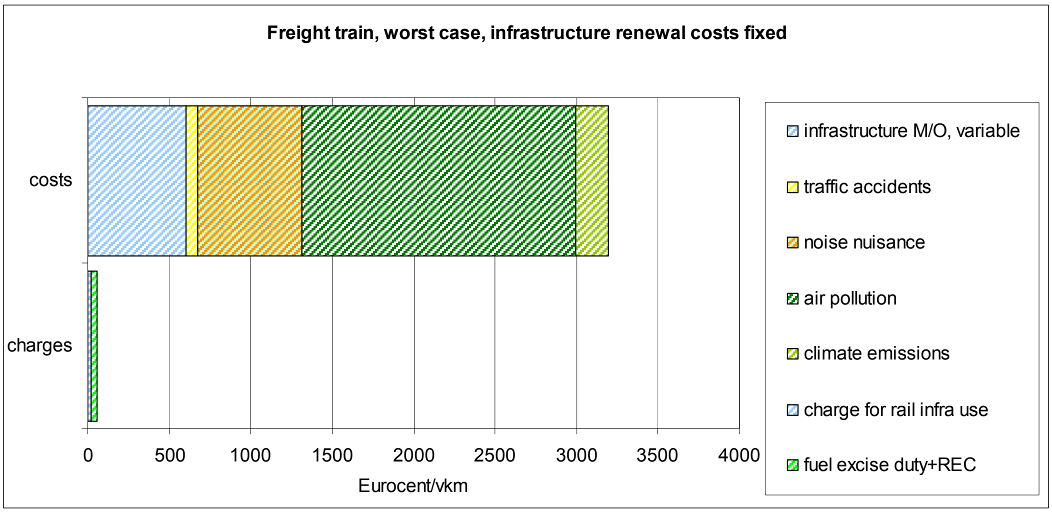


figure 18 Variable social costs and user charges, rail freight transport, worst case (€ct/train kilometre; costs of rail infrastructure renewal assumed fixed)



Inland shipping

17 For inland shipping the picture is broadly similar to that for rail freight, although here there are virtually no variable charges and in the worst case these are lacking entirely (figure 19 and figure 20).

figure 19 Variable social costs and user charges, inland shipping, best case (€ ct/vessel kilometre)

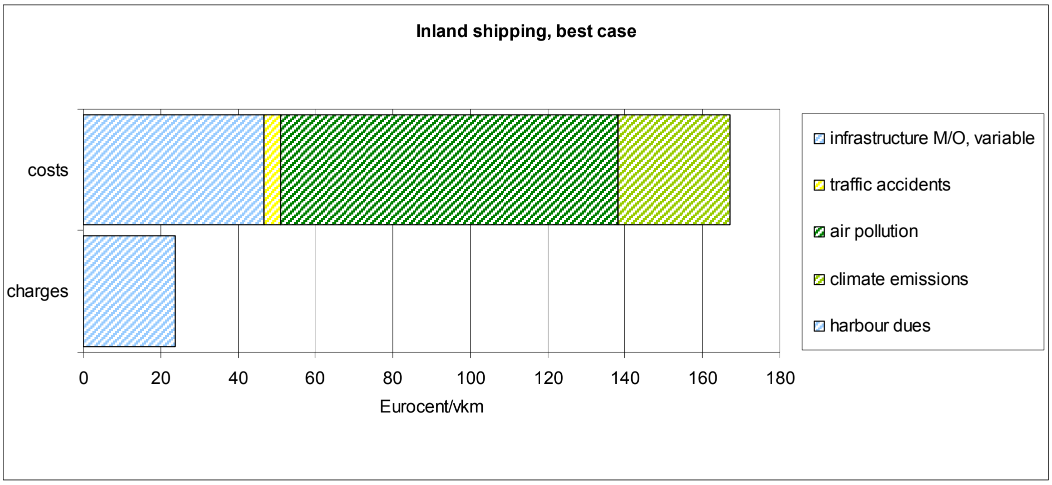
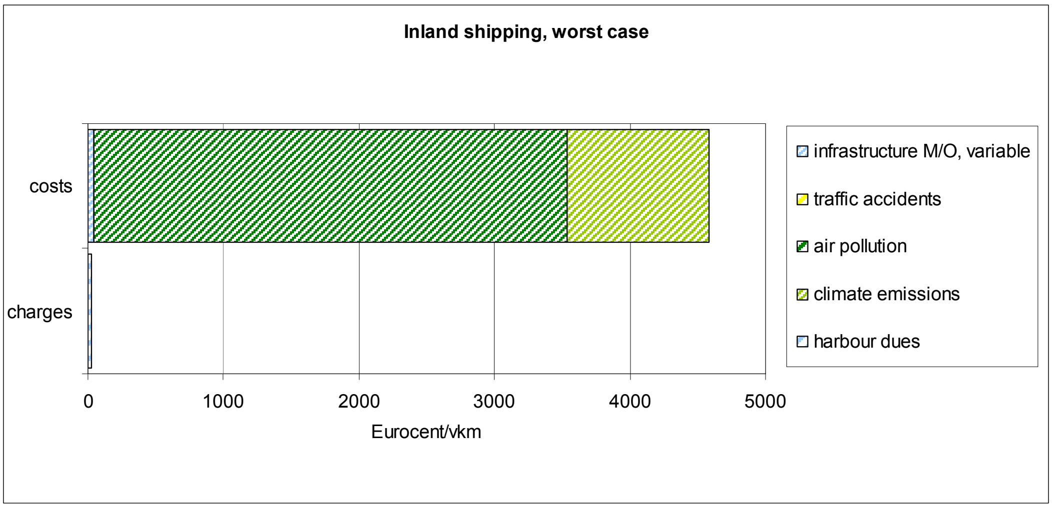


figure 20 Variable social costs and user charges, inland shipping, worst case (€ ct/vessel kilometre)



1 Introduction

1.1 Background

The Dutch Ministry of Transport, Public Works and Water Management is currently preparing a key policy paper on transport and mobility issues and in this context the ministry's Directorate for Passenger Transport commissioned CE to review the social costs of the principal modes of transportation used in the Netherlands today.

Among the main components of these costs are those of infrastructure maintenance and operation. Calculation of these costs and their allocation across transport modes has been the subject of an Interdepartmental Policy Study with the working title 'Charging freight transport for infrastructure use'. This IPS study was carried out in parallel to the present study, allowing us to incorporate the results here.

Besides the costs of infrastructure maintenance and operation, there is a wider array of external costs which - for reasons stemming from welfare-theoretical and/or 'fairness' principles - deserve to be passed on in the pricing of transport and mobility. In 1999 our institute brought out a study entitled 'Efficient prices for transport' [CE, 1999], which examined the entire range of external costs. The present study, undertaken in close collaboration with the Free University of Amsterdam, can be seen as an update.

1.2 Goal of the study

The main goal of this study is to provide insight into the social costs of the various modes of transport in use in the Netherlands. To this end we have established:
- The specific costs to be included.
- The respective magnitude of these costs.
- The proportion of costs recovered from the transport sector via taxes and charges.
- The extent to which existing payment structures are keyed to cost drivers[7].

The results of this study will provide policy-makers with a useful tool for assessing how these costs might best be passed on to the various user categories, given current convictions that these are the parties that should largely be paying, whether for considerations of welfare optimisation, i.e. economic efficiency, or fairness, or indeed both. In this context it is above all the funding of (the variable costs of) transport infrastructure that policy-makers are interested in.

---

[7] Shedding light on whether current charging structures create an incentive for transport behaviour desirable from the perspective of optimum social welfare.

1.3 Relationship with pricing policy

When inventorying the external costs of transport it is important to give careful consideration to how these costs are to be allocated across the various modes of transport. More precisely, choices must be made as to which costs are to be deemed variable, i.e. usage-dependent, and which fixed, i.e. independent thereof. This difference is particularly relevant when it comes to the costs of infrastructure building and the fixed costs of infrastructure maintenance and operation.

Ultimately, how the respective costs are allocated to transport modes will also determine the structure and magnitude of the price incentives at the heart of any pricing policy. In this context, pricing policy can be geared to several different objectives:

1 The first objective is rooted in the 'fairness' principle and takes as its point of departure that *every mode of transport should be confronted with the sum total of social costs to which it gives rise (total cost variant). In this case both the variable (marginal) costs and the fixed costs are allocated to users*, the latter comprising the costs of construction, land take, maintenance and operation.

2 The second possible aim of pricing policy is *to optimise social welfare (efficiency variant).*This can be achieved by charging all *variable* costs to users, i.e. part of the costs of infrastructure maintenance and operation, as well as congestion costs, accident costs, environmental costs and noise costs. In this case, then, the fixed costs are not passed on to users.

Finally, pricing policy can be used simply as a means of funding all the costs of transport infrastructure (construction, land take, maintenance and operation), for example. In contrast to the first two objectives, this says nothing about *how* these costs are to be passed on. It can therefore be combined with either of the first two perspectives.

By definition, the revenues generated by a pricing policy geared to confronting users with the sum total of social costs (on the first principle) will be more than sufficient to cover the aggregate costs of infrastructure. However, the revenues accruing from charges set with a view to optimising social welfare (on the second principle) may well also be sufficient to cover the full costs of infrastructure construction, land take, maintenance and operation. Such will be the case if the costs of the external effects across all transport modes for which users are charged are equal to, or exceed, the costs of construction and land take and the fixed costs of maintenance and operation[8].

In inventorying and allocating these costs, in this study we have adopted the first two of the principles above. How they have been elaborated is detailed in section 1.6, below. First, though, we set out the general analytical procedure adopted and the precise scope of the study (section 1.4) and summarise the main changes introduced with respect to the aforementioned studies from 1999 and 2003 (section 1.5).

---

[8] Note that the variable costs of maintenance and operation are already incorporated in 'optimally efficient' charges.

1.4 Scope and procedure

Reference year
In consultation with the project principal we have taken 2002 as the reference year for our quantitative analysis. At the time of writing, most of the statistics for that year were available and judged to be relatively solid and reliable. There were several exceptions, however[9]:

1. The costs of road infrastructure maintenance and operation, which are based on the government's 'Basic Maintenance' (BM) programme, as described in [DWW, 2002].
2. The costs of rail infrastructure maintenance and operation, which are based on the 'standard cost' approach of keeping the infrastructure at the present level of upkeep, as adopted in a recent government scenario study. We have taken 'standard costs' for 2004 (at the 2002 price level).
3. The untaxed travel allowance, where we have based ourselves on the new arrangements that came into force on 1 January, 2004. As this study is concerned with exploring and designing future (pricing) policy, it is reasonable to proceed from standing regulations rather than past history.

With the exception of these three items, all costs derived from years other than 2002 have been corrected for inflation.

Vehicle categories
We have focused on the same categories of vehicle and vessel distinguished in the earlier study 'Efficiently priced?' [CE, 2003a,b], with the following exceptions:

- With respect to *rail* transport, the 'Betuwe' freight line and the high-speed passenger link have not been included in this study.
- *Aviation* has not been included either, because of project time constraints, the likely efforts that would be required to update and refine the data for this mode, and the sometimes heated debate that the issue of social costs inevitably generates. Although aviation is undoubtedly one of the sectors with a major mismatch between social costs and user charges, we have opted to invest in a deeper, higher-quality analysis of the other modes of transport.
- *Sea shipping* has also been ignored. This was also the case in earlier studies and to include it here now would involve an excessive amount of work, as in the case of aviation.

Given these exceptions, we can now detail the categories of vehicle and vessel considered in this study.

With respect to passenger transport:

- Passenger car, petrol.
- Passenger car, diesel.
- Passenger car, LPG.
- Motorcycle.

---

[9] The exceptions for the costs of infrastructure maintenance and operation are due to choices made in the aforementioned IPS study 'Charging freight transport for infrastructure use'. Note that basing calculations on 'standard costs' affords greater insight into the real-world costs of transportation than basing them on expenditures, the latter being governed by *political* decisions.

- Moped / scooter[10].
- Local / district bus.
- Long-distance coach.
- Train, electric.
- Train, diesel.

With respect to freight transport:
- Heavy goods vehicle (HGV), 3.5-12 tonne.
- HGV > 12 tonne, single-unit truck.
- HGV > 12 tonne, tractor-trailer or -semitrailer combination (i.e. rigid or articulated).
- Inland shipping vessel.
- Train, electric.
- Train, diesel.

Vans, or light goods vehicles (LGV), have been included as a separate category, as they are used for both freight and passenger transport:
- LGV, diesel.

For each of these vehicle categories, we report the costs associated with all travel and transport within the Netherlands by both domestic and foreign drivers and operators.

Cost elements and charges considered
Our analysis encompasses the following cost items:
- The costs of infrastructure building[11].
- The costs of infrastructure maintenance and operation, distinguishing between fixed and variable costs.
- The costs of land take, distinguishing between direct and indirect land take.
- The external costs of traffic accidents.
- The external costs of climate emissions (CO_2).
- The external costs of other air pollutant emissions (NO_X, PM_{10}, HC, SO_2).
- The external costs of noise nuisance.
- The external costs of congestion.

As in our earlier studies [CE, 1999] and [VU, 2002], for ‘construction costs’ we have taken the capital costs of the investments concerned, i.e. depreciation plus interest (on annuity basis). In the case of infrastructure maintenance and operation, we make no distinction between investments and operating costs, treating all these costs as current, i.e. with no depreciation or interest.

---

[10] Motorcycles and mopeds/scooters are included in the ‘total cost’ variant only. As these vehicle categories were only added in a later phase of the study, there was no time to define best and worst cases for inclusion in the analysis.

[11] In this study ‘fixed infrastructure costs’ are solely the costs of building new infrastructure, with the costs of infrastructure renewal being included under ‘maintenance and operation’, in line with the procedure adopted by the IPS taskforce.

Our analysis takes in the following taxes and charges:

- Vehicle Circulation Tax (VCT).
- Passenger Car and Motorcycle Purchase Tax (VPT).
- The 'Eurovignette'.
- Parking dues.
- Charge for rail infrastructure use.
- Harbour and fairway dues[12].
- Fuel excise duty.
- Regulatory Energy Charge (REC).

We include the following subsidies and exemptions:

- Public transport operating subsidies.
- Special VAT rates.

This study does *not* consider the social costs of:

- Visual intrusion.
- Habitat fragmentation.
- Barrier effects.
- Scarcity costs (rail only).

There is presently too little (methodological) information available for these cost items to be quantified and assigned an appropriate value.

1.5 Differences from the 1999 CE study

Below, we briefly summarise the main differences from the earlier CE study 'Efficient prices for transport', published in 1999.

Additions to the 1999 study

Compared with the 1999 study, there are two important additions:

- The costs of land take for transport infrastructure have now been included. Being independent of vehicle and vessel usage, we have taken these costs as fixed. In the case of new infrastructure in rural areas, it is presently unclear to what extent the costs of land purchase (i.e. land take) are officially recorded as 'construction costs'[13]. We therefore report the costs of rural land take separately, as to include them under construction costs would mean double-counting.
- Parking costs as well as revenues from parking tolls have now also been included. Because both are independent of traffic volumes, they have been taken as fixed.

---

[12] Subsequently referred to simply as 'harbour dues', these being by far the largest item.

[13] Netherlands Statistics (CBS), who compile the official statistics on the costs of infrastructure construction, were unable to tell us whether these also include the costs of land purchase.

Methodological improvements

Relative to the 1999 study the following methodological improvements have been introduced:

- *Allocation of infrastructure costs* (construction, but particularly maintenance and operation, M/O) has been handled differently. We now follow the method adopted in the aforementioned IPS study, which means that variable costs have in principle been allocated based on the cost driver in question and fixed costs on the basis of capacity utilisation.
- *Congestion costs*, although included in the 1999 study, have also been treated differently. In that study the congestion costs were omitted in the results, because they are subject to extremely wide variation and there was no straightforward way of converting them into average marginal costs. The present study is concerned not so much with average marginal costs, however, distinguishing rather, in the *efficiency variant*, a worst and a best case, with and without congestion. After all, it is more efficient for society as a whole to allocate the external costs of congestion (always variable) to the party causing them. In the *total cost variant*, on the other hand, congestion costs have been ignored, as this variant proceeds from the ‘fairness’ principle and *confronts every mode of transport with the sum total of the social costs to which it gives rise.* In the case of congestion, though, the social costs induced by road users are also borne by the same group as a whole.

Presentation

At the request of the project principal, the Netherlands Ministry of Transport, Public Works and Water Management, in this study we first of all report *total* costs and charges (in million or billion euro), to give a basic impression of the degree to which the various modes of transport presently ‘pay their way’.

We then present the results of the efficiency variant, which is concerned with *variable* costs and charges per vehicle or vessel kilometre. The 1999 study additionally presented fixed costs and charges, expressing these per passenger or tonne kilometre. In the present study, though, these have been presented separately from usage-dependent, i.e. variable costs and charges and are shown as totals in the various figures for the total cost variant (in million or billion euro).

Improved data

To further refine the accuracy of our estimates, we retrieved a substantial body of new data for the purposes of the present study. Although the reference year remains the same as in the 1999 study, viz. 2002, we were now in a position to use *actual costs* and empirical data rather than estimates. For example, we have used reports detailing government expenditures rather than budgets as well as the latest accident statistics, computed new cost figures for noise nuisance, tracked down the latest traffic volume statistics for the various vehicle categories and employed more recent emissions data.

1.6 Principles of cost calculation and allocation

1.6.1 Two calculation methods

The different principles in which pricing policy can be grounded are reflected in the parallel calculation methods employed in this study. The first of these, which we call the 'total cost variant', is concerned with whether each individual mode of transport is charged enough to cover the *total costs* for which it can be held responsible. The second method, termed the 'efficiency variant', is concerned with whether individual users incorporate all the *variable costs* in their transport and mobility decisions. In this variant, then, we compare variable user charges with variable user costs.

As already noted in section 1.2, when it comes to the practical financing of the overall costs of transport infrastructure (construction, land take, maintenance and operation), either method can be used.

1.6.2 Total cost variant

Aim

The aim of the total cost variant is to identify, for each of the vehicle categories distinguished, the total costs they cause and compare these costs with the total charges paid by the category in question.

Items considered

In the total cost variant we consider both the variable and fixed (i.e. usage-invariable) costs, i.e. all those specified in section 1.4. The only costs ignored in this variant are those of congestion, on the reasoning that while road users generate these costs, they also bear the burden[14]. At the same time, though, road users cause external congestion costs *with respect to one another*, and for this reason overall economic welfare would be optimised by introducing an appropriate charge (efficiency variant). From the perspective of total costs, however, it is 'unfair' to charge road users as a whole for these costs, as they are already suffering the consequences.

Presentation of results

The results presented are the total costs and charges for each of the vehicle categories identified in section 1.4, with the exception of rail transport, for which we report, for passenger and freight transport, totals for both diesel and electric trains.

---

[14] It can be argued that it would be fairer to allocate (total) congestion costs to individual categories of road users, as the degree of congestion due to each does not always match the burden it itself suffers (e.g. motorcycles, HGV). In this study we have chosen not to take this approach, however.

We also provide synoptic summaries at higher levels of aggregation, viz.:

- Passenger transport (total transport by passenger car (petrol, diesel, LPG), bus, coach, motorcycle and moped/scooter).
- Freight transport (total transport by truck and tractor-(semi) trailer combination).

In the case of passenger transport, in annex J we also provide a synopsis of total costs per passenger kilometre.

1.6.3 Efficiency variant

Aim

The aim of the efficiency variant is to establish, for each vehicle category, how variable user charges compare with usage-dependent external costs. This variant we term the 'efficiency variant', because pricing based on variable user costs is the most efficient option in economic terms, i.e. from the perspective of optimising overall welfare[15].

In this context it should be noted that to achieve the economic optimum it is not only important that the sum total of variable user costs corresponds to the sum total of variable charges. In addition, the structure of the charges levied on vehicle usage should reflect the structure of the costs arising through that specific behaviour, so that precisely the right incentives are given for a socially and economically optimum pattern of transport mobility. In this variant, then, costs and charges are expressed *per vehicle or vessel* and, more precisely, in euros or euro cents per vehicle or vessel kilometre.

Items considered

In the efficiency variant only variable costs are considered, i.e. those costs that are a function of vehicle usage, as follows:

- The variable costs of infrastructure maintenance and operation (M/O).
- The external costs of traffic accidents.
- The external costs of climate emissions (CO_2).
- The external costs of other air pollutant emissions (NO_X, PM_{10}, HC, SO_2).
- The external costs of noise nuisance.
- The external costs of congestion / scarcity.

The analysis takes in the following taxes and charges:

- Charge for rail infrastructure use.
- Harbour and fairway dues.
- Excise duty.
- Regulatory energy charge (REC).

No subsidies and tax exemptions have been included in the efficiency variant, as the aim of this variant is to establish whether, and to what degree, incentives

---

[15] According to economic theory, to achieve optimum welfare means full allocation of marginal costs. In practice, however, it is generally all but impossible to determine actual marginal costs. In this study we have therefore derived the variable costs from average costs (for all items except congestion), an alternative we believe yields a good approximation for the true marginal costs.

arising through variable charges and tax schemes balance the variable external costs. In this connection, it is not always clear whether subsidies and tax exemptions are keyed to variable costs or are also (part-)compensation for fixed costs.

Best and worst cases

The variable costs and charges of a vehicle or vessel depend very much on its precise design and operating characteristics as well as on the precise context within which travel or transport takes place. We have therefore opted not to define ‘average’ vehicles but rather to present best and worst cases, to gain an impression of the range of costs involved.

For almost every mode of transport we distinguish a best and worst case scenario, defining the former (latter) as that in which there is least (greatest) difference between the variable costs of the vehicle or vessel in question and the variable charges actually paid.

For *passenger transport*, the details of the best and worst cases are summarised in table 3. With respect to costs, these are built up around the following variables:

- *Year of car manufacture*: for a given fuel type, old cars have significantly higher per-kilometre emissions of air pollutants than new, the result of progressively more stringent European emission standards over the years.
- *Urban/rural*: in the urban environment, the kilometre-indexed external costs of air pollutant emissions, noise and accidents are higher than in rural areas. For health damage and noise nuisance this is because a greater number of people are exposed. In addition, accidents are relatively more frequent (per kilometre) in urban areas.
- *Peak/off-peak*: in peak traffic, vehicle hours are lost in traffic jams, while in off-peak periods we have assumed zero congestion. This distinction has only been made for road transport, i.e. we take there to be *no* congestion on the rail network.
- *Electric/diesel* (rail): the air pollutant emission profile of diesel locomotives is very different from that of their electric counterparts. As there is also wide variation within this latter category, related mainly to train weight (and thus energy use), we have here calculated with two extremes. Because diesel trains are used almost exclusively for rural services in the Netherlands, in this case we do not distinguish a best and worst case, and calculate solely with diesel trains in rural areas.

The only user charges of relevance for passenger transport are fuel excise duty and the Regulatory Energy Charge, as charges for rail infrastructure use are the same for all types of passenger train[16].

The fuel duty paid ‘per kilometre’ depends on the fuel economy of the vehicle in question and has been calculated for passenger cars and diesel trains in rural and urban traffic to give a best and worst case, respectively.

---

[16] In the efficiency variant the charge for the use of stations has been ignored. In 2002 rail operators received approx. € 8 mln on this count, translating to about 7 €ct per train kilometre.

In the case of rail transport, the REC is paid on both electrical power consumption and the ‘red’ (i.e. low-tax) diesel burned in diesel locomotives. In both cases, the charge rates are staggered (less being paid the more fuel is used), with a ceiling above which a zero rate applies (10 million kWh and 135,000 litres, respectively). Per-kilometre costs are therefore governed not only by per-km energy consumption, but also by the aggregate annual consumption of the rail operator in question. Dutch Rail (NS) is the only operator that uses electric locomotives for passenger transport. Given the ceiling in force, REC costs are negligibly small per passenger kilometre (approx. 0.05 €ct/train km) and they have therefore been ignored in our per-km calculations. For diesel trains we have taken the REC costs of an ‘average’ rail operator (Noordned, for which these costs are about 0.67 €ct/train km).

table 3 Definitions of best and worst cases for passenger transport and light goods vehicles (LGV, i.e. vans)

Vehicle type	Best case	Worst case
Car, petrol	Rural, off-peak, 2002 model	Urban, peak, 1993 model
Car, diesel	Rural, off-peak, 2002 model	Urban, peak, 1993 model
Car, LPG	Rural, off-peak, 2002 model	Urban, peak, 1993 model
Bus (town/district)	Rural, off-peak, 2002 model	Urban, off-peak, 1993 model
Rail	Local service (*Sprinter*), 250 seats, rural	Intercity (*Regiorunner*), 1200 seats, urban
	Local service (diesel, *DM 90*), 125 seats, rural*	
LGV	Rural, off-peak, 2002 model	Urban, peak, 1993 model

* As explained above, for passenger diesel rail we do not distinguish a best and worst case.

For *freight transport* we distinguish best and worst cases as detailed in table 4. For the same reasons as for passenger transport, here too we distinguish best and worst case scenarios in terms of year of manufacture, urban/rural, peak/off-peak and electric/diesel.

With respect to rail, as with passenger transport REC costs per kilometre depend very much on annual energy consumption. For our best case (empty electric train, non-bulk, rural) we have therefore based ourselves on a carrier (ACTS) using a relatively large amount of power each year and consequently paying a relatively high REC bill. For our worst case (full diesel train, bulk, urban) we have taken a carrier (Railon) consuming a relatively large amount of fuel, resulting in a comparatively small REC charge per kilometre.

In the case of rail freight transport, we make no distinction between energy consumption in urban and rural areas.

table 4 Definitions of best and worst cases for freight transport

Vehicle type	Best case	Worst case
HGV, 3.5-12 tonne	Rural, off-peak, 2002 model	Urban, peak, 1993 model
HGV >12 tonne, single-unit truck	Rural, off-peak, 2002 model	Urban, peak, 1993 model
HGV >12 tonne, tractor-(semi)trailer combination	Rural, off-peak, 2002 model	Urban, peak, 1993 model
Rail	Non-bulk service, electric, empty, 80 km/h	Bulk service, diesel, 1,700 tonne load, 80 km/h
Inland shipping	‘Spits’ barge (*M1*, 350 tonne, smallest inland vessel), empty, downstream, 15 km/h, year 2000 engine	Quadruple pushed barge unit (*BII-4*, 8,000 tonne) fully laden, upstream, 10 km/h, 1990 engine

1.6.4 Tabular synopsis

On the next few pages we present a tabular synopsis of the methods and procedure adopted for each of the cost items include in our analysis, providing details on each of the following:
- Calculation methods for total costs.
- Principles of cost allocation.
- Best and worst case scenarios, as relevant.

table 5 Synopsis: Cost calculation and allocation methodologies (vkm = vehicle/vessel kilometre)

Cost category	**Transport mode**	**Efficiency variant**	**Total cost variant**	**Calculation method for total costs**	**Allocation basis (total costs in billion euro, marginal costs in euro per vehicle/vessel km = vkm)**	**Worst and best cases distinguished? (with respect to marginal costs per vkm)**
Infrastructure: construction	Road		X	Expenditures over 35-year period (1974-2008 for national roads, 1967-2001 for provincial and local roads).	11% allocation based on vehicle weight (4th power of axle load), 89% based on peak-time capacity utilisation (in 'passenger car equivalents', pce).	n.a.
	Rail		X	Expenditures over 25-year period (1985-2010$^{1)}$), excl. high-speed train links and Betuwe freight line.	For capacity expansion: allocation to passenger transport based on peak-time capacity utilisation. For extension of services: allocation to specific user groups (incl. passenger vs. freight, electric vs. diesel) as indicated, otherwise to passenger rail.	n.a.
	Inland shipping		X	Expenditures over 25-year period (1985-2010).	95% allocation to commercial inland shipping (estimate), the rest to recreational shipping (ignored in this study).	n.a.
Infrastructure: maintenance & operation, fixed costs	Road		X	National roads: based on 'standard costs' of basic maintenance (BM); provincial and local roads: based on CBS statistics. Fixed/variable split: based on BM for all road types (as per IPS study).	Allocation based on pce and vkm, the former as per European directives in [EC, 2003].	n.a.
	Rail		X	Costs based on 'standard cost' approach used in government scenario '*Niet verder weggglijden*', using data from ProRail.	Allocation based on vkm, except for fixed costs of stations and energy supply (allocation to specific user groups) as per IPS study.	n.a.
	Inland shipping		X	Estimated costs for 2002 (Transport ministry budget, Infrastructure Fund; CBS). Fixed/variable split: as per IPS study.	Allocation based on capacity utilisation (average length of vessel class), as per IPS study.	n.a.

Cost category	Transport mode	Efficiency variant	Total cost variant	Calculation method for total costs	Allocation basis (total costs in billion euro, marginal costs in euro per vehicle/vessel km = vkm)	Worst and best cases distinguished? (with respect to marginal costs per vkm)
Infrastructure: maintenance & operation, variable costs	Road	X	X	National roads: based on 'standard costs' of BM; provincial and local roads: based on CBS statistics. Fixed/variable split: based on BM for all road types (as per IPS study).	Fourfold breakdown of variable costs, based on BM programme: 1 Costs related to vkm and vehicle weight: 94% allocation based on 4th power of axle damage factor and vkm, 6% based on square of axle damage factor and vkm. 2 Costs related solely to vkm: allocation based on vkm. 3 Accident-related costs: allocation according to number of casualties. 4 Noise-related costs: allocation based on noise weighting factors and vkm.	No further distinction between worst and best case within size class.
	Rail	X	X	Costs based on 'standard cost' approach for government scenario '*Niet verder wegglijden*', using data from ProRail.	Wear and tear to track and engineering structures: based on tonne km. Stations: passenger trains. Train timetables: based on train km. Energy supply: based on kWh power consumption. Freight terminals: based on train km.	For freight transport, additional distinction based on tonnage.
	Inland shipping	X	X	Estimated costs for 2002 (Transport ministry budget, Infrastructure Fund; CBS). Fixed/variable split: as per IPS study.	Allocation based on number of passages (commercial vs. recreational shipping).	Allocation based on vessel km, i.e. no distinction between worst and best case.
Accidents	Road	X	X	Traffic accident statistics: [AVV, 2004b]. Valuation: [UNITE, 2000].	Allocation between passenger and freight: based on accident statistics. Intermodal accidents: based on intrinsic risk and accident statistics.	Urban vs. rural.
	Rail	X	X	Traffic accident statistics: [AVV, 2004b] and [Railned, 2002]. Valuation: [UNITE, 2000].	Allocation between passenger and freight: based on accident statistics. Intermodal accidents: based on intrinsic risk and accident statistics.	No distinction between best and worst case.

Cost category	Transport mode	Efficiency variant	Total cost variant	Calculation method for total costs	Allocation basis (total costs in billion euro, marginal costs in euro per vehicle/vessel km = vkm)	Worst and best cases distinguished? (with respect to marginal costs per vkm)
Accidents	Inland shipping	X	X	Traffic accident statistics: [AVV, 2004c]. Valuation: [UNITE, 2000].	Intermodal accidents: allocation based on intrinsic risk and accident statistics. Additionally, allocation between transport and other functions (water management) and between inland and sea shipping.	No distinction between best and worst case.
Land take	Road		X	Land take: based on VU study. Valuation: expert workshop.	Direct land take for roads and service areas, rural: based on vkm. Indirect land take (noise contours): based on vkm. Parking space allocated to passenger cars.	n.a.
	Rail		X	Land take: based on VU study. Valuation: expert workshop.	Allocation based on vkm.	n.a.
	Inland shipping		X	Land take: based on VU study. Valuation: expert workshop.	Allocation based on vkm.	n.a.
Environment: climate (CO_2)	Road	X	X	Emission factors as per Traffic & Transport Taskforce (TTT)[2)].	No allocation issues.	Urban vs. rural
	Rail	X	X	Emission factors: TTT.	No allocation issues.	Passenger: *Sprinter* vs. Intercity vs. diesel local service. Freight: diesel (bulk service, 1,700 tonne load, 80 km/h) vs. electric (non-bulk, empty, 80 km/h).

Cost category	**Transport mode**	**Efficiency variant**	**Total cost variant**	**Calculation method for total costs**	**Allocation basis (total costs in billion euro, marginal costs in euro per vehicle/vessel km = vkm)**	**Worst and best cases distinguished? (with respect to marginal costs per vkm)**
	Inland shipping	X	X	Emission factors: TTT.	No allocation issues.	’Spits’ barge (smallest inland vessel (M1, 350 tonne), empty, downstream, 15 km/h, year 2000 engine 2000) vs. quadruple pushed barge unit (BII-4, 8,000 tonne, fully laden, upstream, 10 km/h,1990 engine).
Environment: air pollution	Road	X	X	Emission factors: TTT.	No allocation issues.	Passenger: urban, Euro-0, rural, Euro-4. Freight: urban, Euro-1, rural, Euro-3.
	Rail	X	X	Emission factors: TTT.	No allocation issues.	Passenger transport: ‘Sprinter’ rural vs. Intercity urban vs. diesel local service rural. Freight transport: diesel train (bulk service, 1,700 tonne load, 80 km/h, urban) vs. electric train (non-bulk, empty, 80 km/h, rural).
	Inland shipping	X	X	Emission factors: TTT.	No allocation issues.	‘Spits’ barge (M1, 350 tonne, empty, downstream, 15 km/h, year 2000 engine) vs. quadruple pushed barge unit (BII-4, 8,000 tonne, fully laden, upstream, 10 km/h, 1990 engine).
Noise	Road	X	X	Number of exposed people or dwellings: RIVM. Valuation: based on Swedish Road Authority study.	Intermodal allocation using weighting factors based on noise emission levels and vkm (ECMT).	Urban vs. rural.
	Rail	X	X	Number of exposed people or dwellings: RIVM. Valuation: based on Swedish Road Authority study.	Intermodal allocation using weighting factors based on noise emission levels and vkm (ECMT).	Urban vs. rural.
	Inland shipping			n.a.	n.a.	n.a.

Cost category	Transport mode	Efficiency variant	Total cost variant	Calculation method for total costs	Allocation basis (total costs in billion euro, marginal costs in euro per vehicle/vessel km = vkm)	Worst and best cases distinguished? (with respect to marginal costs per vkm)
Congestion	Road	X			Allocation based on vkm and vehicle category (passenger car vs. HGV).	Peak vs. off-peak and urban vs. rural.
	Rail			n.a.	n.a.	n.a.
	Inland shipping			n.a.	n.a.	n.a.

[1] Shorter period than for road, because of data availability.

[2] A joint taskforce of RIVM (National Institute for Public Health and the Environment), CBS (Netherlands Statistics), TNO (Netherlands Institute of Applied Scientific Research), RIZA (National Institute for Inland Water Management and Waste Water Treatment) and AVV (Dutch Transport Research Centre) set up to harmonise Dutch national emissions data.

2 Costs of infrastructure

2.1 Introduction

In this chapter, the first of a series dealing with six specific cost categories, we explain the procedure adopted in this study for estimating the costs relating to road, rail and waterway infrastructure. These costs have two basic components: the costs of building new infrastructure and the costs of infrastructure maintenance and operation. For each, we shall indicate the proportion taken as variable i.e. usage-dependent, and as fixed. For the costs of railway infrastructure renewal we carried out two variant calculations, taking these costs as either part-variable or entirely fixed. Finally, we provide a justification for the choices made with respect to allocation of costs across infrastructure users.

2.2 Road infrastructure

In this first section we identify the various costs associated with the building of new transport infrastructure, on the one hand, and maintenance and operation, on the other, thereby making a distinction between ‘urban’ and ‘rural’ infrastructure. We then explain how these costs have been allocated to the categories of vehicle and vessel covered by this study. To this end we discuss the costs to be allocated and where they arise (sections 2.2.1, 2.2.2 and 2.2.3), the allocation of individual costs items across vehicle categories (section 2.2.4) and the raw data on which allocation has been based (section 2.2.5). Finally, we present the costs associated with each vehicle category (section 2.2.6).

2.2.1 Construction costs

To arrive at a figure for annual outlay on building new infrastructure we made use of official reviews of government investments and expenditures. As in our earlier studies [CE, 1999] and [VU, 2002] we quantified investments as capital costs, i.e. depreciation plus interest, on annuity basis. For this purpose we took a 35-year depreciation period for infrastructure investments and an annual interest rate of 4% (as per the guidelines of the Dutch Finance ministry).

In the on-line statistics published by Netherlands Statistics [CBS-Statline] infrastructure investments are broken down according to the party administering the infrastructure in question, viz. national, provincial or local authorities, and in some cases water management boards or other agencies. These data were available for the period 1985-2001. In this study we have included expenditures by water boards and other agencies under the heading ’local’.
The government Infrastructure Fund 2004 details intended national expenditure on infrastructure construction up to and including 2008. As we are using a 35-year depreciation period, we took investments from 1974 to 2008 to calculate the average construction costs accruing to national government. For the years 1974-1984, over which no CBS data are available, we took the same figure for total government investments in infrastructure as used in our earlier study [CE, 1999].

To our knowledge, there are no forecasts of future investments in transport infrastructure by lower echelons of government. To estimate the construction costs borne by provincial and local authorities we therefore based ourselves on expenditures in the period 1967-2001, again taking the figures used in [CE, 1999] for the years 1967-1984, over which no CBS data are available.

2.2.2 Maintenance and operating costs

Our figures for the costs of infrastructure maintenance and operation are based on the details of the government's 'Basic Maintenance' (BM) programme, elaborated by the national Road and Hydraulic Engineering Institute as being the level of maintenance required for the Dutch national road grid to remain in optimum condition [DWW, 2002]. In the referenced document, BM is defined as follows:

'The Basic Maintenance level indicates the minimum package of maintenance and operational measures required to ensure the long-term physical and functional integrity of existing infrastructure under current conditions, based on the user service levels agreed with the principal (the Directorate-General of Public Works and Water Management, *Rijkswaterstaat*) and the standards and directives in force with respect to execution of maintenance activities.'

In [DWW, 2002] the costs of such Basic Maintenance are calculated using a 'standard cost' method, which has the great advantage of making allowance for maintenance backlogs. After deducting the costs of infrastructure improvement (approx. 8% of the total figure) and correcting for inflation, the DWW-computed costs come to 634 million euro in 2002.

Unfortunately, these kind of cost calculations are not available for roads administered at the provincial or local level, and for these we had to take recourse to CBS statistics on actual government expenditure [CBS-Statline]. These statistics are for the years 1985-2001 and distinguish maintenance costs incurred on infrastructure administered by provincial and local authorities and by water boards and other road administrators (as stated above, the latter two have been included under the heading 'local'). For the maintenance costs of both provincial and local roads in 2002 we used the data for 2001, adjusting them upwards by the average annual rise in costs over the period 1985-2001. The CBS statistics make a similar distinction with respect to the operating costs of provincial and local roads, but only for the years 1985-1999. For these costs we therefore took the data for 1999 and added three times the average annual cost increase over 1985-2001.

The costs of infrastructure maintenance and operation have been summed and from now on will be referred to jointly as M/O costs. This is because the BM matrix we have used for a further breakdown of costs does not distinguish 'maintenance costs' from 'operating costs'. With this matrix it is possible to establish, for each individual cost item, what portion is fixed and what portion variable, i.e. dependent on actual usage. For each of the variable costs, moreover, it can be determined in exactly what respect the cost is a function of transport activity: a function of vehicle kilometres or axle load, for example, or in the case of inland shipping, number of passages. These functions are what determine how the costs in question are to be allocated across the various categories of vehicle and vessel[17]. Table 6 provides a basic breakdown of BM costs into fixed and variable. As can be seen, a sizable portion of the costs is to be deemed variable. The detailed figures from the BM document [DWW, 2002] are reported in annex A, which gives quantitative data on the variable and fixed costs and how they were calculated.

table 6 Variable and fixed costs of national road maintenance and operation in 2002 (mln €), 'Basic Maintenance ' level [DWW, 2002]

Type of cost	Cost (mln €)	Percentage
Fixed	372.5	59%
Variable, dependent on:		
Kilometres driven and vehicle weight	205.0	32%
Kilometres driven	36.4	6%
Noise production	11.0	2%
Number and severity of accidents caused	8.9	1%
Total	633.8	100%

As table 6 shows, in 2002 the variable costs of maintaining and operating the Dutch national road grid amounted to € 261.3 mln, representing about 41% of total costs[18]. Further study of the full array of BM cost items (annex A) allows four basic cost categories to be distinguished, viz.:

1. M/O costs associated with damage to the road pavement (wear and tear); these user costs are a function of kilometres driven and vehicle weight.
2. M/O costs that are dependent on kilometerage *only*, such as the costs of traffic control measures, or signs and beacons.
3. M/O costs of noise provisions, which are a function of vehicle noise emissions.
4. M/O costs related to the number of traffic accidents caused (part-dependent on kilometerage) and their severity.

In the present study, the percentage breakdown of M/O costs given in table 6 has been adopted for national roads as well as provincial and local roads, despite the BM programme having been drawn up solely for the national road grid.

2.2.3 Synopsis of allocable road infrastructure costs

To establish an ultimate figure for the costs associated with road infrastructure, we corrected investments in construction for inflation, taking the price index for roads used by CBS (reference year: 2002). This index is derived from a time

---

[17] We are grateful to Mr. Nagtegaal and mr. Van der Vusse for providing us with the BM data [DWW, 2002] and for their expert opinion on estimating the variable portion of each specific cost item.

[18] Earlier studies on variable M/O costs ([DWW, 2000] and [KOAC/WMD, 2001]) yielded a significantly lower percentage. These studies did not have the detailed, bottom-up data of the BM study at their disposal, however [DWW, 2002].

series going back to 1979 and for the years prior to that date we based ourselves on the trend in the Retail Price Index (RPI). Maintenance costs were corrected using the real price index for road maintenance, while operating costs were corrected using the RPI, as no specific index could be found for these costs.

The resultant costs then underwent a three-step transformation:

1. First, the standard CBS statistics for infrastructure investments and M/O costs were broken down according to the body administering the roads in question. Because there are no exact data available on what proportions of national, provincial and local infrastructure costs are to be taken as 'urban' and 'rural', on this point an assumption had to be made. Based on statistics on the area occupied by local roads, it can be calculated that about 57% of local roads are to be classified as 'urban'. Consequently, 57% of the costs of local roads have been allocated under the heading 'urban' and 43% under the heading 'rural'.
2. The second issue is that 'total infrastructure construction costs' implicitly includes the costs of new cycle paths and lanes. Although no specific data are reported for this item, cycle paths and lanes prove to account for about 5% of the total area occupied by road infrastructure, in both urban and rural areas (see Chapter 6). We made the reasonable assumption that there are no cycle lanes along national roads. Ultimately, then, we allocated 5% of the construction costs of local 'urban' roads to cycle path construction. For rural areas we calculated these construction costs as comprising 5% of the construction costs of provincial roads plus 5% of these costs for local 'rural' roads.

   On 'urban' roads 50% of these costs were allocated to mopeds/scooters, and on 'rural' roads 25% (for reasons explained in Chapter 6). The remaining costs are for cyclists and play no further part in this study. It should be noted, though, that allocation of cycle paths to mopeds/scooters means this must be duly accounted for when allocating the other costs associated with road infrastructure. We have assumed that 25% of moped/scooter 'urban' kilometerage is on cycle lanes and 75% of 'rural' kilometerage. The remaining kilometerage, both 'urban' and 'rural', has been used to allocate the other infrastructure costs.
3. Third and last, the precise relationship between road construction and maintenance needs be examined more closely, for the key reason that road 'maintenance' generally entails improvement of the road pavement, the costs of which should strictly speaking be booked under 'construction' rather than 'M/O'. In the case of national roads, approx. 8% of M/O costs are for pavement improvement (see annex A). For national as well as provincial and local roads we have therefore assigned 8% of total M/O costs to 'road construction'.

It should also be noted that the costs of local 'urban' infrastructure normally include the costs of parking space. However, the specific method adopted here for allocating 'urban' costs (as explained in the following subsection) means that these costs are not in fact allocated. We have therefore booked the costs of parking space as a separate cost item, allocating them to passenger cars and

light goods vehicles on the assumption that heavy goods vehicles park on business premises, i.e. private land.
On this point we have taken our cost figures from a study on the economics of parking carried out by IOO [IOO, 2002]. In that study the investment costs (including those of parking meters), operating costs and costs of land purchase associated with public parking space were calculated for the year 2000. Because in our analysis the costs of land purchase for public parking on or along streets are already included under the heading 'land take for urban roads' (see Chapter 6), here these costs have been left out of the equation. Correcting for inflation, we arrive at a figure of € 1,937 mln for the total costs associated with public parking space in 2002. Table 7 provides a synopsis of the total infrastructure costs to be allocated across vehicle categories.

table 7 Total construction and M/O costs of Dutch road grid and costs of parking space and cycle lanes, 2002 (mln €)

Cost category	Urban	Rural	Total
Construction	1,325.9	2,907.5	4,233.4
M/O, fixed	703	1,019	1,722
M/O, variable, depending on:			
vehicle kilometres & vehicle weight	387	561	948
vehicle kilometres	68.6	99.5	168
noise production	-	30.2	30.2
number/severity of accidents	16.7	24.3	41.0
Cycle lanes*	69.8	69.2	139
Parking space*	1,937	-	1,937

* Excluding costs of land purchase.

2.2.4 Allocation of costs

In this section we explain how the various categories of cost have been allocated across the vehicle categories distinguished in this study. We do so in the following sequence:

- Allocation of construction costs.
- Allocation of fixed M/O costs.
- Allocation of variable M/O costs.

It should be noted that of these three types of cost it is only the variable M/O costs that are in fact allocated marginally across vehicle categories. In this report, the other costs of road infrastructure (i.e. construction costs and fixed M/O costs) only play a part in the 'total cost' variant. The present section concludes with a separate discussion on allocating the costs of 'urban' infrastructure, this being a relatively complex issue in its own right.

Allocation of construction costs
From a study by [Tebodin/DHV, 1992] and using the methodology employed in [CE, 1999], [VU, 2002] and [TLN, 2002], it transpires that approximately 11% of construction costs can be identified as related to vehicle weight. Consequently, 11% of construction costs have been allocated according to the 4th power of the axle load (as discussed below in section 2.2.5). This is by way of compensation for the higher construction costs accruing from strengthening roads for the sake

of heavier vehicles. Note, however, that these costs, despite being allocated on the basis of axle load, are reported in the results as *fixed* costs. This is because, although construction costs may be pushed up as ever heavier goods vehicles take to the roads, the extra costs associated with increased road *utilisation* by these vehicles is probably fairly minimal.

In the present study the remaining 89% of construction costs, both 'urban' and 'rural', have been allocated on the basis of peak-time road capacity utilisation by the vehicle category in question. The reasoning here is that new infrastructure will be built as traffic intensity nears maximum road capacity. As heavy goods vehicles occupy more road space than cars and therefore mean new infrastructure having to be built sooner, it is justifiable to apportion them a greater share of the costs. The weighting factors employed are discussed in the next section.

Besides weight, vehicle dimensions (height, width and shape of free loading space) are another factor affecting construction costs. Indeed, these costs are related in one way or another to a variety of other factors, too. Thus, additional costs may arise as a result of:

- 'Soggy' road substrates, e.g. in peaty areas.
- Road safety considerations, e.g. porous asphalt, escape routes.
- Local quality of life considerations, e.g. noise screens, sunken roadways.
- Mitigating measures for the environment and wildlife, e.g. compensation for habitat fragmentation and barrier action.

In the case of safety, quality of life and mitigating environmental measures, we see the social costs already being partially internalised in the costs of construction.

Allocation of fixed M/O costs

In contrast to construction costs, in this study the fixed costs of infrastructure maintenance and operation (approx. 39% of aggregate M/O costs) have been allocated on the basis of vehicle kilometerage and 'kilometre-equivalence factors', as defined in the European Commission's proposal for amendment of the 'Eurovignette' directive (see [EC, 2003]). This document defines kilometre-equivalence factors for passenger cars (a factor 1) and heavy goods vehicles (3), but not for other vehicle categories. Here we have used the HGV factor for buses and coaches, the passenger car factor for light goods vehicles and a factor 0.5 for motorcycles. The reasoning behind these choices derives from earlier studies (see [CE, 1999] and [VU, 2002]), in which similar assumptions were made with respect to the 'passenger car equivalents' (pce) of buses, coaches, vans and motorcycles.

Allocation of variable M/O costs

As we saw in the previous section, for the purpose of allocation four basic kinds of variable cost can be distinguished. By far the most significant of these costs are those that are a function of vehicle weight and kilometerage, and these require closer examination. In particular, we need to look at the issue of road damage, or 'distress to road pavements' as it is known in the business. There are five types of distress to be distinguished, known as ravelling, fatigue cracking, shoving, rutting and adhesion [KOAC/WMD, 2001]. The share of each in the variable M/O costs is shown in table 8.

table 8 Share of five types of road pavement distress in variable M/O costs

Form of distress	Share in costs
Ravelling	75%
Fatigue cracking	18%
Shoving	1%
Rutting	4%
Adhesion	2%
Total	100%

Source: Own calculations, based on table 25 of [KOAC/WMD, 2001]

The exact relationship between pavement distress and vehicle weight is derived using 'axle damage factors' and quadratic and higher-power functions (see section 2.2.5). Powers higher than unity mean that road damage increases more than proportionally to axle load. [DWW, 2000] and [KOAC/WMD, 2001] report that a fourth-power relationship is appropriate for all forms of distress except rutting and adhesion, for which a quadratic function suffices. Ultimately then, we have allocated (4% + 2% =) 6% of variable M/O costs according to the square of axle load and 94% according to the fourth power thereof. (Again, for a more detailed description of these relationships, see section 2.2.5.)

With respect to the described allocation, it should be note that the KOAC/WMS study was concerned with pavement distress to the *main road grid*. On provincial and local roads there proves to be comparatively more damage due to rutting and adhesion than on main roads. Because no quantitative data are available on this point, however, we have used the cited percentages for *all* categories of road. The consequence, however, is that on these secondary roads too high a proportion of costs are allocated to heavier vehicles[19].

A major fraction of the other three categories of variable M/O costs (see section 2.2.2) are purely a function of vehicle kilometerage and have been allocated on that basis. The M/O costs that are a function of traffic accidents (number and severity) were allocated using the 'conflict tables' compiled by CBS, attributing costs according to the total number of casualties in accidents involving each vehicle category. This is based on the reasonable premise that the more serious an accident, the greater will be the cost of repairing the resultant damage to infrastructure. The M/O costs related to noise nuisance, finally, were allocated across vehicle categories using noise weighting factors, as specified in annex G.

---

[19] Besides this difference in the damage occurring on main and other roads, porous asphalt appears to be used far more frequently for repairing main roads, pushing up the share of ravelling in pavement damage. This is of no consequence for ultimate allocation, however, as the costs of both types of distress are subject to the same 4th power rule.

Allocation of 'urban' costs
In the urban environment, road transport infrastructure not only serves the traffic it carries but other functions, too (as in the case of pavements, town squares and pedestrian precincts). This makes it inappropriate for all the attendant costs to be passed on to transport. The share of costs to be allocated to motorised transport could not be derived from the statistics maintained by Dutch municipal authorities. In [TLN, 2002] a fairly detailed method was used to allocate the costs of 'municipal' infrastructure, which we have adopted here under the proviso that we have used it for the category of 'urban' roads only, and TLN for all 'municipal' infrastructure. To our mind, though, restricting the method to this type of roads is justified because the arguments for using the method (see above) probably do not hold for 'rural' roads.

Taking their lead from the Swiss Statistical Office, [TLN, 2002] adopted a figure of 70% for the share of transport in the functionality of urban infrastructure. Of this 70%, 35% is characterised by [TLN, 2002] as '…stabling and resting sites for passenger cars and vans…', or in other words parking space. In the present study, the costs of parking space have been treated as a separate item, using data taken from an IOO study [IOO, 2002]. As a result, we ultimately allocate only 65% of 70% (= 45.5%) of 'urban' costs to road users. In allocating these costs, we distinguished four categories of municipal road, establishing for each the types of vehicle using it and its share in the overall municipal road grid, see [TLN, 2002]. Based on this information, the costs reported in [TLN, 2000] were ultimately allocated as follows:

- Category 1: 50% allocated solely to passenger cars, motorcycles, mopeds and LGVs.
- Category 2: 30% allocated solely to passenger cars, motorcycles, mopeds, LGVs and HGVs (single unit) < 12 t.
- Category 3: 5% allocated solely to passenger cars, motorcycles, mopeds, LGVs, HGVs (single unit): all weight classes.
- Category 4: 15% allocated to all vehicle categories.

This subdivision of costs holds for both construction and M/O costs. Parking costs (passenger cars, LGVs) and the costs of cycle lanes (mopeds/scooters) were allocated directly, as the above method is not relevant for these costs. Note, finally, that the costs of the direct land take associated with this 'urban' infrastructure have been allocated using this same method (as discussed in Chapter 6).

Synopsis of allocation procedures
The allocation procedures employed for the various cost categories are summarised in table 9. No distinction is made in this table between 'urban' and 'rural' infrastructure. Needless to say, 'urban' costs were first allocated to the appropriate vehicle categories using the above method. Following this initial allocation, though, 'urban' costs were allocated is exactly the same manner as 'rural' costs.

table 9 Allocation procedure for various costs of road infrastructure

	pce[1)] vkm	pce (peak)[2)] vkm	square of axle load	4th power of axle load	total
Construction costs		89%		11%	100%
M/O costs, fixed	100%				100%
M/O costs, variable			6%	94%	100%

1) For the fixed M/O costs we followed the IPS study [CE/VU, 2004b], taking the passenger car equivalent (pce) ratings used in [EC, 2003].

2) Construction costs allocated on the basis of peak-time pce's, see [HCG, 1996].

2.2.5 Basic statistics

Before the various infrastructure costs can be allocated, as described in the previous section, we need several sets of basic statistics, including 'urban' and 'rural' annual kilometerages and average weights for the various vehicle categories. Below, we report the basic statistics used in this study and the sources used. As a start, table 10 gives the data for passenger and light goods vehicles.

table 10 Basic statistics: passenger vehicles and LGVs

	Average weight (t)	vkm, urban (mln)	vkm, rural (mln)	pce, peak-time[1)]	pce, IPS[2)]	No. of axles
Passenger transport						
Car	1.15	24,011	76,035	1	1	2
Bus	12.99	273	117	1.85	3	2
Coach	16.79	35	141	1.85	3	2.5
Motorcycle	0.58	1,042	1,175	0.5	0.5	1
Moped[3)]	0.17	1,382	51	0.5	0.5	1
LGV	1.87	9,406	9,406	1	1	2

1) Peak-time capacity utilisation in pce, for allocation of construction costs (urban and rural).

2) As per IPS study [CE/VU, 2004a,b] and based on [EC, 2003], for allocation of fixed M/O costs.

3) Kilometerage (urban and rural) includes correction for kilometres on cycle lanes (see section 2.2.3). Source: CE and [VU, 2002].

In the case of freight transport, the basic data used in this study for cost *allocation* on the basis of vehicle kilometres and axle damage factors are largely the same as those used in the VU study [VU, 2002][20]. The data on the average laden weight of the (many) categories of HGV distinguished in that study were taken from [CBS, 1996b]. For each HGV category, estimates of unladen vehicle weight, number of axles and axle configuration were also provided by the Dutch hauliers' organisation TLN. Average vehicle weight, both laden and unladen, is consequently known for each category. The [CBS, 1996b] report also includes, for each category, a split between laden and unladen vehicle kilometres. For the final allocation of costs, total vehicle kilometres in 2002 were used, allocating

---

[20] In the results ultimately presented we distinguish only three categories of HGV. As allocation of variable M/O costs hinges on non-linear relationships, allocation in terms of only three categories would mean an underestimate of the overall costs of freight transport. To address this issue, the costs were first allocated to the categories specified in table 10, prior to calculation of the average costs for the three categories included in the reported results.

these across the HGV categories identified here using data from [CBS, 1996b]. These data are presented in table 11. Although this table distinguishes HGVs with a maximum vehicle weight of less than 3.5 tonnes [cf. CBS, 1996b], we would emphasise that this subcategory does *not* include LGVs (i.e. vans)

table 11 Basic statistics: road freight transport

Maximum weight	Average weight, unladen[1]	Average load[2)]	Relative vkm[2]	vkm, urban[3]	vkm, rural[3]	% of vkm loaded[2]	No. of axles[1]	Axle configuration[1)]
HGV, single unit < 12 t								
2.5 - 5.5	1.75	0.89	47%	165.2	247.7	75%	2	Single
5.5 – 9	3.5	1.96	21%	72.2	108.3	75%	2	Single
9 – 12	4	4.31	32%	110.8	166.2	75%	2	Single
			100%	**348**	**522**			
HGV, single unit > 12 t								
12 – 16	6	4.31	42%	170.3	681.2	75%	2	Single
16 – 22	6.5	9.14	37%	149.9	599.8	69%	3	Single
22 – 30	8.5	13.96	13%	51.2	204.9	62%	3 - 4	Single
30 – 35	11	19.11	5%	19.7	79.0	52%	4	Single
35 – 45	13	25.76	3%	10.8	43.2	52%	4 - 5	Single
45 – 50	17	28.29	1%	3.8	15.0	48%	5	Single
			100%	**406**	**1,623**			
HGV, tractor-trailer combination > 12 t (rigid)								
12 – 16	5	3.20	0.6%	2.5	22.7	80%	3	Single
16 – 22	7	6.72	1.8%	7.1	64.3	76%	3	Single
22 – 33	11	6.54	2.6%	10.3	92.7	76%	3 - 4	Single
33 – 40	14	12.44	6.4%	25.4	229.0	74%	4	Single
40 – 45	16	15.55	8.5%	33.9	304.7	72%	4 - 5	Tan-/tridem
45 – 50	17	23.98	9.0%	35.7	321.7	64%	6	Tridem
HGV, tractor-semitrailer combination > 12 t (articulated)								
12 – 16	6	3.03	0.2%	0.8	7.6	60%	3	Single
16 – 22	8	7.00	2.7%	10.7	96.5	75%	3	Single
22 – 32	11	10.50	5.6%	22.3	200.6	80%	4	Tandem
32 – 38	12.5	13.57	12.4%	49.4	444.7	76%	4	Tandem
38 – 45	13.5	16.05	26.9%	107.4	967.0	75%	5	Tridem
45 – 50	14.5	24.90	23.4%	93.3	839.5	67%	6	Tridem
			100%	**399**	**3,591**			

[1] Average unladen weight in tonnes, no. of axles and axle configuration (source: estimate, TLN).

[2] Weight in tonnes, vehicle kilometres in millions (source: [CBS, 1996b]).

[3] Percentages of ‘urban’ kilometres from CE (HGV, single unit < 12 t: 40%; HGV, single unit > 12 t: 20%; HGV, tr/tr combination: 10%).

As mentioned in the previous section, the variable M/O costs related to traffic accidents have been allocated using CBS ‘conflict tables’, according to the total number of casualties in accidents due to the various vehicle categories (on the reasoning the graver an accident, the greater the cost of infrastructure repair). As a rough approximation of the relative number of serious accidents caused by the various vehicle categories, we have taken the number of fatal casualties (see table 12). The noise weighting factors used for allocating the variable M/O costs related to noise barriers and other such provisions are also shown in table 12.

table 12 Basic statistics for allocating variable M/O costs related to traffic accidents and noise measures

Vehicle	Annual fatal traffic casualties		Noise weighting factors[1)]
	urban	rural	rural
Freight transport			
HGV, single unit < 12 t	9.8	3	27
HGV, single unit > 12 t	13.2	4.2	27
HGV, tr/tr comb. > 12 t	16.6	5.5	42
Passenger transport			
Car	1.0	1.0	405
Bus	9.5	3.3	4.5
Coach	9.8	3.3	4.5
Motorcycle	13.2	4.2	28
Moped	4.0	1.7	21
LGV	1.5	1.2	68

Source: [INFRAS/IWW, 2003], [VROM, 2002]

1) Allocation assumes no noise measures on urban roads and thus no M/O costs related to such provisions..

Vehicle kilometres and pce

The annual kilometerages of the various vehicle categories on ‘urban’ and ‘rural’ roads were provided by CE. As mopeds drive partly on cycle lanes and have consequently been allocated part of the cost of these lanes (see section 2.2.2), for this vehicle category the kilometerage on other roads must be corrected downward accordingly. Not to do so would mean double-counting and mopeds being over-allocated. As stated earlier, we have allocated the fixed M/O costs using the same method adopted in the IPS study [CE/VU, 2004a,b]. In that study it was opted to adhere to the European directives on passenger car equivalence (pce) factors, see [EC, 2003].

For HGV peak-time capacity utilisation (measured in pce) we based ourselves on [HCG, 1996]. In that study trials were held with cars and heavy goods vehicles to assess the average distance between two successive vehicles (as a yardstick for space requirements) using traffic data for the A2 motorway between Utrecht and Amsterdam. The report presents a range of results using different measuring units and in different situations. We have chosen to use the results based on the space measured in front of the vehicle (as recommended in the report itself) and the situation in which there was ‘limited’ space between vehicles, as this best replicates a full-capacity situation (in peak-time traffic vehicle spacing is likewise cramped). The pce factors for buses and coaches have been taken equal to those for a light HGV; see for example [CE, 1999] and [VU, 2002]. For a detailed description of the various methods and results the reader is referred to the HCG report [HCG, 1996]. It should be reiterated that the results are based on motorway traffic data. Peak-time pce factors in urban traffic will be different. There are no concrete data available on this point, however, and for urban traffic we therefore used the ‘rural’ values, under the proviso that in reality there may be (substantial) differences.

Axle damage factors

The damage to road pavements caused by various vehicle categories can be calculated using 'axle damage factors'. These factors are key in the allocation of all variable M/O and construction costs indexed to vehicle weight (see table 10). Three sets of data are required to compute these factors:

1. First, the unladen weight and average load of each vehicle category. For this purpose we used CE data.
2. Second, the number of axles on the vehicles in each HGV category (based on maximum permissible weight), using these to calculate respective axle loads (based on average vehicle weight). [VU, 2002] reports on the number of axles on a range of heavy goods vehicles and a weighted average of these data were used to compute an average figure for the number of axles applying in each HGV category.
3. Finally, we needed data on axle configuration, suspension and tyre condition, all of which impinge on axle damage factors. As virtually every HGV now has air suspension, on this point there is little need to differentiate. Tyre condition, on the other hand, has been insufficiently studied for inclusion in the present study. The influence of vehicle suspension and tyre condition on the damage factor has thus been ignored here. The situation is better when it comes to axle configuration, for which a quantitative relationship with damage factor is available [DWW, 2000]. The VU study [VU, 2002] also reports the axle configurations on a range of HGVs. We therefore took a weighted average of these latter data to calculate an average axle configuration for each HGV category.

From these data the axle damage factor of a vehicle is then calculated as follows:

Axle damage factor = Axle Configuration Factor (ACF) * Load Equivalence Factor (LEF).

According to [DWW, 2000] the ACF is 'a factor expressing the relative influence of axle load in a tandem or tridem axle configuration relative to the same load via a single axle'. Thus it is 1 for a single axle, $(0.6)^n$ for a tandem and $(0.45)^n$ for a tridem, where *n* is the relevant power, as explained below.

The Load Equivalence Factor is calculated as follows:

$LEF = (P / P_{std})^n$.

where P is the axle load (average total vehicle weight divided by number of axles) and P_{std} the standardised axle load, which we have taken as 10 tonnes, in accordance with [DWW, 2000] and standard Dutch practice. The power *n* is two in the case of pavement distress due to rutting and adhesion and four for distress due to ravelling, shoving and fatigue cracking. Annex B provides a worked example of damage factor calculation.

2.2.6 Costs per vehicle category

Table 13 provides a synopsis of the road infrastructure costs allocated to the respective categories of road vehicle. Table 14 is devoted to the variable M/O costs only, now expressed per vehicle kilometre. Besides total costs there is also a breakdown into ’rural’ and ‘urban’ costs, with the latter serving as pivots for the two extreme (best and worst) cases considered in this study, viz. rural, off-peak variable costs vs. urban, peak-time variable costs. Note that the variable M/O costs per vkm are the same in peak and off-peak traffic. Note, additionally, that the total costs per vkm are a weighted average of ‘urban’ and ‘rural’ costs, using vkm as a weighting factor.

table 13 Total fixed and variable costs of road infrastructure in the Netherlands, by vehicle category (mln €)

Vehicle category	Fixed, construction2)	Fixed, parking	Fixed, M/O	Variable, M/O
Freight transport				
HGV, single unit < 12 t	46.0	-	19.9	88
HGV, single unit > 12 t	144	-	49.7	106
HGV, tr/tr comb. > 12 t	474	-	107	493
Passenger transport				
Car	2.63	1.92	960	240
Bus	15.8	-	4.79	30.9
Coach	15.9	-	4.27	180
Motorcycle	23.5	-	10,	76
Moped, scooter	63.31)	-	6.44	5.9
LGV	417	545	176	198

1) Including the cost of cycle lanes.

2) The totals presented in this table for construction costs and fixed M/O costs are different from those in table 7. This is because in table 7 construction costs and fixed M/O costs (urban) are only part-allocated to transport (see 'Allocation of ‘urban’ costs' in section 2.2.4). In table 7, moreover, the costs of cycle lanes are allocated partly to mopeds and partly to bicycles. Because this latter mode of transport has not been included in our analysis, the costs allocated to bicycles are absent from table 12.

The pattern of costs per ‘rural’ vkm are as to be expected on the basis of the weight (axle damage factors) of the various vehicle categories. In the case of ‘urban’ vkm, the pattern is different. The most salient difference is that single-unit HGVs < 12 t are allocated substantially higher costs than the other two categories of heavy goods vehicles. This is due solely to the specific allocation methodology used for ‘urban’ costs (see section 2.2.4). In urban traffic this lighter category of HGV uses a wider variety of roads than its heavier counterparts and is therefore apportioned a greater share of the costs. More precisely, the higher costs accruing to the lighter HGV are due to the use of secondary roads. These roads are responsible for 30% of the overall ‘urban’ costs to be allocated and lighter HGVs are by far the heaviest vehicle using them (in our methodology). It is to this vehicle category that the bulk of this 30% is therefore allocated (this same pattern emerges in [TLN, 2002]).

table 14 Variable M/O costs of road infrastructure, by vehicle category (€ct/vkm)

Vehicle category	Urban	Rural	Total
Freight transport			
HGV, single unit < 12 t	24.16	0.76	10.12
HGV, single unit > 12 t	5.39	5.17	5.21
HGV, tr/tr comb. > 12 t	7.71	12.87	12.35
Passenger transport			
Car	0.50	0.16	0.24
Bus	7.99	7.78	7.93
Coach	7.43	10.91	10.21
Motorcycle	0.38	0.31	0.34
Moped, scooter	0.32	1.74	0.37
LGV	1.93	0.18	1.05

2.3 Railway infrastructure

In this section we explain the procedure adopted for calculating the costs of railway infrastructure and their allocation to users. In principle, the reference year of this study is 2002 and this has therefore also been used in calculating railway construction costs. This means that the costs of two ‘mega-projects’, the High Speed Link and the Betuwe line, have not been included. With respect to the costs of infrastructure maintenance and operation (M/O) we have based ourselves on [CE/VU, 2004a,b], a study carried out as part of the IPS project ‘Charging freight transport for infrastructure use’, as already mentioned. We have consequently adhered to the method adopted there.

2.3.1 Construction costs

We can distinguish two basic motives for investment in new railway infrastructure:

1 First, there are investments to expand network capacity. Decisions in this area are motivated by capacity shortfalls in the busiest, peak-time travel hours. For this reason we have allocated investments in capacity expansion across users on the basis of peak-time capacity utilisation. Because freight trains rarely run during rush-hours, this allocation means the full costs of investments in capacity expansion are allocated to rail passenger transport.

2 Second, there are investments geared to improving the customer service provided by the infrastructure, as with upgrading of a track section to carry heavier trains (in terms of axle load). In this case, we have allocated investments to the specific user group to whom the benefits accrue (in the cited example, to rail freight). Note, however, that investments in service improvement are dwarfed by those in capacity expansion.

When it comes to investments in new transport infrastructure, the government’s infrastructure budget distinguishes between investments for the benefit of freight transport and those for passenger transport. Being specifically earmarked as freight transport investments, in our calculations the former have been allocated solely to the rail freight sector. The latter category covers all investments not geared specifically to freight transport, some of which may benefit both user groups. Most such investments are either in capacity expansion or in specific

provisions for passenger services. These have been allocated according to peak-time capacity utilisation.
In the Netherlands, the share of freight transport in total train kilometerage is about 10%. For peak hours we have taken a figure of 4%, based on the estimate of operators ProRail, thus allocating 96% to passenger transport. Because of the relatively minor extent of construction investments for the benefit of rail freight, we have allocated the costs of planning studies entirely to passenger rail.

Two datasets were available for assessing the magnitude of investments in new railway infrastructure: CBS statistics[21] for the years 1983-1996 and the data reported in the government's infrastructure budget for 1999 through to 2008. In the latter case we have restricted ourselves to the following budget items:

- 01.02.01 New railway infrastructure: reconnaissance & planning studies.
- 01.02.02 New railway infrastructure: implementation, Freight.
- 01.02.02 New railway infrastructure: implementation, Passenger

This means that any expenditures on new railway infrastructure booked under the codes 04.03 'Intermodal transport' or 01.03 'Regional/Local infrastructure' have been excluded from our analysis. We anticipate no railway projects being carried out under code 01.03, and in 2003 expenditure under code 04.03 totalled only about € 7 mln. As already mentioned, the High Speed Link and Betuwe 'mega-projects' have not been included either.

As in the earlier studies by CE [CE, 1999] and VU [VU, 2002] investments are reported here as capital costs, i.e. depreciation plus interest. Calculating with 4% annual interest and 35 years' depreciation and following the outlined allocation procedure then leads to an allocation of construction costs as shown in table 15.

table 15 Construction costs of railway infrastructure (mln €)

Year	Freight transport	Passenger transport[22]
2002	74	810

---

[21] *Historie Verkeer en Vervoer sinds 1899* via [CBS-Statline] and [CBS, 2002].

[22] In the Infrastructure budget, the heading 'freight' covers all expenditures solely and specifically for rail freight. All other expenditures have been allocated on the basis of peak-time capacity utilisation.

2.3.2 Maintenance and operating costs

In the study [CE/VU, 2004a,b], part of the cited IPS project, two sets of data are reported for the costs of railway infrastructure maintenance and operation:

- In the first variant, a distinction is made between costs derived using the 'standard cost' method and figures based on actual expenditures. Proceeding from a certain level of infrastructure maintenance ('Niet Verder Wegglijden'), ProRail has calculated the total cost of such upkeep, with an exact specification of all cost items involved and an indication of the extent to which they are variable [ProRail, 2003a]. The adopted approach served as the basis for [CE/VU, 2004a,b].
- The CE/VU study also reported a second variant in which the 'standard costs' were scaled down on the basis of actual expenditures in 2002, which in that year were about 83% of the former figure.

In consultation with the project principal, it has here been opted to calculate with 'standard costs' with no downscaling.

Renewal costs: two approaches

In the CE/VU study [CE/VU, 2004a,b] the costs of infrastructure renewal were also reported in two variant formats, which we shall now consider in a little more detail. Renewal costs, borne in the Netherlands by track administrators *Railinfrabeheer*, refer to the costs of replacing rail track at the end of its service life, including not only the actual rails but also the 'substructure', consisting of sleepers, ballast and points (cf. [CE/VU, 2004a,b]).

Track and substructure are replaced only after a substantial period of time: anything from 18 up to over 30 years, depending among other things on intensity of use. Decisions on renewal schedules are made with reference to track 'usage classes', which at the same time specify the requisite strength of the track section concerned. The higher the usage class, the greater the renewal costs, in two respects: the frequency of renewal will be greater, and renewal itself will be more expensive on each occasion, heavy-duty track being more expensive.

As so often with M/O costs, the relationship between the costs of track renewal and intensity of use is non-linear. In this particular case, this is due to the definition of 'usage classes'. However, this does not detract from the fact that if a cost-price approach is adopted, annual renewal costs will rise as a track section is used more intensively.

In [CE/VU, 2004a,b] variable M/O costs were defined as 'M/O costs that vary with traffic volume (vehicle km, tonne km, ship passages) for a given infrastructure capacity'. Proceeding from this definition, designation of costs as 'variable' does not depend on the point in the future when the costs are actually incurred. This is the approach we have taken here, and renewal costs have therefore been taken as part-variable. This is also the approach adopted in various international studies on this topic, as referenced in the annex to [CE/VU, 2004b].

The European Commission's position on infrastructure renewal costs is somewhat ambiguous. In the White Paper published in 1998, renewal costs were explicitly defined as being variable. Although Directive 2001/14 mentions (recovery of) costs associated directly with rail services, it does not pronounce on whether the costs of track renewal are to be included under this heading. There are therefore differences of opinion as to how the article in question is to be interpreted. The European Commission has instructed DG TREN (Transport and Energy) to set up a 'Rail charging taskforce', one of whose tasks will be to examine precisely the issue of whether or not renewal costs are to be deemed variable.

Here in the Netherlands, renewal costs are not considered variable by either the transport ministry or network operators ProRail [ProRail, 2003a]. Up to a point, both parties base themselves on the cited European Directive. They reason that, in practice, actual usage seldom deviates from forecasts and that it is therefore unusual for a track section to be put in a different usage class. On the rare occasions this does occur, the 'variability' of the costs in question is an extremely long-term affair. According to the ministry, until now it has not been standard practice to work with variable costs over such lengths of time. This is certainly the procedure adopted in (international) studies that focus on short-term marginal costs.

For further discussion of the international literature on the variability of renewal costs the reader is referred to annex G of [CE/VU, 2004b].

It still remains to be noted that defining variable costs as in [CE/VU, 2004a,b] probably means that the costs of renewing engineering structures should also be deemed part-variable in the longer term. This obviously holds in equal measure for railway and road infrastructure. However, we were unable to obtain any information on this particular category of 'renewal costs', let alone on the proportion to be designated variable. For railway as well as for road infrastructure, therefore, we were unable to include the costs of renewing structures under the heading 'variable costs'.

In this study we report the costs of railway infrastructure renewal in two variants:
1 The first variant proceeds from the study carried out as part of the cited IPS project and variable costs as defined there. This means that renewal costs are taken as being part-variable.
2 The second variant is based on current administrative practice in the Netherlands as well as in most EU member states, and takes only costs with short-term variability as being variable.

In the first variant it needs to be established to what *extent* renewal costs are variable. On this point we consulted a number of documents, including a study carried out for British Rail [BAH, 2000], in which recommendations are made as to the fraction of renewal costs to be considered variable, with a breakdown into four basic categories as shown in table 16.

table 16 Variable costs of railway infrastructure according to recommendations in [BAH, 2000]

Renewal	Percentage of costs variable
Track	95
Sleepers	25
Ballast	30
Points	25

Source: Adapted from table 5 of [BAH, 2000].

It is unclear to what extent the recommendations of [BAH, 2000] are valid for the variable portion of the renewal costs associated with the Dutch rail grid, one reason being that the British rail network is less intensively used than the Dutch. For lack of more accurate information, however, we have based ourselves on this source. It should be noted, then, that these particular data are not robust and that additional study is required on this issue.

We dispose over no reliable estimate of how renewal costs are to be apportioned to track, sleepers, ballast and points. In our calculations we have therefore assumed that all four items make an equal contribution, yielding a weighted average figure of 44%. Given estimated total renewal costs of € 190 mln – once again, these are (estimated) ‘standard costs’ – this means the variable portion amounts to approx. € 83 mln.

Variable costs

Here, we shall report only the relevant results from [CE/VU, 2004a,b], thereby indicating which costs are variable and which fixed. The data presented below were derived using the ‘standard cost’ approach. As discussed in the previous section, in the case of renewal costs two variants are reported.

The variable costs of railway infrastructure maintenance and operation are attributable to a wide variety of cost drivers, ranging from track wear and tear to the dynamics of station stoppage and electrical power distribution. We have categorised these costs under five headings according to the cost driver from which they derive, as follows:

1 Track and structures, comprising:
   a Track and structures.
   b Renewal thereof.
2 Stations:
   a Station complexes.
   b PA systems.
3 Signalling and traffic control:
   a Safety, signal boxes, crossings and telecommunications.
   b Central Traffic Control.
   c Decentralised areas.
   d Slot allocation and local planning.
   e Hump shunting control
4 Electrification:
   a Electrification.

5 Other category 2:
   a Freight terminals.
   b Marshalling yards.
   c Formation yards
   d Stabling yards.
   e Maintenance yards and facilities.

With reference to these categories, the variable costs of railway infrastructure maintenance and operation were allocated as follows:

- The cost drivers behind degradation of *Track and structures* are discussed at length in [CE/VU, 2004a,b]. In the present study it was decided ultimately to allocate these costs on the basis of tonne kilometres.
- The variable costs associated with *Stations* have been allocated to station users, i.e. rail passengers, based on number of station stops.
- In the case of *Signalling and traffic control*, the cost drivers are highly dependent on traffic volume. The variable costs have therefore been allocated according to train kilometerage.
- The heading *Electrification* covers the costs associated with operating and maintaining overhead cable systems, including the costs of wear and tear, but does not include the actual cost of electricity use. As the cost of power transport and distribution is above all a function of kWh consumption, we have opted to allocate these costs on the basis of annual kWh.
- *'Other category 2'* costs are associated with a range of cost drivers. In most cases the principal cost driver will be the intensity of use of the provisions in question. There is little understanding of these issues, however, and because this group of costs makes up only a very small proportion of total railway M/O costs, we have take a pragmatic approach and based allocation on train kilometerage.

For detailed calculations on the respective cost items, the reader is referred to [CE/VU, 2004a,b]. The results are summarised below in table 18. This table also shows the allocation of costs to passenger and freight rail transport, based on the volume data reported in table 17.

table 17 Rail traffic volumes, 2002 (mln train kilometres)

	Passenger[23]	Freight[24]	Other companies and unknown[25]
Train kilometres, total	118.2	10.2	0.5
of which, diesel	14.8	7.6	Unknown
of which, electric	103.4	2.6	Unknown
Train kilometres, billable (actual)	110.0	8.3	0
Gross tonne kilometres (incl. train weight, estimate)	28,400	9,700	Unknown

Source: Train kilometres [ProRail, 2003b], tonne kilometres: projected gross tonne kilometres for 2003 [ProRail, 2003a], diesel / electric split, passenger: [RIVM, 2002], freight: [Railion, 2004].

Fixed costs

In contrast to the variable costs, the fixed costs are unrelated to any particular cost driver. In the IPS, fixed costs were allocated according to capacity utilisation. In the case of rail transport, however, practical considerations have led us here to allocate these costs according to kilometerage. This holds for all three types of fixed costs distinguished in this study, viz.:

1. The fixed costs related to station use, totalling € 39.6 mln, and allocated entirely to passenger transport.
2. The fixed costs of electrical power supply, totalling € 39.9 mln, and allocated according to total train kilometres with electrical traction.
3. Other fixed costs, totalling € 600.1 mln, and allocated to freight and passenger transport in proportion to their respective kilometerage.

Table 19 summarises our allocation of the fixed costs of railway infrastructure maintenance and operation to passenger and rail freight transport.

---

[23] Following [RIVM, 2002] we have assumed that 12.5% of rail passenger kilometres are attributable to diesel trains.

[24] In the case of rail freight, allocation is based on information provided by Railion [2004], the largest carrier of rail freight in the Netherlands. As of June, 74% of train kilometres had been diesel-fuelled in 2004.

[25] These kilometres have not been included in the calculations, because the costs cannot be allocated to any particular party.

table 18 Magnitude and allocation of variable M/O costs, 2002

	Total variable costs, 2002	Allocation	Passenger	Freight	Rate per cost driver, based on standard costs
	mln €	mln €	mln €	mln €	€
Track and structures (renewal part-variable)	159.4	according to tonne km	130.1	29.3	0.0046 (per gross tonne km)
Track and structures (renewal non-variable)	76.3	according to tonne km	62.3	14.0	0.0022 (per gross tonne km)
Stations	30.9	Passengers according to no. of station stops	30.9	0	2.45
Signalling and traffic control	67.1	according to train km	61.8	5.3	0.52 (per train km)
Electrification	40.4	according to kWh	38.6[26]	1.6	0.03 (per kWh)
Other category 2	4.2	according to train km	3.8	0.3	0.03 (per train km)
Total (renewal part-variable)	*302*		*265.4*	*36.6*	
Total (renewal non-variable)	*218.8*		*197.5*	*21.3*	

table 19 Allocation of fixed standard costs (mln €)

	Total (mln €)	Allocation according to mln train km	Passenger	Freight
Fixed, M/O (renewal part-variable)	600.1	128.4 (118.2 + 10.2)	552.4	47.7
Fixed, M/O (renewal non-variable)	683.2	128.4 (118.2 + 10.2)	628.9	54.3
Fixed, stations	39.6	118.2 (118.2 + 0)	39.6	
Fixed, power supply	39.9	106.0 (103.4 + 2.6)	38.9	1.0
Total (renewal part-variable)	*679.6*		*631.0*	*48.6*
Total (renewal non-variable)	*762.7*		*707.5*	*55.2*

2.4 Waterway infrastructure

In the Netherlands, expenditures on inland waterways take place at two levels:

1 National government.
2 Local government.

---

[26] This is merely an indication of the split in Electrification costs between passengers and freight transport, based on train kilometres using electric traction, assuming 96% of kWh are for passengers and 4% for freight.

For expenditure at the national level, we had four basic sources of data at our disposal:

1 Infrastructure Fund documentation.
2 The Multiannual Programme for Infrastructure and Transport, MIT.
3 Netherlands Statistics, CBS.
4 The portion of the Transport ministry budget administered by the Road and Hydraulic Engineering Institute, DWW, as specified in DWW's budget application for 2005 to 2009.

Additionally, DWW provided us with a review of national government expenditure on waterway maintenance and operation in 2002, insofar as this M/O related to the shipping rather than water management function of waterways [DWW, 2004].

The only source of information on local government expenditure is CBS[27], in the form of statistics on local government outlay on both construction and M/O compiled up to the end of 2001.

However, none of this information can be used as its stands, because:

- The Infrastructure Fund makes no distinction between costs attributable to water management and those relating specifically to shipping.
- The CBS data on local expenditure do not specifically identify the costs of bridge and lock operation; when pressed for further information, CBS were also unable to tell us whether or not these costs are included under the heading 'maintenance'.
- Not all expenditure on waterways is attributable to commercial inland shipping.

On top of this, the figures in DWW's budget application are, in a sense, a 'wish-list' for a certain level of preventive maintenance rather than a budget for corrective maintenance, which would be a better reflection of reality.

Below, we discuss how we addressed these issues, considering first the construction costs and then those of maintenance and operation. With respect to the latter, we have once again based ourselves on the research for the IPS project 'Charging freight transport for infrastructure use'.

2.4.1 Construction costs

For construction costs we used the most recent time series available, again employing an interest rate of 4% and a 35-year depreciation period. Costs for inland shipping comprise investments in both capacity expansion (construction costs) and functional improvement. To allow a margin of error, we apportioned 95% of construction costs to inland shipping.

For investments by local government, we based ourselves on a time series from 1992 to 2001 [CBS, 2003]. To obtain a cost estimate for the year 2002, we used the average real growth rate over the past ten years.

---

[27] Compiled as Monthly Financial Statistics: [CBS 2003].

For investments in national waterways we augmented the CBS series with Infrastructure Fund data for the years 2002-2008. These latter data do not distinguish between investments for the benefit of shipping and those relating to water management. This breakdown is available in the MIT data, however, and from their data for 2001-2005 we estimated that about 65% of the construction costs cited in the Infrastructure Fund relate to actual waterway construction, with the rest relating to water management.

Besides general construction costs, there are also costs that relate to specific user groups. A case in point are the costs of bridge heightening, for the sole benefit of vessels with a high superstructure. In principle, these costs should be allocated analogously to fixed M/O costs relating to specific user groups. As such cost items are the exception rather than the rule, however, we have opted to subsume them under general construction costs and allocate them accordingly.

The annual costs of infrastructure construction and their allocation to inland shipping are shown in table 20.

table 20 Construction costs of waterway infrastructure (mln €, euros of 2002)

	Local government	National government	Total
Total, 2002	67	234	301
Allocated to inland shipping (95%)	64	222	286

2.4.2 Maintenance and operating costs

In this section we present a brief summary of the main results of [CE/VU, 2004a,b] concerning the costs of maintaining and operating Dutch waterway infrastructure. As in the case of rail, we distinguish variable and fixed costs.

Variable costs of national waterways

We take variable costs to be those that vary with changes in shipping or transport volume at a given infrastructure capacity [cf. [CE/VU, 2002a,b]). As discussed in that study, in the case of waterways variable costs are classed under three headings:

a Navigation[28].
b Vessels[29].
c Bridge and lock operation.

---

[28] 'Navigation' comprises buoying, beaconing, lighting installations, port illumination, signalling, radar reflector masts, radar stations, lighthouses, nautophones, navigation equipment for piloting operations and harbour authorities/traffic control.

[29] 'Vessels' comprises service vessels, patrol vessels, pontoons, passenger ferries, sounding vessels, monitoring vessels and so on.

The aggregate budget for the first two of these items is an estimated € 36 mln[30], of which € 29 mln for 'Navigation' and € 7 mln for 'Vessels'. The budgeted costs of bridge and lock operation are € 49.5 mln.

'Navigation' costs derive almost entirely from pilot stations/traffic control (about 50%) and buoying and beaconing (also about 50%). Buoying and beaconing to mark fairways is essential even when there is little shipping traffic. Although these costs may conceivably rise as fairway traffic swells, we have taken them as entirely fixed. The costs of pilot stations/traffic control, on the other hand, have been taken 100% variable, navigational assistance being superfluous when traffic is quiet and required more and more as shipping intensifies.
The direct cost drivers of the variable portion of these 'Navigation' costs (i.e. those of navigational assistance) include the number of pilot stations and their times of opening. Above all, though, it is the volume of shipping that ultimately dictates the bulk of these costs. The greater the kilometerage of a vessel, or the more often it sails a given route, the more it will make use of piloting services. We have therefore allocated the variable costs of navigational support on the basis of vessel kilometerage.

Expenditures under the heading '*Vessels*' relate partly to patrol vessels, used for rapid response in the case of incidents and, more generally, for monitoring and inspection. Although more of these vessels will be in use when it is busy, there will still be a need for them even when traffic is quiet. It is by no means straightforward to estimate the variable fraction of these costs. However, there is only a relatively small sum involved[31].
For the variable portion of 'Vessel' costs it is again the case that the direct cost drivers (such as number of vessels and usage thereof) are ultimately governed more than anything else by shipping intensity. We have therefore again allocated the variable part of these costs on the basis of vessel kilometres.

Of the € 36 mln for 'Navigation' and 'Vessels', approx. 80% is for inland waterways and the remainder for fairways and seaports. Of these costs 50% are variable, as we saw above. The total variable costs to be allocated to inland shipping are therefore approx. 0.80 * 0.50 * € 18 mln = € 14.4 mln.

We have taken the costs under the heading '*Operational*' to be part-variable. Although the costs of 24-hour bridge and lock operation are already at a ceiling, however intense traffic may become, if traffic drops beyond a certain point it may be decided to keep bridges and locks serviced for only part of the day. Costs that vary with traffic volume are defined in this study as variable. As a change in operating regime may have consequences for effective infrastructure capacity,

---

[30] There was no breakdown between 'Navigation' and 'Vessels' in 2002. For an estimate we based ourselves on DWW's budget application for 2005-2009 [DWW, 2003], thereby assuming that the share of variable costs cited there will hold for real-world M/O expenditures. The average annual figure quoted by DWW for 'shipping' as a whole is € 359.8 mln. This includes the costs of seaports and fairways. Of this sum, about € 41.3 mln relates to 'Navigation' and 'Vessels'. Scaling this down to € 313 mln yields a figure of € 36 mln (€ 28.9 mln 'Navigation' plus € 7 mln 'Vessels').

[31] Based on [DWW, 2003] we are talking about an average figure (2005 to 2009) of approx. € 8 mln, of which only part is to be allocated to inland shipping.

however, there is no good way of establishing when and whether we are dealing with cost variability or capacity effects. In our calculations we have therefore taken 50% of these costs as variable.

In 2002 the total 'Operational' costs of the national waterway network were € 55 mln. From [DWW, 2004] it follows that the kind of waterway 'operation' concerned relates almost exclusively[32] to shipping activity (rather than water management) and can be attributed to 90%[33] to inland waterways. The remaining 10% is for the operation of lighthouses and sea locks. Of the operating costs of inland waterways administered at the national level we have therefore allocated € 49.5 mln to inland shipping, taking 50% of this figure as variable.

When it comes to deciding how these costs should be apportioned between commercial and recreational shipping, there was little information to be found. In wintertime and at night (when tariffs are higher) there is little recreational shipping, at any rate. DWW estimate that 20% of the costs should be allocated to recreational and 80% to commercial shipping. Lacking more solid data, we have opted to use this split. The variable portion of the operating costs allocated to commercial inland shipping in this study is therefore (as a rounded figure) € 20 mln.

With respect to a breakdown of 'Navigation' and 'Vessel' costs by type of waterway, information is rather more plentiful. Using the data on vessel passages reported in [AVV/CBS, 2002] (cf. annex C) we calculated the approximate kilometerages of both commercial vessels and pleasure craft on the various classes of waterway, eventually arriving at the allocation shown in table 21.

table 21 Variable M/O costs, national waterways, 2002 (mln €)

Cost category	Commercial inland shipping	Recreational inland shipping	Total
'Navigation' & 'Vessels'	9	5	14
'Operational'	20	5	25
Total	*29*	*10*	*39*

Fixed costs of national waterways

As already mentioned, maintenance and operation of waterways is concerned not only with their shipping function but also with water management as well as environmental and other policy areas. In addition, it is only certain categories of water(way)s, viz. inland waterways, that are of relevance for the present study. More specifically, the costs of seaports and harbour and coastal fairways are beyond our scope.

---

[32] 'Operations' relating to water management and associated functions often entail no more than switching a pump on or off, which takes little time. In DWW's estimate, 0.69% of total 'operational' costs relate to water management.

[33] This follows from detailed calculations in [DWW, 2004].

The total M/O costs associated with the shipping function of nationally administered inland waterways amount to € 300.2 mln. This figure comprises two elements: total costs exclusive of 'operational' costs, and 'operational' costs.

In 2002 the total M/O costs associated with the water management and shipping functions together (*excluding* 'operational') were € 441.3 (items 02.02.03 and 02.02.04 of the Infrastructure Fund). CBS applies the rule of thumb that 71% of these costs are for the shipping function [CBS, 2004]. This is in good agreement with estimates based on DWW's budget application[34]. The total M/O costs associated with the shipping function of waterways are therefore € 313.3 mln. Of these costs, 20% are for seaports and their fairways[35] and there consequently remain 0.80 x 313.3 = € 250.7 mln attributable to shipping on inland waterways.

Table 22 provides a full review of the variable and fixed costs of Dutch national waterways and their allocation to commercial and recreational shipping.

Costs to local government

In addition to the costs associated with waterways administered at the national level, costs also arise in the administration of waterways at more devolved levels of government. Although these costs were not within the scope of the aforementioned IPS study, their derivation is described at length in one of the appendices of [CW/VU, 2004a,b]. Here, we shall limit ourselves to a brief summary of those results, referring interested readers to the original document.

Fixed M/O costs of locally administered waterways

According to CBS[36], in 1992 and 2001 the costs of maintaining and operating locally administered waterways were a nominal € 54 and € 108 mln, respectively. CBS were not able to tell us whether this figure included the 'operational' costs, as defined above for national waterways. We presume it does, though. Converting to euros of 2002 yields figures of € 70 and € 112 mln, respectively, which in turn implies a real growth rate of 5.4%. Applying this rate to the 2001 data gives a figure of € 118.5 mln for 2002.

In line with the percentage used for expenditures on national waterways (incl. 'operational'), we have here assumed that 81% can be attributed to inland waterways, or in other words € 96.2 mln. In the absence of data on the fraction of local-level M/O costs that are variable, we have taken the same percentage as for national waterways. At the national level, variable M/O costs (incl. 'operational') accounted for 13.1% of aggregate expenditure on inland waterways. Using the same percentage for 'local' waterways gives a figure of

---

[34] It should be borne in mind here that expenditures relating to the shipping function cannot be disentangled entirely from those relating to water management. DWW calls this 'conditional sale': you can't have one without the other.

[35] It follows from DWW [2004] that approx. 80% of the M/O costs for the shipping function are for inland waterways, with the remainder going to sea locks and seaport fairways.

[36] DWW cast these figures into some doubt, for on their information the province of South Holland alone was scheduled to incur costs of € 22 mln in 2004. Further study is needed to clarify matters, and the same holds for revenues to local government in this context.

€ 12.5 mln. At an estimate, then, the fixed M/O costs of locally administered waterways amount to € 96.2 - € 12.5 = € 83.6 mln.

We again allocated the costs between commercial and recreational shipping on the basis of capacity utilisation. Using data on vessel length (see [CE/VU, 2004b] for precise calculations) we calculated that 66.9% of the fixed M/O costs of locally administered waterways should be apportioned to commercial inland shipping, i.e. € 55.9 mln.

Variable M/O costs of locally administered waterways
There was no information available for assessing what share of the M/O costs of locally administered waterways should be taken as variable. We therefore used the same percentage as for national waterways. As calculated above, this yields an estimated figure of € 12.5 mln.

We allocated between commercial and recreational shipping on the basis of kilometerage/number of passages. This means 16% of the variable costs being allocated to commercial inland shipping, or a total of € 2 mln.

The charges levied in this connection (the bulk of them harbour dues) amount to approx. € 26 mln [NEA, 2002]. This figure is debatable. For lack of accurate information, we have taken an estimate of € 16 mln for the amount paid by the inland shipping sector.

The key fixed and variable cost data are presented in table 22. A synopsis of how these costs have been ‘peeled off’ is reported in annex D. The table below also includes a split between waterways covered by the Mannheim Convention (i.e. the Rhine basin) and those not covered by these provisions.

table 22 Allocation of M/O costs, national waterways (mln €) (2002 data)

	Total costs	Fixed costs	Variable costs	Of which for comer-cial shipping	Of which for recrea-tional shipping
M/O costs[1)]	250	236	14	9	5
of which, 'Mannheim' waters [2)]	(45)	(42)	(3)	(2)	(1)
of which, non-'Mannheim'	(205)	(194)	(11)	(7)	(4)
Operational (bridge and lock operation)	50	25	25	20	5
of which, 'Mannheim' waters [2)]	(10)	(5)	(5)	(4)	(1)
of which, non-'Mannheim'	(40)	(20)	(20)	(16)	(4)
Total, national waterways	300	261	39	29	10
of which, 'Mannheim' waters [2)]	(55)	(47)	(8)	(6)	(2)
of which, 'non-Mannheim'	(245)	(214)	(31)	(23)	(8)
Total, locally administered waterways	118	105	13	2	11

1 Total M/O costs for national waterways, as relating to the shipping function and specifically to inland waterways, excluding Operational.

2 Data on 'Mannheim' waters are from the Dutch Transport ministry.

In the 'efficiency' variant of our analysis we also calculated the variable costs per vessel kilometre. The total variable costs of Dutch inland waterways (both nationally and locally administered) amount to € 31 mln. Dividing this sum by the vessel kilometerage (table 23) yields a figure of € 0.47 for variable costs per vessel kilometre[37].

table 23 Shipping performance on Dutch waterways (mln km, % in brackets) [1)]

	Commercial shipping [3)]	Recreational shipping	Total
National waterways [2)]	54.8 (60%)	37.0 (40%)	91.8
Other waterways	12.1 (16%)	63.6 (84%)	75.7
Total	*66.9*	*100.5*	*167.4*

1 Vessel kilometres: [AVV, 2004b].

2 Percentages calculated on the basis of number of passages; see annex C.

3 54.8 mln kilometres on national waterways based on AVV data: pers. comm. Ernst Bolt, April-May, 2004 [AVV, 2004a].

---

[37] This figure differs from the € 0.53 calculated in [CE/VU, 2004b], which was solely for nationally administered waterways and was therefore obtained by dividing the costs of national waterways by the volume of inland shipping on those waterways.

3 Costs of traffic accidents

3.1 Introduction

In this chapter we examine the following issues:

- The procedure adopted to calculate the marginal costs of traffic accidents.
- Which costs items are to be deemed external.
- The procedure adopted to assign a value to traffic casualties.
- The allocation procedure adopted for accidents involving multiple parties.

The chapter concludes with a review of accident statistics for each vehicle category and the monetary value assigned in each case.

3.2 Overall strategy and methodology

To establish the marginal costs of traffic accidents we adopted an approach based on the medium rather than short term. This is because short-term marginal costs fluctuate so widely depending on traffic situation, time of day and so on as to make a short-term approach entirely impracticable. This choice means that marginal costs have been assumed to equal average costs. As the High Level Group on Infrastructure Charging has stated in a sub-report of [HLG, 1999a], moreover, the relation between traffic intensity and accidents is largely proportional, implying little difference in approaching marginal costs from a short- or medium-term perspective.

3.3 Structure of accident costs

In calculating the external costs of traffic accidents, it is important to duly consider the degree to which such costs have already been internalised through payment of insurance premiums. To the extent that is indeed the case, the costs are not passed on to society as a whole and do not therefore qualify as external. Over and against these, though, we can distinguish four categories of cost that can be designated external and which we therefore included in our analysis:

1. Transaction and prevention costs, i.e. those associated with police and fire departments, court hearings, accident investigations, public information and education, and congestion. Being external, these should all be allocated to (the parties involved in) traffic accidents[38].
2. The costs of medical care, return to work and in some cases staff replacement. The portion not reimbursed by insurance companies is external.
3. The cost of production losses. Here, a value must be assigned to persons no longer able to participate in economic production.
4. The costs of accident risks, reflecting willingness to reduce or avoid the risk of traffic accident. As we shall see below, this item features very prominently in the total external costs of traffic accidents. There is wide variation in the

---

[38] It may be noted that the Railway Police is paid in equal measure by rail operators (internal costs) and the government procurement department RIB (included above under the heading ‘maintenance/operation’).

values reported in the literature (with in some instances no value being given at all). We would stress that this has nothing to do with ‘the price of a life’, which is of course essentially infinite, but is concerned with valuation of the risks people are prepared to take[39].

3.4 Valuation of accident costs

In assigning a value to the external costs of traffic accidents we have taken as our point of departure the UNITE study [UNITE, 2000], undertaken as part of the 5th Framework Programme on the marginal costs of traffic. In this study, accident costs are valued according to the concept of the ‘value of a statistical life’ (VOSL) and, based on several European studies, UNITE recommends adopting a value of € 1.5 mln for this purpose (1998 market prices). To account for the ‘hard’ economic costs cited above (transaction/prevention; medical care; production losses) this figure should be increased by 10%. An additional correction is needed to account for loss of purchasing power, conversion of market prices to factor costs and, lastly, inflation. For the Netherlands this leads to an ultimate figure of € 1.5 mln for the value of a statistical life (2003 cost level).

With respect to the external costs of casualties requiring hospitalisation, we took the same approach as two earlier studies: [INFRAS/IWW, 2000] and [ECMT, 1998]. In both, the external costs of a hospitalised casualty is estimated as being 13% of the figure for a fatality. Based on its own research, the UNITE study sees no reason to deviate from this method and for the present study we therefore adopted a figure of € 227,500 per hospitalised traffic casualty.

3.5 Allocation of accident costs to vehicle categories

In the case of traffic accidents involving only one vehicle (a car hitting a lamppost, for example) allocation of external costs to a vehicle category is straightforward, costs simply being allocated in their entirety to the vehicle in question. With accidents involving more than one vehicle things are rather more complex, though. Here, we have opted for allocation based on the intrinsic risk of each vehicle category, as recommended in the cited UNITE study. Using the so-called ‘conflict tables’ provided in the CBS accident statistics, we worked out a distribution key for allocating the external costs of multiple-vehicle accidents.

This means we have rejected the option of allocating these costs according to respective degree of involvement in accidents (which, after all, stands in no relation to the magnitude of overall external effects) or ‘responsibility’ (which cannot be established by statistical means and is, arguably, morally untenable)[40].

---

[39] This might be termed the willingness to pay (WTP) per change in risk.

[40] This is also the position of the High Level Group in [HLG, 1999a], although these experts do indicate that it would be a good thing to have more information on the issue of ‘responsibility’. Allocation based on accident involvement would mean vulnerable parties (pedestrians, cyclists and others on two wheels) being allocated more costs, offset by less for the least vulnerable (e.g. heavy trucks).

The methodology used to calculate and allocate the external costs of traffic accidents is described at length in annex C.

3.6 Synopsis of traffic accident costs

Table 24 summarises how we have allocated the costs of traffic accidents, per billion vehicle kilometre, to the various vehicle categories[41]. The last two columns show the external costs of traffic accidents as calculated from these statistics and the values reported above.

table 24 Traffic accident statistics, associated external costs (per billion vkm, urban vs. rural) and financial valuation (€ct per vkm)

Vehicle category	Fatalities				Injuries				Value (€ct/v-km)	
	Urban	Rural			Urban	Rural			Urban	Rural
		Total	of which MRN*	of which SRN*		Total	of which MRN	of which SRN		
Passenger transport										
Car	8	5	3	8	160	45	27	64	5.0	2.0
Bus	46	34	20	46	311	105	77	128	11.9	6.9
Train	213				1,318				67.8	
Motorcycle	11	24	14	120	136	191	120	242	5.0	8.5
Moped, scooter	13	101	--	101	354	1,296	--	1,296	10.4	47.4
Freight transport										
LGV	4	7	3	10	55	66	47	78	1.9	2.8
HGV, sing. unit	42	18	9	43	187	79	50	164	11.6	4.9
HGV, tr/tr	40	16	7	56	150	53	37	130	10.5	3.9
Train	213				1,318				67.8	
Inland shipping	5				147				4.3	

* MRN / SRN: Main and Secondary Road Network, distinguished to provide additional information, but not used in the calculations.

On the face if it, table 24 may appear to contain a number of rather odd statistics, such as the relatively high figure for accidents on the railways, a mode of transport generally deemed fairly safe. It should be remembered, however, that these figures are per *vehicle* kilometre. Trains (and aircraft) carry vastly more passengers than cars, giving rise to an entirely different set of figures per passenger or tonne kilometre.

---

[41] These data are from [AVV, 2004b]. AVV base their statistics on police registration data, while CBS derive theirs from statistics on ‘unnatural mortality’ in consultation with AVV. According to the CBS data, the total number of fatal traffic casualties in 2002 was not 987 but 1,066. This would imply 10% higher total accident costs. Here we have taken the AVV data, however, because these are what are used in the ‘conflict tables’ needed for cost allocation.

4 Costs of emissions

4.1 Introduction

In this chapter we briefly review the costs associated with transport emissions of air pollutants and carbon dioxide. We first run through the specific emissions requiring valuation, and then discuss the emission factors employed and monetary values adopted for the cost analysis. A full account of the methodological choices as well as a full synopsis of all relevant data are to be found in annex F.

4.2 Strategy and method

Table 25 lists the atmospheric emissions included in this study, their respective environmental effects and whether a distinction has been made between 'urban' and 'rural' emissions for the purpose of valuation. An appropriate decision on this latter point depends on the environmental impact of the pollutant in question. Emissions with potentially significant health effects require differentiation between urban and rural, because in the former case a greater number of people will be affected per unit emission.

table 25 Synopsis of environmental effects of atmospheric emissions included in this study

Emissions	Environmental effects	Urban / rural distinction ?
CO_2	Forced greenhouse effect	No
NO_X	Acidification and eutrophication Photochemical smog formation (→ forced greenhouse effect) Health effects	Yes
PM_{10}	Health effects	Yes
HC	Photochemical smog formation (→ forced greenhouse effect) Health effects	Yes
SO_2	Acidification Health effects	Yes

4.3 Emissions by road, rail and inland shipping

Road

Our emission factors for road vehicles are based on data from CBS and the Traffic and Transport Taskforce (TTT). Besides fleet-average emissions for 2002, used to calculate total costs, in calculations for the efficiency variant we also took year-of-manufacture emission factors for 1993 and 2002.

Inland shipping

To calculate the total costs of inland shipping emissions, we used the 2002 emission data listed in the 'Inland Shipping Emission Protocol' [AVV, 2003]. This

Protocol, which sets out the new method adopted for calculating Dutch inland shipping emissions, identifies the following main factors as determining emissions: vessel size, waterway dimensions, vessel loading factor, river flow and direction, vessel speed and engine age. For the efficiency variant, we defined best and worst cases around these factors. Thus, the worst-case scenario is a large vessel, fully laden, sailing upstream on the River Waal. Under such conditions, average vessel speed is around 10 km/h (relative to the water). The best-case scenario is the smallest commercial vessel presently in service, unladen, going downstream, again on the Waal, giving a speed of 15 km/h. Per unit energy consumption, emission factors have been taken the same in both cases.

The Emission Protocol also reports a slight improvement in inland shipping emission factors between 1990 and 2000 as more modern engines were incorporated into the fleet. For the worst-case scenario we therefore additionally took emission factors for 1990-1994, and for the best-case scenario those for 1995-2000, both data sets as reported in the Protocol.

Rail
To compute the total costs of rail transport emissions, for freight and passenger transport by diesel train we used CBS emissions statistics, while for electric trains we calculated the emissions occurring during electrical power generation.

In the efficiency variant we took a constant figure for emissions per unit energy, as rail emission factors have likewise remained more or less constant over the past decade.

All modes
In the case of liquid transport fuels (i.e. for non-electric trains) we also included the emissions occurring during the fuel refinery and production processes.

4.4 Valuation of emissions

To assign a value to emissions of air pollutants and CO_2 we used the prevention cost method, augmenting this with direct valuation of damages. Table 26 summarises the monetary values adopted. These have been taken from an earlier (2001) CE study, '*Petrol, diesel and LPG: Balancing the environment and economy'* a comparative analysis of international studies on emissions valuation. The data were corrected for inflation.

table 26 Synopsis of financial values assigned to transport emissions, urban and rural (CO_2: € per tonne, otherwise € per kg)

Substance	Value of rural emission	Extra value of urban emission	Total value of urban emission
CO_2	56	0	56
NO_X	8	5	13
HC	3	4	7
PM_{10}	78	258	336
SO_2	4	7	11

Source: [CE, 2001]. Values are adjusted to 2002 price level

4.5 Synopsis of emission costs

Table 27 provides an overview of the calculated costs of CO_2 emissions for all categories of vehicle/vessel for the best and worst case scenarios in the efficiency variant (€ct per vkm) as well as the total costs (in million euro).

table 27 Value assigned to external costs of CO_2 emissions: 2002 fleet average (€ct per vkm) and total (million €)

Vehicle / vessel type	Best case (€ct per vkm) *	Worst case (€ct per vkm) *	Total costs (million €)
Road			
Car, petrol	1.13	1.69	847
Car, diesel	0.97	1.37	270
Car, LPG	0.88	1.32	76
Local/district bus (diesel)	5.31	8.85	40
Coach (diesel)	5.31	8.85	11
Motorcycle	-	-	19
Moped, scooter	-	-	10
LGV (diesel)	1.33	1.77	293
HGV, single unit < 12 t	1.77	2.65	18
HGV, single unit > 12 t	4.42	7.96	104
HGV, tr/tr comb.	5.31	8.75	226
Rail			
Passenger train, electric	12.90	50.57	24
Passenger train, diesel[42]	36.04	36.04	5
Freight train, electric	14.38	-	2
Freight train, diesel	-	200.26	7
Inland shipping			
Commercial shipping vessel	28.8	1,053.7	118

* For definition of best and worst cases, see multi-page table in section 1.6.4.

---

[42] Given the limited number of diesel passenger trains, for this category we do not distinguish a best and worst case.

Table 28 details the calculated costs of air pollutant emissions for all categories of vehicle/vessel for the best and worst case scenarios in the efficiency variant as well as total fleet costs, in million euro.

table 28 Value assigned to external costs of air pollutant emissions (NO_X, HC, PM_{10} and SO_2): 2002 fleet average (€ct per vkm) and total (million €)

Vehicle category	Best case (€ct per vkm) *	Worst case (€ct per vkm) *	Total costs (million €)
Road			
Car, petrol	0.13	6.05	651
Car, diesel	0.86	9.04	496
Car, LPG	0.27	2.69	71
Local/district bus (diesel)	6.18	65.03	152
Coach (diesel)	6.18	65.03	32
Motorcycle	-	-	159
Moped, scooter	-	-	199
LGV (diesel)	1.73	18.98	894
HGV, single unit < 12 t	3.44	23.96	69
HGV, single unit > 12 t	7.34	59.01	312
HGV, tr/tr comb.	8.69	68.73	550
Rail			
Passenger train, electric	3.71	21.32	4
Passenger train, diesel[43]	118.39	118.39	23
Freight train, electric	6.06	-	0
Freight train, diesel	-	1,679.12	29
Inland shipping			
Commercial shipping vessel	87.30	3,487.40	384

* For definition of best and worst cases, see multi-page table in section 1.6..4.

---

[43] Given the limited number of diesel passenger trains, for this category we do not distinguish a best and worst case.

5 Costs of noise nuisance

5.1 Introduction

In this chapter we turn to traffic noise. We first calculate the total costs of noise nuisance associated with each individual mode of transport and then allocate these over the various categories of vehicle and vessel. In doing so, we use weighting factors to account for the major differences in vehicle noise emissions, heavy goods vehicles usually producing considerably more decibels than passenger cars, for example. A detailed account of the costs calculated for noise nuisance and how these costs were allocated is provided in annex G.

5.2 Strategy and method

The method most commonly used to calculate the external costs of noise nuisance, and at the same time a theoretically sound one, is based on the impact of such nuisance on property prices, as reflected in the difference in price between a house near Schiphol Airport and a similar house in a quieter area. The problem with this method, though, is that it is hard to distinguish the influence of noise on housing prices from other factors. In our present context, particularly, prices may well also be affected by other traffic-related factors such as air quality[44].
Alternative methods for estimating the external costs of noise nuisance are basex on the concept of 'stated preference'. The methods most frequently adopted are 'willingness to pay' (WTP) and 'willingness to accept' (WTA), as these enable more ready quantification of noise nuisance. In this study we use the WTP method.

We estimated noise costs per vehicle kilometre by calculating, for each mode of transport, the total noise-affected population and then multiplying this figure by a cost value for noise nuisance. The latter was obtained by multiplying the number of decibels above a certain cut-off value to which an individual is exposed by a fixed price per decibel per person per annum, derived using the WTP method[45].
Within each transport mode, total noise costs were then allocated to the constituent vehicle categories using weighting factors and the annual traffic performance of each category.

---

[44] The Overschie district of Rotterdam is a case in point.

[45] In doing so, we have followed the international convention that noise below 55 dB causes no nuisance and that noise above 65 dB causes health damage as well as nuisance.

5.3 Total noise costs

The total noise-affected population is greatest for road transport, followed by rail. Although inland shipping vessels also produce noise, it causes little nuisance as population density is low in the direct vicinity of waterways. We have consequently adopted a value of zero for the external costs of inland shipping noise, in line with other European external cost studies such as [UNITE, 2000] and [INFRAS/IWW, 2000].

The data used for road and rail noise-affected populations are based on RIVM statistics for the years 2000 to 2003. From these data we calculated the number of people affected in each 5 dB(A) increment, or ‘noise class’, taking the class mean as the average noise nuisance for that class. Per-decibel damage was then assessed on the basis of a comparison of the results of international studies. A wide range of values are cited in the literature for willingness to pay for noise reduction and on this point we chose to follow the recommendations of the ECMT, taking a value of € 25 per dB (above the cut-off value) per person per annum, the figure also used in the INFRAS/IWW study. Because noise levels over 65 dB also cause health damage, for the higher noise classes we added an additional ’mark-up’. The latter were derived from the INFRAS/IWW 2000 study and range from € 12 per dB at levels above 65 dB(A) to € 17 per dB above 75 dB(A).

A wide range of studies have shown that for a given decibel output, noise nuisance due to rail transport is experienced as less of a nuisance than road traffic noise. To correct for this effect, rail transport is often given a 5 dB ‘discount’. A recent study for the European Commission, for example, stipulates that the cut-off point below which noise nuisance need not be assigned an economic value should be 55 dB(A) for road traffic and 60 dB(A) for rail. Below these levels, in other words, there is presumed to be zero damage [Navrud, 2002]. In our analysis we have used this higher cut-off value of 60 dB for noise due to rail transport. In the case of health damage, though, we have take the same cut-off value for all transport modes (see above).

5.4 Noise costs per vehicle category

The total costs of noise nuisance were calculated using weighting factors and the share in overall traffic volume of the constituent vehicle categories. Weighting factors are necessary here because heavy goods vehicles generally produce far more noise than passenger cars, particularly in built-up areas. To arrive at suitable values for these factors we first reviewed the latest scientific findings and studied the available international literature. This yielded no satisfactory solution, however, and we therefore turned to a protocol for measuring and calculating road traffic noise issued by the Environment ministry, VROM, using the reference values adopted there to derive weighting factors for the various vehicle categories. One striking observation is the far greater spread of values in urban areas compared with rural areas.

Here we have worked with an ‘urban’ versus ‘rural’ split, not so much because vehicles produce more noise in built-up areas, but because more nuisance is caused per unit noise emission. We have therefore assumed that 80% of the total costs of noise nuisance are to be designated ‘urban’ and 20% ‘rural’.

5.5 Synopsis of noise costs

Table 29 shows the calculated costs of noise nuisance for all vehicle categories in the urban and rural environment.

table 29 Value assigned to external costs of noise nuisance (€ct per vkm and million €)

Noise nuisance	Urban (€ct per vkm)	Rural (€ct per vkm)	Total costs (million €)
Road			
Car, petrol	0.9	0.1	208
Car, diesel	1.1	0.1	89
Car, LPG	0.9	0.1	24
Local/district bus	8.6	0.4	31
Coach	8.6	0.4	4
Motorcycle	11.6	1.7	141
Moped, scooter	3.5	0.5	66
LGV	1.3	0.2	138
HGV, single unit < 12 t	8.6	0.4	32
HGV, single unit > 12 t	11.6	0.6	56
HGV, tr/tr comb.	14.5	0.7	84
Rail			
Passenger train	160.4	12.5	57
Freight train	641.5	49.9	20

6 Costs of direct and indirect land take

6.1 Introduction

This chapter deals with the costs of direct and indirect land take by transport infrastructure. First, in section 6.2, we define exactly what we mean by these two terms and consider how (the pricing of) land take is to be approached from the two perspectives of fairness and economic efficiency. Sections 6.3 to 6.5 are concerned with the direct and indirect land take associated with road, rail and inland shipping, in that order. Section 6.6 presents a summary of the land take involved and how it has been allocated to the various vehicle categories. Section 6.7 then considers the respective values to be assigned to 'urban' and 'rural' land take, while section 6.8, finally, reports the overall results of the cost calculations. Augmenting this chapter are Appendices H and I, dealing respectively with the funding of urban and rural infrastructure and the value assigned to direct and indirect land take in each case.

6.2 Definitions and basic premises

6.2.1 Definitions

Direct land take
In this study we use the term 'direct land take' to refer to the area of land physically occupied by transport infrastructure. A distinction can be made here between private and public land take, as exemplified by a private car park and a city street. Because the costs of private land take have already been internalised – the property having been paid for by its owner – these have been ignored in the present analysis, the prime aim of which is to assess transport sector coverage of its costs. This is not to imply that private parking causes no 'visual intrusion', with the costs implied. However, our analysis does not extend to this category of impact.
To arrive at quantitative figures for direct land take we have generally proceeded from statistics on the length of road, rail and waterway networks, multiplying these data by minimum specifications (minimum roadway width for a given number of lanes, etc.) to yield square kilometre data. The resultant figure for direct land take can therefore be seen as the *minimum* area occupied by the infrastructure network in question.

Indirect land take
The term 'indirect land take' refers to the area of land adjacent to transport infrastructure that is subject to development restrictions in connection with any of three issues:

- Transportation of hazardous substances.
- Noise zones.
- Sight zones (for inland shipping only).

With respect to the transportation of hazardous substances, the Dutch Transport ministry distinguishes two types of risk that may mean restrictions being set on development. First there is individual risk, defined as the probability of a hypothetical, unprotected person sustaining a given level of harm in the event of the hazardous substance escaping, exploding or burning. Second there is group risk, defined as the probability of more than N casualties arising for various categories of casualty. For individual risk, a physical risk contour can be defined. Group risk is far more diffuse, however, being co-determined by such local factors as building density, building class and so on. As a consequence, standards are set on the basis of individual risk contours.
In both cases – individual and group – risk contours are drawn up, defining areas in which restrictions on land take apply, which are strictest for housing and less so for offices and other commercial buildings.

Noise zoning is another important determinant of indirect land take. Under the Dutch Noise Act, areas exposed to noise levels above 50 dB(A) are held to suffer noise nuisance. In the case of the Netherlands' road grid, an overall area of 2,900 km^2 is thus affected, necessitating a variety of at-source (road and vehicle) measures, including use of porous asphalt concrete for road surfaces, enforcement of speed limits, disincentives for car use, vehicle noise standards, baffle boards or other noise screens, noise insulation in dwellings and so on. Beyond these measures, no 'hard' restrictions on land take are in force, though, as local authorities can apply to the provincial executive for exemptions on building within this 50 dB(A) contour.
At the 70 dB(A) contour strict limitations do come into play, however, and within this area no new development is permitted.
The problem remains, though, that noise is cumulative – coming from railways, industry and other sources besides – so that the individual contribution of road traffic cannot be measured.

It is important that indirect land take be factored in to the analysis only when there are indeed actual restrictions on land take in place, which in practice means including only land on which all development is explicitly prohibited. We have therefore ignored those areas where there may be noise or other forms of nuisance, but no actual restrictions on land take. (Needless to say, the nuisance itself has been incorporated under the headings of noise nuisance, emissions and so on.)

6.2.2 Basic premises

In the case of both direct and indirect land take, there will inevitably often be tensions between the efficiency and fairness perspectives on the social costs being passed on by users of the transport infrastructure in question. These tensions arise from the fact that (direct and indirect) land take are often short-term givens – 'short term' here being used in the economist's sense and thus not referring to any particular time frame (less than a year, say) but to the question of whether or not a marginal change in infrastructure use at some moment in time (one extra journey, say, or one extra vehicle km, depending on the definition adopted) will lead to a change in land take. If such a marginal change does not affect land take, it would upset economic efficiency to pass on the unpaid land take costs in the form of a user charge, even though this might be deemed desirable for reasons of fairness. In other words, average (per user) land take costs are not then an appropriate yardstick for an average optimum charge level.

Does this then mean that the costs of land take cannot be passed on to users without upsetting efficiency of usage? Not necessarily, and this is where long-term social cost functions come into play. ‘Long term’, again in the economic sense, is defined as the period over which all decision variables, i.e. including the capacity of the infrastructure and thus direct land take, are deemed amenable to change. Obviously, this will only be desirable if the infrastructure becomes congested beyond a certain level. In that case, ‘optimum’ policy will consist in introduction of an optimum congestion charge combined with optimum capacity-setting. A decision on the latter naturally at once draws in the issue of land take costs, which will have to be weighed up against the benefits of capacity expansion. The greater the local costs of land take, the lower optimum capacity will be and the higher the optimum user charge. At the optimum, therefore, the amount charged per m^2 land take will be positively correlated with the cost per m^2 land take and under certain, technical conditions these will be precisely equal. By a roundabout route (a congestion charge) users as a whole will then pay an aggregate charge precisely equal to the total cost of the land take involved, thereby ‘automatically’ resolving the tensions between the fairness and efficiency perspectives. This is not because land take costs are passed on directly in a charge, however, but because the congestion charge and optimum land take are now calculated at one and the same time and result in equality of optimum charge revenues and optimum capacity costs (including the costs of land take).

In conclusion, the non-user-paid costs of land take reported below should not be seen as providing any direct indication of optimum charge levels.

6.3 Land take by road infrastructure

6.3.1 Direct land take

Our calculations of the direct land take associated with roads encompass all traffic lanes (incl. bus lanes) and verges, but excluding roundabouts, major traffic intersections, acceleration/deceleration and other ‘weaving’ and turning lanes, and bus-stops[46]. In urban areas we also excluded pavements, town squares and ‘fancy’ streets from our calculations, as these are all mainly for the benefit of pedestrians. Table 30 summarises the land take associated with the key elements of Dutch road infrastructure, with these figures representing a lower bound.

---

[46] If one assumes an additional 10% land take for roundabouts, intersections and the various traffic lanes cited, this would add almost 22 km^2 to the direct land take of national and provincial road infrastructure.

table 30 Land take of Dutch road infrastructure (km^2)

	Urban	Rural
Metalled roads	356.7	682.9
Unmetalled roads	3.3	65.1
Parking space	119.1	n.a.
Motorway service areas	n.a.	15.8
Total	479.1	763.8

In this study we have allocated the costs of urban and rural road infrastructure separately. It is important to reiterate in this connection that the prime concern of our analysis here is to establish whether the transport sector 'pays its way' in terms of the costs it causes. There is a fundamental difference in the way 'urban' and 'rural' roads are funded, however, as set out briefly below. The issue is discussed at greater length in annex H.

In the Netherlands 'rural' roads are centrally funded, i.e. paid for by the taxpayer. There is consequently virtually no direct linkage of interests between the users of a particular item of infrastructure and those funding it (it is a very select group of taxpayers indeed that actually use any particular item). Of course, these expenditures are to some extent offset by revenues from fuel excise duty and vehicle circulation and purchase taxes, all of which go to the national treasury, but in general there is no direct linkage between those paying and those enjoying the resultant benefits. From the efficiency perspective, then, there may be good reason to charge infrastructure users for use of this category of 'rural' road infrastructure.

In urban areas, on the other hand, land purchase for transport infrastructure as well as the costs of building new local infrastructure (and often major elements of supra-local infrastructure, too) are paid out of the revenues later accruing from development. The costs are consequently paid for by the users of the area in question, i.e. local residents and businesses. In this case, then, the linkage of interests between those paying and benefiting is more direct, particularly when the infrastructure in question is used mainly by local traffic. The costs of urban transport infrastructure can therefore be said to be borne by those to whom the services are provided and are thus covered, at least in part, by an interested party. The more this holds, the less correct and 'fair' it becomes to pass on these costs a second time to those same parties, but now as infrastructure users. On top of this, there will probably also be a significant overlap between those for whom the infrastructure services are provided and those indeed using them. In residential districts, after all, it is residents themselves who are responsible for much of the traffic. To levy a user charge for local infrastructure would then be a form of double-charging. This might – again from the perspective of fairness – be reimbursed to home owners and/or businesses, as appropriate.

The weakest link in all these calculations is the direct land take of parking space. In the Netherlands there is no quantitative review of the total amount of public parking space. There are three basic modes of parking: public car parks (open-air, multi-storey), roadside parking (parking bays) and private car parks. For the purposes of the present study, concerned with financial valuation, we are interested solely in public car parks and roadside parking along the public highway. The latter has already been included in calculations of the land take of the road network itself. In the case of private car parks (in residential areas, at shopping centres, outside business premises), the parking space has already been duly paid for on purchase by the property owner. In the case of privately owned multi-storey car parks, it is users who pay for the parking space.

The land take we have allocated here is for parking in dedicated public parking bays in residential districts. Being in urban areas, these are intended for – and have therefore been allocated to – passenger cars and light goods vehicles. Even though parking fees may be charged, in many cases the full costs may not be recovered, so that costs and benefits must be included in the analysis (cf. [IOO, 2002]).

The referenced IOO study estimates the number of public parking spaces in the Netherlands at a minimum of 8.9 million (possibly 12 million), with 81% of these on or along roads, 17% in open-air car parks and 2% in multi-storey car parks [IOO, 2002]. Of these 8,864,000 parking spaces, 137,000 are on private property, though, leaving 8,727,000 on publicly owned land. This latter category of ‘public’ parking space covers an area of 164.2 km^2 altogether. However, this includes roadside parking. In this study we have therefore used the land take figure from the VU study, which does not include parking on or along the public highway.

The costs of land take for petrol stations, sales areas, servicing facilities, garages and suchlike have in all cases already been internalised (the activities in question taking place on privately owned land) and have not therefore been included in our analysis. The only exception here are motorway service areas, which are built on public land.

One other specific vehicle category included in the analysis are mopeds. Since 15 December, 1999, mopeds are in principle no longer permitted to use cycle tracks, unless considerations of traffic safety prevent them from using the public highway. This is the case on roads with a speed limit over 60 km/h. Local councils are free to deviate from this general rule, however, allowing them to restrict moped traffic to cycle tracks even when a lower speed limit is in force. According to a study by the Dutch Cyclists Union ENFB, many local councils make use of this provision, with 17% of councils surveyed indicating that mopeds were permitted on over a quarter of cycle tracks. Away from urban areas, the difference in speed between mopeds and other traffic will generally be such that mopeds are likely to be delegated to cycle lanes. At the same time, though, in rural areas there are often dedicated cycle tracks through woods and other natural areas.

The direct land take associated with urban and rural cycle tracks/lanes amounts to 25.3 km^2 and 40.3 km^2, respectively. In both cases this is almost 5% of the total amount of land take of road infrastructure. When asked, ENFB said their study did not allow them to estimate the proportion of cycle tracks/lanes, urban and rural, on which moped traffic was permitted. Allocation must therefore remain fairly arbitrary and we have here opted for 25% allocation in urban areas and 50% in rural areas.

6.3.2 Indirect land take

As defined here, the ‘indirect’ land take of road infrastructure arises as a result of the zoning regulations associated with transportation of hazardous substances and noise emissions.

Along parts of the routes on which hazardous goods and substances are transported there are physical planning restrictions in force. These routes coincide largely with the fine-meshed structure of LPG transport and distribution on the Dutch road grid. According to the Transport ministry, the land take associated with road transportation of hazardous substances amounts to 32.7 km^2 in all [V&W, 2003a]. This figure includes the land occupied by the roads themselves, however. The ministry’s Freight division told us that deduction of this figure would leave some 21 km^2 to be designated as indirect land take.

Besides transportation of hazardous substances there is also LPG storage at filling stations. The licensing conditions for these filling stations are stipulated in the ‘LPG at Filling Stations Decree (Nuisance Act)’ of 11 March, 1988. In this case, then, there are no restrictions on use of adjacent land, as the surrounding area does not have to adapt to the filling station, which is simply refused a license if it fails to meet the conditions in force. In other words, the associated costs have already been internalised by means of regulation. From this perspective, LPG installations at petrol filling stations are accompanied by no indirect land take and in our analysis this aspect has therefore been ignored.

With respect to noise zoning, for the purpose of this study the National Institute for Public Health and the Environment (RIVM) calculated the total area of roadside land falling within 70 dB(A) contours. The resultant area of indirect land take amounts to some 400 km^2, about 65 km^2 of which is in urban areas. There are two problems here when it comes to allocation. In the first place, although planning regulations stipulate that no new development is permitted here, particularly in urban areas there will be very little space available for development anyway. Secondly, the development restrictions associated with noise emissions overlap to a major extent with those for hazardous goods transport, while the former need to be allocated across all vehicle categories and the latter solely to freight vehicles.

The third category of indirect land take, sight zones, is only relevant for inland shipping and is discussed below in section 6.5.2.

6.4 Land take by railway infrastructure

6.4.1 Direct land take

The area of land occupied by the rail network itself has been calculated by summing the areas of all plots owned by track operators ProRail. In principle this covers all track sections in the Netherlands, including 7-metre zones on either side of the track mid-line as well as station platforms and access to them. Stations, offices, other buildings and associated land are the property of the company *NS Vastgoed* (part of Dutch Rail), with whom ProRail has a contract for shared use.
As the latter are under private ownership, rail passengers and rail freight shippers may be assumed to pay the costs of land take via fares and tariffs. In other words, costs are already being passed on to customers. It is the same situation as for land take by private parking areas, discussed above (and how airport land take was dealt with in earlier studies).
The land owned by track operators ProRail does need to be allocated, though, and the area in question was duly calculated for us by the company's land registry department. In addition, a limited fraction of this area must be allocated to one or other of ProRail or *NS Vastgoed*, viz. urban stations and the property on which they stand. However, this is only a very limited area (0.179 km^2) and it is by no means clear to which party it should be allocated. This particular subcategory of land take has therefore been omitted from our analysis.

The final issue with respect to direct land take by railway infrastructure is the major difficulty of establishing the right urban/rural split (a task that would require manual flagging of the GIS database for the entire country). ProRail estimates that about 25% of the land falls into the 'urban' category. Based on this figure, the rail network occupies 18.6 km^2 of urban land and 55.9 km^2 of rural land.

6.4.2 Indirect land take

When it comes to rail transportation of hazardous goods and substances, it is the so-called individual group risk that sets the zoning boundaries, along a contour indexed to transport of flammable substances. In the Netherlands there are 21 routes along which this individual group risk is exceeded (that is, posing a risk greater than 10^{-6} per annum). According to Transport ministry data, indirect land take along these routes amounts to 4.1 km^2, excluding the track itself [V&W, 2001].

Provisions regarding noise zoning along railways are the same as for roads, with a blanket ban on any new development at noise levels above 70 dB(A). According to RIVM, approx. and area of 150 km^2 lies within this 70 dB(A) contour, of which about 50 km^2 is to be designated 'urban'. In the case of rail, too, in urban areas there is a degree of overlap between zones affected by hazardous substance transport and the limited amount of physical space available for development.

6.5 Land take by waterways and allocation to inland shipping

6.5.1 Direct land take

The direct land take associated with inland shipping has been calculated as follows. The waterways themselves have not been allocated at all, as their principal function relates to water management. Only the area physically occupied by infrastructure specifically dedicated to inland shipping has been allocated under the heading ‘direct land take’. It comprises two elements: the area occupied by non-port anchorages and waiting areas, totalling 3.15 km^2, and harbour basins: the 16 largest seaports, 47.41 km^2, and 11 largest inland harbours, 9.15 km^2. All these data were furnished by the relevant government records office (*Meetkundige Dienst Eindhoven*), which claims they are 95% accurate. For the largest seaports, 20% of the cited area has been allocated to inland shipping as co-users. The total area allocated therefore comes to 21.78 km^2.

6.5.2 Indirect land take

Very few zoning restrictions arise from waterway transportation of hazardous goods and substances, and those that are in force have only a negligible impact (along the Lek Canal, part of the Amsterdam Rhine Canal and a small section of the ‘Old’ Maas [V&W, 2003b]). The zones in question lie entirely within ‘sight zones’ (with the exception of the Old Maas; see below) and have therefore been ignored. Although more extensive zoning restrictions apply on the Western Scheldt, these relate to hazardous goods transportation by sea-going vessels and are not allocable to inland shipping.

The aforementioned ‘sight zones’ derive from the ‘Waterway Directives’ of the Dutch Waterway Administration Committee [CVB, 1999], which stipulate that, to guarantee vessels an unobstructed navigational view, all waterways must be bounded by an undeveloped zone varying in width from 10 to 30 metres, depending on waterway class (I to IV/V) concerned. Besides waterway class, the width of the zone is also determined by a ‘rural’ vs. ‘urban’ setting. As approximately 10% of the Netherlands is urbanised, we have defined 10% of the length of the waterway network as ‘urban’ and the remainder as ‘rural’.
Fairways have *not* been included under the heading ‘indirect land take’, as these are in open water, *nor* have rivers in rural areas, where a natural sight zone is generally present in the form of an undeveloped floodplain. In urban areas, in contrast, where rivers are bounded by embankments and quays, due allowance does need to be made for sight zones.

The total length of Class I-III waterways in the Netherlands is 2,647 km, associated with 103.2 km^2 indirect land take, calculated on the following premises:

- Canals only (with urban/rural allocation).
- Rural 90%, urban 10%.
- Sight zone: rural 20 metres, urban 15 metres.
- Sight zone on either side of canals.

The total length of Class IV/V waterways is 1,940 km (excl. fairways, but incl. 841 km rivers), associated with 67.1 km^2 indirect land take, calculated on the following premises:

- Canals: rural/urban allocation; rivers: urban only.
- Rural 90%, urban 10%.
- Sight zone: rural 30 metres, urban 20 metres.
- Sight zone on either side of canals/rivers.

The total figure for indirect land take due to undeveloped sight zones therefore comes to 170.3 km^2, of which 15.7 km^2 is to be designated ‘urban’.

6.6 Synopsis of allocable land take

Table 31 provides a synopsis of the direct and indirect land take to be allocated, on which we shall briefly elaborate below.

table 31 Synopsis of land take to be allocated (km^2)

			Urban	Rural	Allocation
Road	Direct	Roadways Parking space Service areas Cycle lanes	360 119.1 n.a. 25.3	748 n.a. 15.8 40.3	Full / partial Full Full Partial
	Indirect	Risk contour Noise contour	2.1 65	18.9 335	None Partial
Rail	Direct	Track & other infrastructure	18.6	55.9	Full
	Indirect	Risk contour Noise contour	4.1 50	n.a. 100	None Partial
Inland shipping	Direct	Harbours & anchorages	21.8	n.a.	Partial
	Indirect	Sight zones	15.7	154.6	Partial

The direct land take associated with roads has been allocated across all categories of road vehicle. A problem here is how to allocate the ‘rural’ moiety. In urban areas it is clear, in the Netherlands at any rate, that the costs of land purchase and consequently land take are not included in the infrastructure construction costs booked by municipal authorities[47]. ‘Urban’ land take has therefore been allocated as appropriate. In rural areas, however, it is unclear to what extent expenditures on land purchase for infrastructure are booked as construction costs. This applies across the board, whether the roads are administered at the national, provincial or local level. Netherlands Statistics (CBS) is unable to provide clarification on this point, because the data furnished by all three echelons of government are inadequate for the purpose. All we can do, then, is report the costs of ‘rural’ land purchase as a separate item under ‘fixed costs’.

---

[47] In municipal accounts, land purchase and infrastructure are booked as separate items.

Parking space has been allocated to passenger cars and LGVs only, HGVs being assumed to park privately rather than on the public highway.

Motorway service areas have been allocated across all vehicle categories except for mopeds, which are banned on motorways.

Cycle tracks and lanes have been allocated to mopeds to 25% in rural areas and to 50% in urban areas (outcome of expert workshop). In annex I we report the margins that would arise if cycle lanes were either not allocated at all or in their entirety.

When it comes to indirect land take by roads, we have not allocated the area within the risk contours for hazardous substance transportation. Given the nature of the area thus defined, it is extremely plausible that it lies entirely within the area already defined by noise contours (outcome of expert workshop). The land take defined by risk contours should really be allocated entirely to HGVs. However, because we have allocated noise-zone land take on the basis of vehicle noise emissions, the associated costs accrue largely to HGVs anyway. The noise weighting factors adopted for allocation purposes are a weighted combination of the ‘urban’ and ‘rural’ factors used for allocating the costs of noise nuisance (see table 32 and table 49 in annex G.)

table 32 Noise weighting factors for road and rail transport

Road	
Car	1
Bus	5.8
Coach	6
Motorcycle	8
Moped, scooter	4
LGV	1.5
HGV, single unit < 12 t	3
HGV, single unit > 12 t	6
HGV, tr/tr comb. > 12 t	10
Rail	
Train, electric, passenger	1
Train, diesel, passenger	1
Train, electric, freight	4
Train, diesel, freight	4

In urban areas, noise zones mean restrictions on development. It has been assumed there is very little, if any, urban space available for such development and that such restrictions will bear mainly on commercial and industrial estates (ignoring the relatively minor area occupied by parks and other such open urban spaces). In the absence of such restrictions, these estates would be rezoned to permit housing and other development. As most of them lie along main roads (and railways) where noise restrictions are in force, we have assumed, arbitrarily, that 10% of the urban area located within noise contours would be potentially eligible for a change of function if there were no longer any restrictions on

development (outcome of expert workshop). Of this figure of 10%, we have assumed half is for public amenities such as infrastructure non-transport infrastructure and parks, leaving 5% for ultimate allocation.
In rural areas, too, we have allocated only a certain fraction of noise-zone land take. As mentioned earlier, approximately 10% of the Netherlands is urbanised. In rural areas this obviously converts to a much lower figure, say 2%. It is therefore to be expected that if zoning restrictions on development were removed, no more than this average fraction of land would become eligible for development. In rural areas we have therefore allocated 2% of indirect land take to vehicle categories.

With respect to railway infrastructure, we have allocated only the land take of the track and platforms on land owned by ProRail, as the costs associated with NS-owned land are already passed on to passengers or freight shippers in fares and tariffs. Indirect land take has been allocated using the same method as for roads.

With respect to waterways, the only form of direct land take that has been allocated to inland shipping is that associated with ports and anchorages. In addition, the costs of indirect land take associated with sight zones have been allocated. In urban areas 50% of this zone has been designated potentially eligible for development (in the absence of other zoning restrictions), with the other 50% taken to be necessary for non-transport infrastructure parks and so on. In rural areas, 2% of the indirect land take has been allocated, as in the case of road and rail.

6.7 Valuation of land take

A crucial phase of this study was establishing the price to be assigned to land take, both direct and indirect, and deciding the appropriate framework for such an exercise. These issues were addressed in two expert workshops. Information on property prices was obtained in telephone interviews with representatives of 13 municipal authorities, augmented with the results of a study on parking in the Netherlands [IOO, 2002] and information from websites for buying and selling land in agricultural districts. A detailed justification of the choices ultimately made is provided in annex I.

Table 33 summarises the financial values adopted for direct and indirect land take.

table 33 Financial value of land (€ per m^2)

	Urban	Rural
Direct	30	7
Indirect	150	1

The reported values per m^2 direct land take in urban and rural areas are a reflection of the average cost of acquiring farmland for conversion to, respectively, other usage (in Dutch planning parlance, from ‘green’ to ‘red’) and rural infrastructure (‘green’ stays ‘green’). Note that the € 30/m^2 average taken for urban land take is far less than the market price paid by consumers for a building plot. However, the higher returns on land associated with that market price must cover the full costs of land take by municipal authorities, i.e. the costs of purchase as well as those of building and operating parks, infrastructure and other such public amenities.

The cited price per m^2 indirect land take in urban areas is again an average figure. On theoretical grounds it can be argued, on the one hand, that the prices paid for inner-city properties is a true reflection of the added value of the benefits accruing from agglomeration. This would mean assigning an average figure of € 300. On the other hand it can be argued that ‘indirect land take’ will frequently entail shuffling the physical boundaries of planning zones. From this perspective, then, the issue is merely one of land distribution. If there is adequate substitutability among the zones being ‘shuffled’, the costs of indirect land take will be virtually zero. These two approaches can be considered extremes, with the truth lying somewhere in between. As there are no entirely convincing arguments for either position, we have opted to price urban land, to the extent that it is affected by zoning restrictions, at a figure halfway between the values suggested by the two approaches, i.e. € 150. For a more detailed discussion, we refer readers to annex I.

In rural areas, the price of indirect land take has been set extremely low. All it embodies is the preferential difference in value attributed to a specific location within a zone where restrictions are in place compared with a location at some small distance where such restrictions no longer pertain but which differs in no other respect (except perhaps a need to build a slightly longer driveway, for example; if there are restrictions in force, just beyond this zone there will still be an unobstructed view of the landscape or lake or whatever it may be). In short, given the high degree of substitutability of rural land, only a very low preferential value need be assigned to indirect land take. This has been taken, arbitrarily, at € 1 per m^2. The precise value is of only minor importance, though, as only 2% of indirect rural land take is allocated anyway.

6.8 Synopsis of direct and indirect land take costs

Table 34 provides a concise summary of the total costs of land take associated with roads, railways and waterways to be allocated across the various vehicle categories. We only considered the interest of the value of the land on which the infrastructure is built or for which development restrictions apply (based on an interest rate of 4%).

table 34 Total costs of land take by road, rail and inland shipping infrastructure (million €)

		Urban	Rural	Total
Road	**Direct**			
	Metalled roads	428	191	619
	Unmetalled roads	4	18	22
	Service areas	0	4	4
	Parking space	143	0	143
	Cycle lanes	30	11	42
	Indirect			
	Noise zones	20	0	20
Rail	**Direct**			
	Railway lines	22	16	38
	Indirect			
	Noise zones	15	0.08	15
Inland shipping	**Direct**			
	Waterways	26		26
	Indirect			
	Sight zones	47.1	0	47

The costs of direct land take by roads have been allocated across vehicle categories in exactly the same way as road infrastructure construction costs: on the basis of peak-time capacity utilisation and vehicle kilometres. The underlying reasoning is the same as for construction costs. As road utilisation nears capacity levels, new infrastructure will need to be built. Because HGVs occupy more space than passenger cars, thus implying an earlier need for that infrastructure, they should be allocated a greater share of the costs (including those of land take). The precise data (based on peak-time passenger car equivalents) are summarised in section 2.2.5.

There are two exceptions to the allocation of direct land take as described above. First, the costs of land take by parking bays and spaces has been allocated solely to passenger cars and LGVs, on the basis of vehicle kilometerage. Second, the costs of direct land take for cycle lanes have been allocated partly to mopeds, as in the case of the construction costs of these lanes (see Chapter 2 for details). Allocation of the costs of the indirect land take due to noise contours is based on noise weighting factors and vehicle kilometres, identically to allocation of the costs of noise nuisance.

When it comes to rail freight transport, peak-time capacity utilisation is virtually zero and no costs have therefore been allocated to freight trains for direct land take. For passenger rail, the costs of direct land take were apportioned between diesel and electric trains on the basis of kilometerage. The costs of indirect land take due to noise contours were again allocated using noise weighting factors and train kilometres.

In the case of waterways, land take costs were attributable solely to inland shipping, obviating the need for an allocation key. The total allocable costs of waterways are therefore the same as the total costs to commercial inland shipping.

The final tables of this chapter present a synopsis of how the total costs of direct and indirect land take have been allocated to the various categories of road vehicle (table 35) and train (table 36).

table 35 Total costs of land take by road infrastructure in the Netherlands, by vehicle category (million €)

Road vehicle category	Direct, urban	Direct, rural	Parking	Indirect
Car	294	164	103	7.8
Bus	1.2	0.5	-	0.5
Coach	0.1	0.6	-	0.1
Motorcycle	6.4	6.9	-	2.7
Moped, scooter *	16.0	0.1	-	1.8
LGV	115.0	20.3	40.2	4.5
HGV, single unit < 12 t	3.9	2.1	-	0.3
HGV, single unit > 12 t	2.1	7.7	-	0.8
HGV, tr/tr comb.	1.5	17.1	-	1.3

* Including cycle lanes, excluding service areas.

table 36 Total costs of land take by railway infrastructure in the Netherlands, by train type (million €)

Train category	Direct	Indirect
Train, electric, passenger	36.3	11.7
Train, diesel, passenger	1.7	0.6
Train, electric, freight	-	1.8
Train, diesel, freight	-	1.0

7 Costs of congestion

7.1 Introduction

Congestion occurs when infrastructure usage nears capacity level. When deciding whether or not to make a journey, road users may sometimes make some allowance for the nuisance due to congestion, in particular lost time. If roads are clogged up, some people will opt to travel later, take a different route, go by train or even refrain from travelling at all. This may be because the value of the journey to them does not outweigh the costs of being caught in a traffic jam (plus any other costs) or because the person concerned, aware of the jams, prefers to travel by a different route or mode.

What motorists often ignore in their deliberations, however, are the delays they themselves cause to other road users. By taking to the roads they further aggravate overall traffic flow, and the busier the roads, the greater will be the delay imposed on others. This is an external effect of infrastructure use. To arrive at optimal traffic flows in terms of economic efficiency/welfare, road users should make due allowance for this effect in their decision whether or not to travel. This can be induced by introducing a charge equivalent to the total cost of the effect.

7.2 Strategy and methodology

As explained in Chapter 1, in this study transport costs are approached from two different perspectives:

1. In the first, the focus is on the *total* costs caused by particular groups of road users and the extent to which these costs are recovered in one form or another. From this perspective, the costs of congestion need not be included in the analysis, because it is the respective group of infrastructure users that both causes the costs and bears the burden. The external congestion costs due to motorist A are internalised in motorist B's decision as to whether or not to travel, and B therefore covers the costs induced by A.

   It is unlikely that each individual category of road users will give rise to costs equal to precisely the burden that falls on them. Motorcyclists, for example, may quite plausibly induce greater costs than they themselves bear, as car drivers keep more distance from motorcyclists and the latter can weave in and out of traffic jams with relative ease. The situation vis-à-vis passenger cars and heavy goods vehicles is unclear in this respect. In due consultation with the project principal, in this study it has been opted to give no further consideration to the degree to which the costs due to specific road user categories are equivalent to the costs they themselves bear.

2 The second approach, our ‘efficiency’ variant, proceeds on the principle that economic welfare will be improved if infrastructure users are subject to a charge equal to the *external* costs of congestion. It is above all when infrastructure usage nears capacity levels that external congestion costs come into play. In the case of inland shipping in the Netherlands this situation rarely arises and in this study we have therefore taken congestion costs on waterways to be zero. Dutch roads, on the other hand, are subject to frequent and heavy congestion and the associated external costs are consequently substantial. This issue is discussed below in section 7.3. Rail transport is a special case. Here, track capacity is allocated via ‘slots’, leading to a certain regulation of traffic volume. In this case, then, congestion is mainly in the form of slot scarcity, an issue discussed in section 7.4.

7.3 Road transport congestion

There can scarcely be a motorist who has not experienced congestion firsthand. When infrastructure use approaches capacity levels, traffic flow starts to plummet[48]. Under such circumstances, people respond in different ways. For those for whom time has little monetary value, the main thing is to reach their destination and they will be prepared to put up with the delay. Those putting a high price on (lost) time will show a greater tendency to seek alternative means or time of travel, or even cancel their journey altogether.

One method of calculating congestion costs proceeds from vehicle hours lost and puts a certain price for time. The delay to other road users caused by one additional vehicle entering the traffic flow is assigned a monetary value based on estimates of how time is valued by these other users. The delay that arises depends very much on capacity utilisation, i.e. on how much traffic there already is on the road(s) in question.

This approach to calculating external congestion costs has the drawback that no value is assigned to the costs borne by those opting to take an alternative route, depart later or refrain from travelling. It is very likely, furthermore, that those stuck in traffic jams put a comparatively low price on time. Both these effects can lead to underestimation of total external congestion costs.

In theory, the best method for computing external congestion costs proceeds from a dynamic model. First, an appropriate hypothetical charge level is set, based on the external congestion costs calculated from time-valued vehicle hours lost, using a speed-flow model for the purpose. Next, the effect of introducing this charge on traffic flow and vehicle hours lost is analysed. The result is then fed back into the model to compute a new optimum charge level, with this iterative procedure being continued until equilibrium is achieved.

This method has, in one form or another, been used in a variety of studies, the results of which we shall now review.

---

[48] This may also occur when effective capacity unexpectedly falls following a road accident. In such cases there will usually be little scope for avoiding the congested road section.

In [CE/VU/4cast, 2002] the revenues from an optimum congestion charge are related to the decision for investment in new infrastructure. In that study the optimum charge for passenger cars in peak traffic was calculated as being up to 50 €ct per kilometre on some roads (in euros of 2001).

The study ‘Reforming Transport Taxes’ [ECMT, 2003] reports on the marginal external costs of various modes of transport in the Dutch coastal conurbation. The difference between peak and off-peak congestion costs gives the external costs of peak-time congestion and the study recommends a congestion charge of 18 €ct per passenger kilometre for cars and 3 €ct per tonne kilometre for HGVs.

As part of the UNITE project[49] a number of case studies have been carried out to calculate the external costs of congestion. The results are summarised in ’Deliverable 15’ of the project [UNITE, 2002]. The congestion costs reported range from 0 to 15 €ct/km (Euro’s 1998) for passenger cars in rural areas up to 80 €ct/km for HGVs in peak urban traffic.

The results of these three studies are summarised in table 37. All figures are for peak urban traffic and have been adjusted to euros of 2002.

table 37 External congestion costs for peak, urban traffic (€/vkm)

	Car	HGV[50]
UNITE	0.46	0.91
CE *et al.*	0.52	Unknown
ECMT	0.31	0.57

Adapted from: [UNITE, 2002], [CE/VU/4cast, 2002], [ECMT, 2003].

There are several reasons for the differences among the reported figures. In the first place, different time values and price elasticities were used in the respective studies. Secondly, there was no consistency with regard to speed-flow characteristics or road type (2-lane vs. 4-lane).

There is, nonetheless, a certain amount of agreement among the results. We have opted to use the UNITE data, because these can be considered state-of-the-art in this particular field and because the CE study provides no figures for heavy goods vehicles.

Because the requisite data are lacking, we were not in a position to distinguish between various types of heavy goods vehicle. This means that the same congestion costs have been allocated to all categories of HGV.

---

[49] In full, Unification of Accounts and Marginal Costs for Transport Efficiency.

[50] The UNITE study provides no specifications for HGVs, while in the case of ECMT we have calculated with a laden vehicle with a GVW of 17.4 t, the average for a single-unit truck > 12 t.

7.4 Rail transport congestion

As mentioned in the introduction to this chapter, there is a fundamental difference between congestion on the roads and the railways. Although in the former case congestion sets in as traffic nears maximum infrastructure capacity, in the case of rail 'slots' or 'paths' are allocated to users, i.e. trains. As there are only a limited number of slots to be allocated, there is consequently a degree of traffic control.

In the context of rail transport, elevated capacity utilisation can manifest itself in two ways[51,52]:

1 First, increased usage means *less scope for accommodating delayed trains* without other trains suffering delay. Here, the term 'congestion' refers to the anticipated delay of these other trains as a result of the initial delay. In this case, congestion does not stem from any considered decision incorporating the interests of other parties, and the associated costs have therefore been omitted from our analysis.

2 Second, increased capacity usage may, over and above congestion, lead to *scarcity*. Under such circumstances, not all rail operators will be able to run their trains as scheduled, or rescheduled. There is, in other words, a scarcity of slots.

The cost of slot scarcity is given by the maximum value of the slot in question when used by another rail operator for an alternative purpose. However, this only counts as an external effect if there is indeed another operator (than the one currently using the slot) wishing to use it. In theory, these costs can be calculated in two ways:

a The first method entails 'auctioning' of slots among operators, providing information on the value of a given slot to each.

b The second method uses social cost-benefit analysis.

In practice, though, neither of these methods is straightforward. For one thing, data requirements are substantial. On top of this comes the fact that railway infrastructure capacity is not a constant given, but highly dependent on actual usage. If Intercity and local trains run alternately on a given line, there will be considerably less capacity (and thus fewer slots to be distributed or auctioned) than when an uninterrupted series of Intercity trains is followed by a run of local trains.

To calculate the costs associated with scarcity on the Dutch rail grid would require an extensive study in its own right. In the present context we have therefore opted to ignore issues of scarcity on the rail network.

---

[51] This analysis is based on Nash & Matthews: *Rail infrastructure charges – the issue of scarcity,[* Nash, CA, and Matthews, B., University of Leeds, 2003] and [HLG, 1999b]: *Calculating transport congestion and scarcity costs*, Final report of the High-Level Group on Infrastructure Charging (working group 2), May 7, 1999.

[52] There may obviously also be congestion on the trains themselves or at stations. This form of end-user congestion has been ignored in this study, however.

7.5 Synopsis of congestion costs

It is only in the efficiency variant that congestion costs are relevant. In the best-case scenario defined here, there is no congestion. For the worst-case scenario we have defined, for *road* transport, the data are shown in table 38.

table 38 External congestion costs for peak, urban road traffic (€ct/vkm)

Car	46
HGV	91

As Dutch waterways are scarcely ever congested, for *inland shipping* we have assumed zero congestion costs.

As explained, congestion on the *railways* has a fundamentally different dynamic from road congestion. As capacity (i.e. slots) is in this case centrally allocated to operators, it is not so much congestion as scarcity that is involved. Unfortunately, it was not within the bounds of the present study to quantify these costs.

8 Charges, exemptions and subsidies

8.1 Introduction

This chapter reviews standing fixed and variable charges, i.e. sectoral payments to government for transport mobility, as well as tax exemptions and subsidies, i.e. direct or indirect government payments to individual sectors.

Charges
In the Netherlands a range of charges and taxes are in force, keyed to a variety of charge bases, including vehicle purchase and ownership, type of fuel and infrastructure utilisation. We distinguish the following:

- Excise duty on petrol, diesel and LPG.
- Regulatory Energy Charge (REC).
- Vehicle Purchase Tax (VPT, passenger cars and motorcycles only).
- Vehicle Circulation Tax (VCT).
- The ‘Eurovignette’ (heavy goods vehicles).
- Charges for infrastructure use (rail and inland shipping).

Exemptions and subsidies
In addition to these charges, there are also tax exemptions as well as specific *mobility subsidies* encouraging the use of certain forms of transport. In the present study we distinguish:

- Public transport operating subsidies.
- Special VAT rates.

As already stated, costs incurred by the government in relation to transport *infrastructure* are treated here as social costs.

In the following section, we first discuss several important basic issues concerning the methods adopted to calculate the various charges.

8.2 Methodological issues

Fixed or variable?
In this study all charges, subsidies and exemptions currently in force are taken to be variable, with the exception of VPT, VCT and the Eurovignette. This is because all the other items depend on mobility levels: the greater the kilometerage, the greater the charge. In the case of the REC this applies somewhat less, as this charge is subject to a ceiling (see section 8.3.2).

General taxation not included
It should be stated at the outset that general taxes – on labour, capital, profits and so on – have not been included in our analysis. These taxes are levied across the economy and do not therefore distort the transport market any more than other sectors. It is consequently only tax arrangements that impinge specifically on the functioning of the transport market that are reviewed here.

VAT not included
The question now arises whether Value Added Tax on fuel excise duty and on other charges should be included in the category of specific transport charges and taxes (note that no VAT is levied on VPT, VCT or the Eurovignette). From the legal-fiscal perspective it might be argued that VAT levied on excise duty and on other charges should be deemed a specific transport tax and therefore included as such in the analysis, VAT on fuel duty being a 'tax on tax'. From an economic perspective, however, excise duty, VPT and VCT are to be designated payments to government for services rendered, in accordance with the 'user pays' principle – as is indeed reflected in reviews of public income and expenditure. From this angle, then, VAT on fuel duty is a general tax rather than a specific transport tax.
Given our aim here, to work towards appropriate cost allocation to the various segments of the transport and mobility sector, it is the economic rather than legal-fiscal approach that should be adopted with respect to VAT. In this study, then, VAT on fuel excise duty has been omitted from the analysis[53].

Company car tax addition not included
As elsewhere, private use of company cars is taxed in the Netherlands, where new arrangements came into force on 1 January, 2004. Under the new scheme, 22% of the net list price of the car must be added to taxable income unless it can be shown that less than 500 km is driven a year. In the case of light goods vehicles the figure is 10%, unless it can clearly be shown that the all travel is purely for commuting purposes.
From a fiscal angle, this 'company car addition' is a means of rendering non-tangible income amenable to income tax. From a different angle, though, some regard it as a specific tax on transport. The situation is then compared with arrangements for 'company computers', over which no income tax is paid[54].
We have not adopted this latter perspective here, for we feel that equal taxation of tangible and intangible income should be the guiding principle. The 'company car addition' is then simply a fiscal correction for indirectly subsidised private kilometerage in company vehicles. That the government leaves 'company computers' untaxed is for purely pragmatic reasons, the likely revenues from the tax not making up for the complexities of levying it. Besides, the government sees the scheme as a means of encouraging home computer use.

---

[53] In fact, charges free of VAT should also be corrected for this lack of VAT, which would mean dividing revenues from these charges by a factor 1.19. We have refrained from doing so, however, because by not levying VAT on these items the government is implicitly saying it considers these charges more fiscal than economic.

[54] See for example [IOO, 1994].

In this study, then, we have proceeded on the grounds that the 'company car addition', as outlined above, is a means of putting a value on private use of these vehicles rather than a specific transport tax. It has consequently been ignored in our analysis. The same holds for standing arrangements between individual companies and the tax office concerning use of company-issued season tickets for public transport for private travel[55].

Untaxed travel allowance not included
Under new Dutch tax arrangements superseding the former 'travel costs allowance for commuters', employer travel to and from work is now subsumed under the heading 'business travel', along with such travel in the stricter sense, whether employees use their own car or public transport, and regardless of total annual kilometerage. Since 1 January, 2004[56] the untaxed allowance for such travel has been set at 18 €ct per km (approx. 17.4 €ct in euros of 2002). Employees using public transport may alternatively be reimbursed by employers based on actual distance travelled.
We have not included this untaxed travel allowance in our analysis, for the main reason that the reimbursement is paid by employers, rather than being a government subsidy. In the case of employees using their own car for on-the-job travel, moreover, the untaxed allowance is generally more or less equivalent to the variable costs of vehicle usage [MinFin, 2003; CE, 1999]. If public transport is used for this purpose this no longer applies, as average user costs (i.e. bus or train fares) currently stand at about 10 €ct per km, in principle creating an incentive for more travel. It is our expectation, however, that most employers will prefer to reimburse actual travel costs – paying for employees' season tickets, for example – and that the 'quasi-excessive' allowance will ultimately therefore have little impact. Public transport will not feature prominently in the overall scheme of things anyway, it may be added, as most people travel by car.

8.3 Charges and taxes

8.3.1 Fuel excise duty

Road vehicle users pay excise duty on the petrol, diesel and LPG they purchase. In our calculations we converted this duty into a charge per vehicle kilometre by dividing it by the energy consumption of the vehicles in question on the respective fuels. In doing so, we again differentiated between 'urban' and 'rural'. Kilometre for kilometre, most vehicles burn more energy in urban traffic, where they will then consequently pay more fuel duty per kilometre. The duty levels in force in the Netherlands as well as the conversion to a 'kilometre charge' are reported in table 39. In addition to actual fuel duty, these figures also include the

---

[55] Closer consideration of the rates pertaining in this connection could be taken as implying that, if anything, the 'company car addition' is more of an indirect transport *subsidy* than ditto *charge*. After recalculation of the private benefits accruing from company car use, the government's working group on income tax reform has suggested that 30% of the vehicle list price should in fact be added to taxable income. Abolition of the former travel cost allowance for commuters and compensation in the 'employed person's tax credit' would then push this rate up further still, to 36%.

[56] As noted in section 1.4, in this study we consider the tax schemes presently in force rather than those current in 2002. Needless to say, the sums involved have been converted to 2002 euros.

Dutch ‘environment fuel charge’, which stands at 1.24 €ct/litre for petrol and 1.37 €ct/litre for diesel. We have not included the so-called ‘fuel stock levy’ (0.59 €ct/litre), which we regard as payment for the cost of strategic fuel stocks being maintained. A final point is that Dutch diesel trains use so-called ‘red diesel’, on which less duty is paid.

table 39 Dutch excise duties in 2002 and conversion to duty-based charge per vkm

Fuel	Energy (MJ/l)	Vehicle category	Duty (€/litre)	Total (mln €/year)	Consumption (MJ/km)		Charge, €ct/vkm	
					Urban	Rural	Urban	Rural
Petrol	31.2	Car	0.621	3,621	3.6	2.4	7.2	4.8
Diesel	35.7	Car	0.339	591	3.1	2.2	2.9	2.1
		LGV		618	4.0	3.0	3.8	2.9
		HGV, single unit < 12 t		40	6.0	4.0	5.7	3.8
		HGV, single unit > 12 t	0.325	218	18	10	16.4	9.1
		HGV, tr/tr comb. > 12 t		474	20	12	18.2	10.9
		Local/district bus		65	20	12	18.2	10.9
		Coach		22	20	12	18.2	10.9
		Passenger train (‘red diesel’)	0.060	1.3	100	65	16.8	10.9
		Freight train (‘red diesel‘)	0.060	1.3	200	200	33.7	33.7
LPG	24.8	Car	0.051	39	3.3	2.2	0.7	0.5

8.3.2 Regulatory Energy Charge (REC)

REC on ‘red diesel’

In the Netherlands a Regulatory Energy Charge (REC) of 13.15 €ct/litre is levied on the ‘red diesel’ used by diesel trains. For ‘bulk users’, however, there is also a rebate scheme for the portion over and above 153,000 litres a year (equivalent in money terms to € 20,120). As a result, bulk operators (like Railion, in the case of rail freight) effectively pay less REC per litre fuel (approx. 0.091 €ct/l[57]). Smaller companies do not generally get as far above this threshold, if at all, and therefore pay more on balance, putting them at a competitive disadvantage.

---

[57] Based on 22 mln litres annual fuel consumption, the figure reported by Railion [Railion, 2004]. The Traffic & Transport Taskforce reports a similar figure (approx. 20 mln litre) for passenger transport by diesel train [Taakgroep V&V, 2004].

In elaborating best and worst case scenarios, we have taken steps to incorporate this issue:

- For rail freight transport, the worst case scenario takes a diesel train carrying bulk freight, run by an operator paying relatively little REC per litre (proceeding from Railion's figure of 22 mln litre annual fuel consumption). As explained above, this implies a 'net' REC of 0.091 €ct/litre. Assuming 13.70 l/km fuel consumption, this is equivalent to a charge of 1.25 €ct/km. NB: The best case scenario uses *electric* traction for rail freight; see below.
- For rail passenger transport by diesel train we took a rail operator using approx. 6 mln litres of fuel a year. This is based on the consumption figure reported by rail company Noordned, but it will not be significantly different for Syntus or Dutch Rail (NS). This yields an effective REC rate of about 0.34 €ct/l. Taking a figure of 1.96 l/km for average fuel consumption, this is equivalent to approx. 0.67 €ct/km.

REC on electricity

The Regulatory Energy Charge is also levied on electrical power, based on the following staggered rates (as of 2002):

• 0 – 10,000 kWh	6.01 €ct per kWh
• 10,000 – 50,000 kWh	2.00 €ct per kWh
• 50,000 – 10 mln kWh	0.61 €ct per kWh
• over 10 mln kWh	untaxed.

As in the case of REC on 'red diesel', here too smaller operators are at a disadvantage relative to their larger competitors. In practice, however, NS (Passengers) is the only operator with any significant share of passenger transport by electric train. On average, NS effectively pays 0.0046 €ct REC per kWh, a figure so negligible that we have ignored it in our calculations. In the case of rail freight, operators Railion and ACTS both use electric locomotives and in this case we have calculated with the two extremes of 0.66 €ct per kWh and 0.12 €ct per kWh for the 'effective' REC[58].

On this basis we defined the following best and worst case scenarios:

- For rail freight transport, the best case is an electric train carrying non-bulk goods, run by an operator paying a relatively large amount of REC per kWh (based here on 2.07 mln kWh, as for ACTS). As we saw above, this means an effective (net) REC of 0.66 €ct per kWh. Taking a figure of 9.72 kWh/km for specific power consumption, this is equivalent to 6.4 €ct/km. NB: The worst case scenario for rail freight is transport by a *diesel* train; see above.
- In the case of passenger transport by electric train, NS is the only operator with any significant share of the market. As already mentioned, their annual power consumption is so high that the effective REC paid per kWh is hardly significant, and we have therefore ignored it in our analysis.

---

[58] Based on 1,231 mln kWh annual power consumption by Dutch Rail (Passengers) [NS, 2003], 48.6 mln kWh by Railion [Railion, 2004] and 2.07 mln kWh by ACTS [ProRail, 2003a].

8.3.3 Vehicle Purchase Tax, Vehicle Circulation Tax, Eurovignette

Most categories of road vehicle are subject to fixed charges, to be paid by vehicle owners. The charges in question are Vehicle Purchase Tax (VPT), Vehicle Circulation Tax (VCT) and the ‘Eurovignette’:

- VPT is purchase tax on passenger cars and motorcycles. For cars it is 45.2% of the listed vehicle price, with a fixed deduction of € 1,540 for cars running on petrol and LPG and a mark-up of € 328 for diesel vehicles. In the case of motorcycles, VPT is 20.7% of the listed price, with a fixed deduction of € 224.
- VCT, paid on a quarterly basis, is indexed to vehicle type, vehicle weight and fuel.
- Under the ‘Eurovignette’ scheme, HGV over 12 tonnes permissible gross weight pay a charge for using trunk roads in the EU.

For each of these taxes, table 40[59] shows the bases and rates in force in the Netherlands and how these have been converted for the purpose of calculating the user costs associated with the Dutch road grid.

table 40 Vehicle Purchase Tax (VPT), Vehicle Circulation Tax (VCT) and Eurovignette rates, by vehicle category (2002)

Vehicle category	Purchase price for VPT	Weight	VPT		VCT	Euro-vignette	Total fixed charges	
	€/vehicle	tonne	€/veh	€/veh/y	€/veh/y	€/veh/y	€/veh/y	mln. €/y
Passenger								
Car, petrol	17,650	1.00	3,791	467	285	n.a.	753	4,159
Car, diesel	20,650	1.20	5,974	737	857	n.a.	1,594	1,521
Car, LPG	19,650	1.15	4,347	536	532	n.a.	1,068	321
Bus, diesel	n.a.	12.0	n.a.	n.a.	526	n.a.	526	2.9
Coach	n.a.	14.0	n.a.	n.a.	526	n.a.	526	2.1
Moped	14,000		2,097	117	51	n.a.	168	80
LGV						n.a.		
Van, diesel	n.a.	1.5	n.a.	n.a.	205	n.a.	205	159
Freight	n.a.		n.a.	n.a.		n.a.		
HGV, sing. unit<12 t	n.a.	4.0	n.a.	n.a.	250	n.a.	250	8
HGV, sing. unit>12 t	n.a.	11.0	n.a.	n.a.	400	650	1,050	42
HGV, tr/tr	n.a.	15.0	n.a.	n.a.	750	1,175	1,925	135

---

[59] We would stress that in this table, as elsewhere in this study, we are concerned with *costs* rather than expenditures or revenues. ‘VPT costs’ have thus been calculated from the average consumer price of a passenger car in *1998* (source: [RAI-BOVAG, 2004]), cars having an average lifetime of about 4 years. The VPT was then discounted over vehicle lifetime, using a social discount rate of 4%. There is consequently no basis for direct comparison with VPT revenues over 2002.

8.3.4 Infrastructure charges for rail and inland shipping

For use of the railway infrastructure, operators ProRail charge train companies per kilometre. In 2002 the rate for passenger transport stood at 44.09 €ct per km, which, multiplied by the number of 'billable' kilometres (see table 17), yields a total figure of about € 48.5 mln for ProRail revenues in 2002. The charge for rail freight transport is 22.04 €ct/km, giving additional total revenues of about € 1.8 mln in 2002. In addition, passenger trains are charged a certain fee for each station stop, the exact fee depending on the category of station involved. It is estimated that revenues on this account totalled approx. € 9 mln in 2002. Overall, then, in that year annual revenues from these user charges amounted to some € 59 mln.

The inland shipping sector pays for use of all infrastructure not administered by the national government. Overall, approx. € 26 mln is paid annually in harbour and fairway dues [NEA, 2002] and we estimate that of this figure some € 16 mln is attributable to inland shipping (see section 2.4.2). Taking 66.9 mln vessel kilometres as the annual volume of inland shipping traffic (on waterways administered at the local as well as national level: [AVV, 2004a]) yields an effective charge of € 0.24 per vessel kilometre.

8.4 Exemptions and subsidies

Alongside the charges discussed in the previous section, which increase cost price, there are also tax exemptions and subsidies in force that reduce prices. In our present context there are two relevant issues here: public transport operating subsidies and special VAT rates.

8.4.1 Public transport operating subsidies

The Dutch government pays subsidies to companies providing public transport services. Bearing no relation to infrastructure costs or external costs, these have here been taken as negative charges.

In 2002, Dutch municipal and district transport companies received a total of € 1.3 bln operating subsidy [TKSG, 2003].

In the second place, Dutch Rail (NS) was reimbursed for charges paid to ProRail for use of railway infrastructure on unprofitable lines. In 2002 this subsidy totalled approx. € 92.5 mln, including compensation for ancillary costs and VAT paid [TKSG, 2003].

8.4.2 Special VAT rates

Operators of public transport services as well as commercial alternatives (i.e. coaches and taxis) pay a reduced VAT rate. The magnitude of this 'price-cutting' subsidy via VAT can be calculated from ticket sales (in 2002, NS: approx. € 1.34 bln, municipal/district approx. € 622 mln). This yields total figures of about

€ 174 mln for NS (Passengers), € 81 mln for municipal/district transport operators and € 89 mln for coach operators.

9 Results for the total cost variant

9.1 Introduction

In this chapter we report the results of the ‘total cost’ variant of our analysis. The focus here is on assessing the degree to which each mode of transport pays its way in terms of the *total costs* to which it gives rise. To this end we chart the total social costs due to each vehicle category, passenger and freight, and compare these with the total user charges paid. Total costs and charges are both expressed in million euros[60].

Throughout this chapter we report, in one and the same figure, the costs of rail transport in two variants:

1. A variant in which the costs of infrastructure renewal (one of the elements of maintenance and operation) are assumed to be part-variable, in line with the definition adopted in the IPS study ‘Charging freight transport for infrastructure use’.
2. A variant in which the costs of infrastructure renewal are taken to be fixed.

In all the figures we employ the following conventions:

- Solid colours: fixed costs or charges.
- Hatched colours: variable costs or charges.

The detailed raw data underlying the figures in this chapter are to be found in annex J.

9.2 Passenger transport

9.2.1 Passenger cars and motorcycles

As can be seen from figure 21, the social costs of petrol-driven passenger cars are almost fully covered by the total user charges paid. We would add immediately, though, that our analysis does *not* include the external costs of habitat fragmentation, barrier action (for wildlife) or ‘visual intrusion’. On all these issues there is still insufficient understanding of how the impacts are to be quantified and valued. With this in mind, we also observe that although in the case of petrol cars the variable costs are almost balanced by the variable charges, there is a mismatch in structure. In other words, the incentives created by the charges do not tally with cost drivers. The same applies to the fixed costs, too. In this case, fixed charges prove to be slightly higher than fixed social costs.

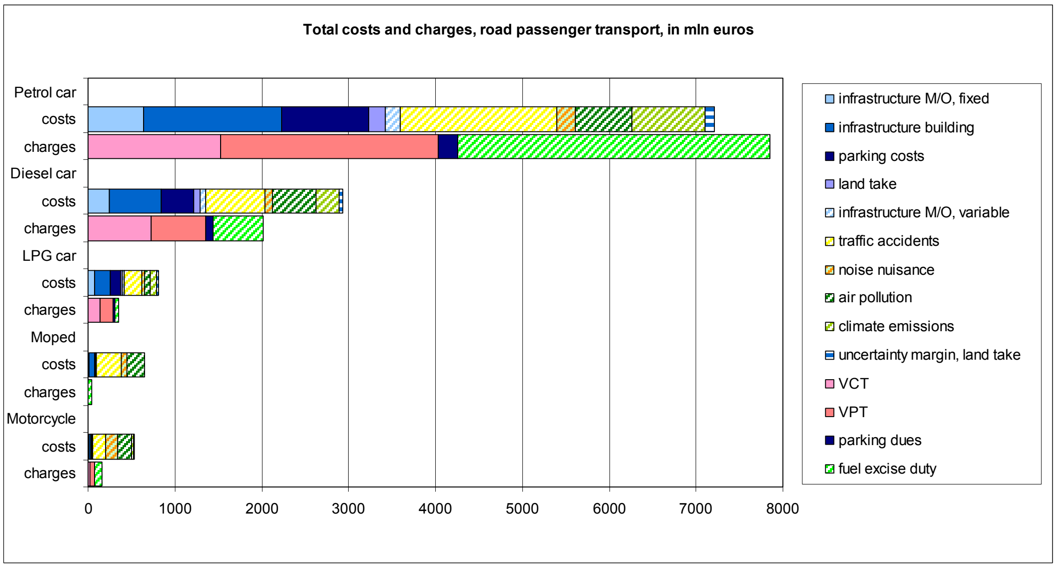
With respect to diesel and LPG cars there is a ‘deficit’. In other words, these vehicles give rise to more social costs than are recovered in fixed and variable charges. This deficit is due mainly to differences on the variable side. In the case

---

[60] At the request of project principal DGP, in annex J we also report the total costs and charges for passenger transport per passenger kilometre.

of diesel cars, the variable costs are about twice as high as the variable charges (mainly fuel excise duty). For LPG-fuelled cars the gap is even greater. As in the case of petrol cars, there is again a structural mismatch between charges and costs. The picture is much the same for motorcycles and mopeds. For the latter, particularly, there is a huge gap between total social costs and total charges paid. The two items that stand out here are the relatively high accident costs and the costs of noise nuisance and air pollution. It should be noted, though, that in absolute terms the costs and charges associated with LPG cars, motorcycles and mopeds are an order of magnitude lower than those for petrol and diesel cars. This is due primarily to the far larger volume of traffic (and parking requirements) of petrol cars.

figure 21 Total social costs and user charges, passenger road transport (€ mln/year)[61]



9.2.2 Buses and coaches

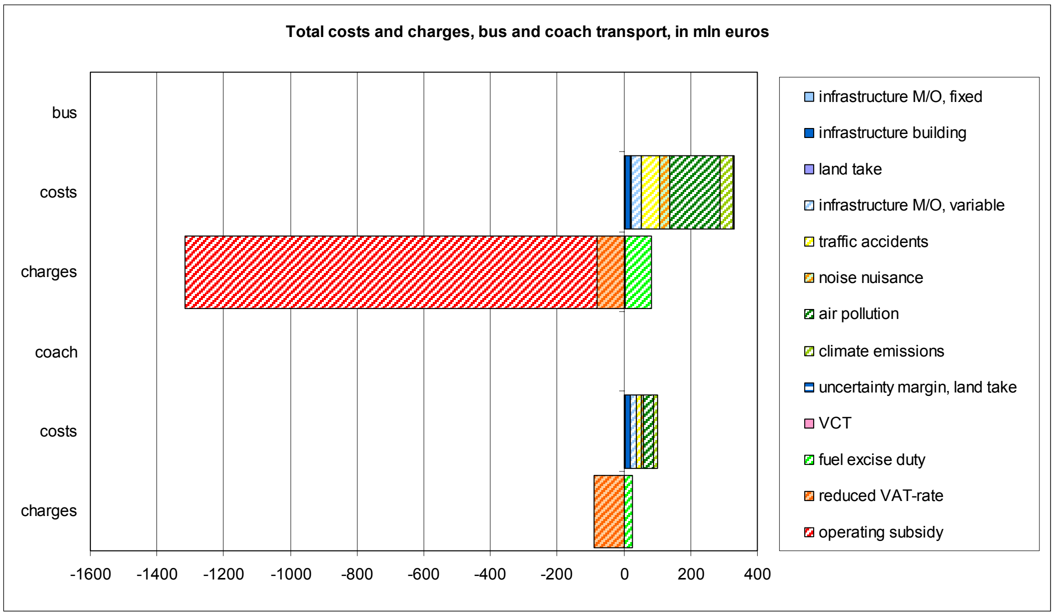
The most striking feature with respect to bus and coach transport (figure 22) is that only a small fraction of the total costs are recovered in the form of charges (here consisting solely of fuel duty). We also see that the bulk of the costs are variable, with the social costs of air pollution standing out as the largest item. This derives from the fact that buses ride mainly in more heavily populated, built-up areas where their emissions give rise to proportionally more health damage.
Another striking feature is the very substantial sum paid out in the form of public transport operating subsidies and the special VAT rate, exceeding by a factor 10 or so the incoming revenues from fuel duty. Here, we make no judgment on the desirability or otherwise of this operating subsidy and the VAT provisions. After all, there are good social and other reasons for their existence. In this sense, the figures are intended above all to provide insight into the overall situation.

---

[61] In all the figures, solid colours indicate *fixed* costs or charges, hatched colours *variable* costs or charges.

In the case of (long-distance) coaches, the total sum embodied in the reduced VAT rate virtually equals the total costs. Revenues from fuel duty are about one-third of this figure and so do not come close to balancing the accounts.

figure 22 Total social costs and user charges, bus and coach transport (€ mln/year)



9.2.3 Rail

In the case of passenger rail transport, the first point to note is that the fixed costs of infrastructure maintenance and operation (M/O) and new construction make up a large proportion of overall costs. On the other side of the accounts stands the charge for railway infrastructure use, although this goes only a very small way to recovering the costs. Being variable, moreover, this charge does not tie in with the fixed nature of the lion's share of the costs.
As mentioned above, in this case we report results in two variants, in which infrastructure renewal costs are assumed either part-variable (figure 23) or fixed (figure 24). For further discussion, see section 2.3.2.

Passenger rail services also receive an operating subsidy and pay a reduced VAT rate, involving a total sum of approx. € 270 mln.

figure 23 Total social costs and user charges, passenger train (€ mln/year; costs of infrastructure renewal assumed part-variable)

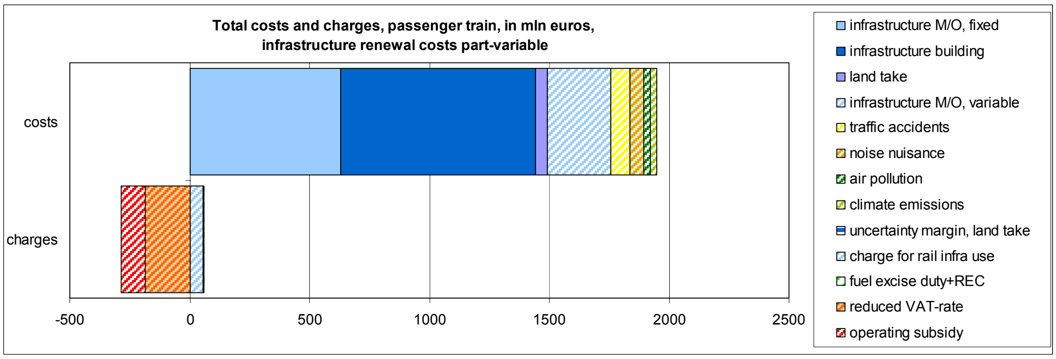
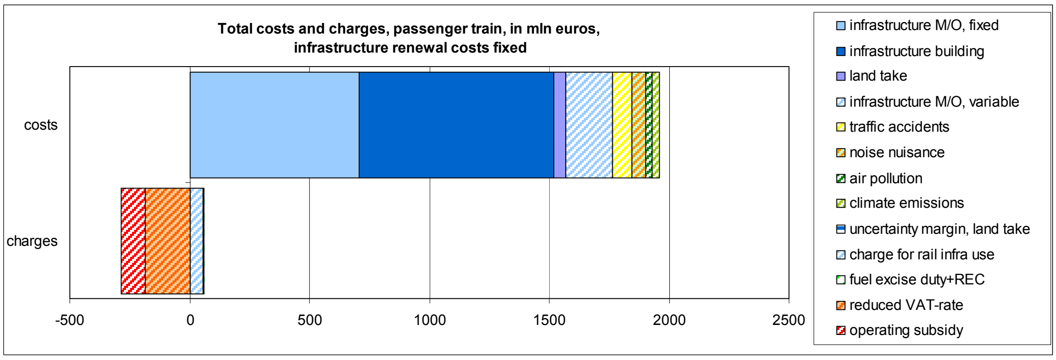


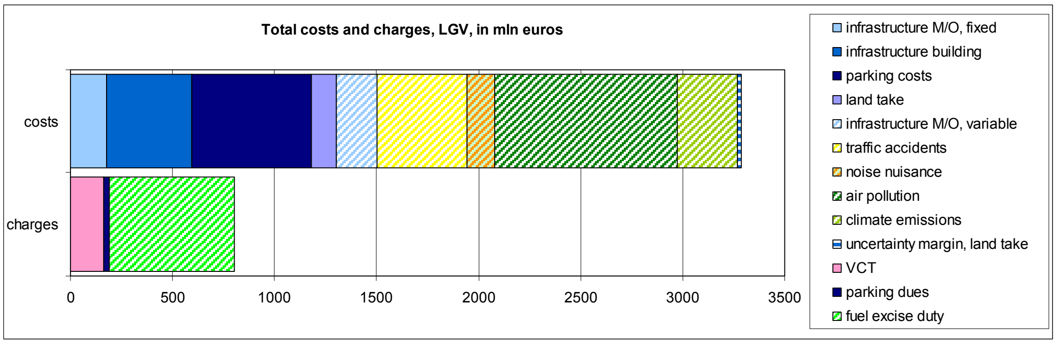
figure 24 Total social costs and user charges, passenger train (€ mln/year, costs of infrastructure renewal assumed fixed)



9.3 Light Goods Vehicles

In the case of LGVs, too, user charges are far too low to cover total social costs (figure 25). One of the reasons is that is no Vehicle Purchase Tax is paid on these vehicles, in contrast to passenger cars. There is therefore insufficient recovery of fixed costs via fixed charges. Usage-dependent, i.e. variable, charges are likewise insufficient to cover variable social costs. A second striking feature are the relatively high costs of air pollution. This is because virtually all LGVs burn diesel, a fuel still currently associated with relatively high emissions of NO_X and fine particulates. In summary, then, there is a pronounced structural mismatch between costs and charges.

figure 25 Total social costs and user charges, LGV (€ mln/year)

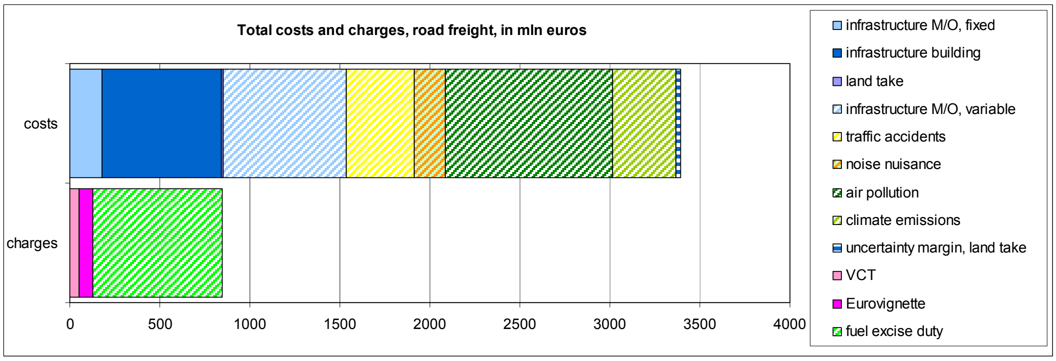


9.4 Freight transport

9.4.1 Road

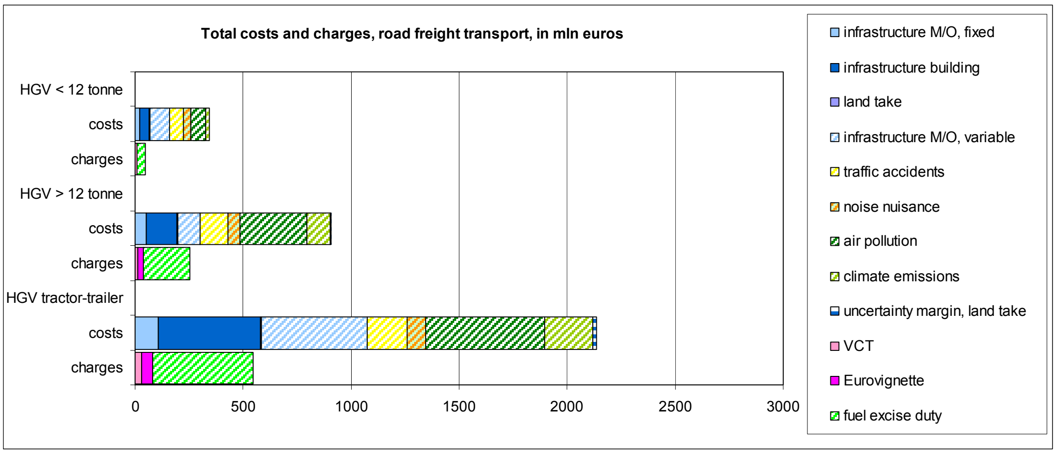
In the case of road freight transport, we see that total (fixed and variable) charges are only a fraction of total social costs (figure 26).

figure 26 Total social costs and user charges, road freight transport (€ mln/year)



When we break these figures down to assess the situation for the various categories of heavy goods vehicle, we see that total costs rise markedly with increasing vehicle size (figure 27). This is because a number of cost items (including land take and climate impact) are fairly tightly linked to vehicle size and weight, but also because of the proportionally larger fraction of domestic transport performance (i.e. number of vehicle kilometres within Dutch borders) due to heavier categories of HGV.

figure 27 Total social costs and user charges, three categories of HGV (€ mln/year)



9.4.2 Rail

The picture for rail freight transport is much the same as for passenger rail. In this case, however, the variable costs are relatively higher. This is due mainly to the costs of noise nuisance and air pollution, the latter caused mainly by the relatively high share of diesel traction in passenger transport. Because of the far lower kilometre performance of freight rail compared with passenger rail, the total costs involved are only about one-tenth of the previous figure. Of these costs, though, only a few per cent are recovered via charges (fuel duty, Regulatory Energy Charge, charge for infrastructure use).
As in the case of passenger rail, the results are reported in two variants for M/O costs, in which renewal costs are assumed to be either part-variable (figure 28) or entirely fixed (part 29).

figure 28 Total social costs and user charges, rail freight transport (€ mln/year; costs of infrastructure renewal assumed part-variable)

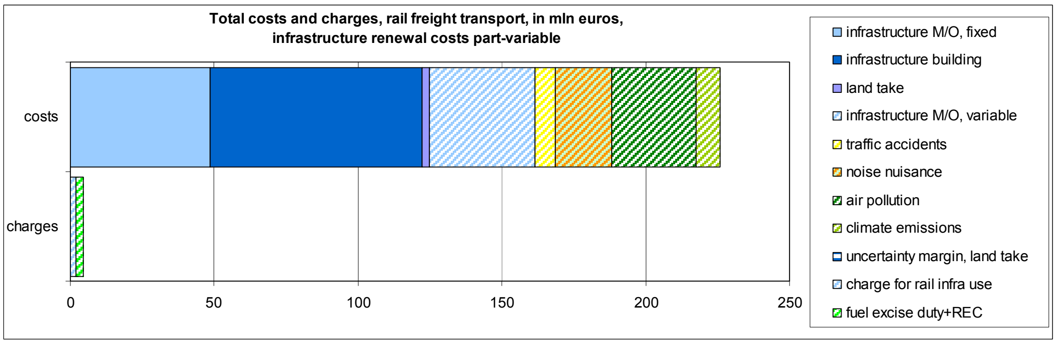
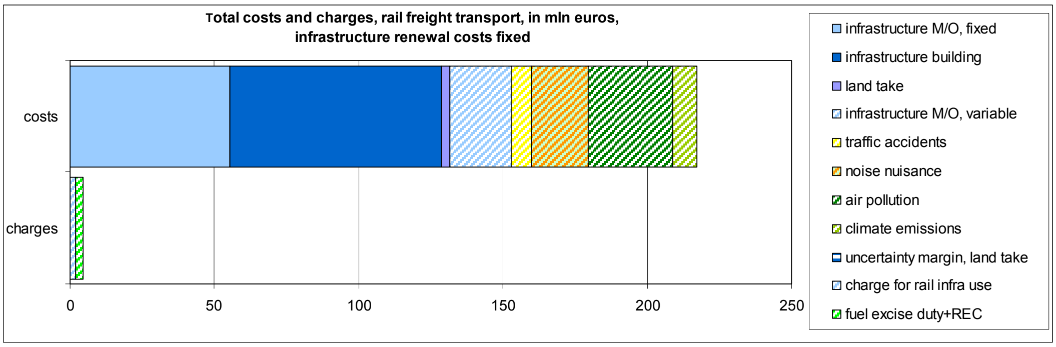


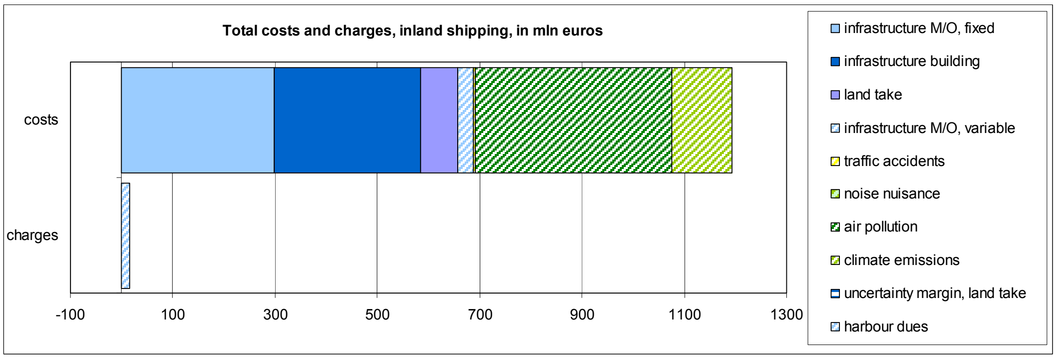
figure 29 Total social costs and user charges, rail freight transport (€ mln/year; costs of infrastructure renewal assumed fixed)



9.4.3 Inland shipping

The total costs generated by inland shipping exceed those of rail freight transport by almost an order of magnitude (figure 30). This is not entirely surprising, however, when it is borne in mind that in the Netherlands the same kind of ratio holds between the figures for respective transport performance in tonne kilometres.

figure 30 Total social costs and user charges, inland shipping (€ mln/year)



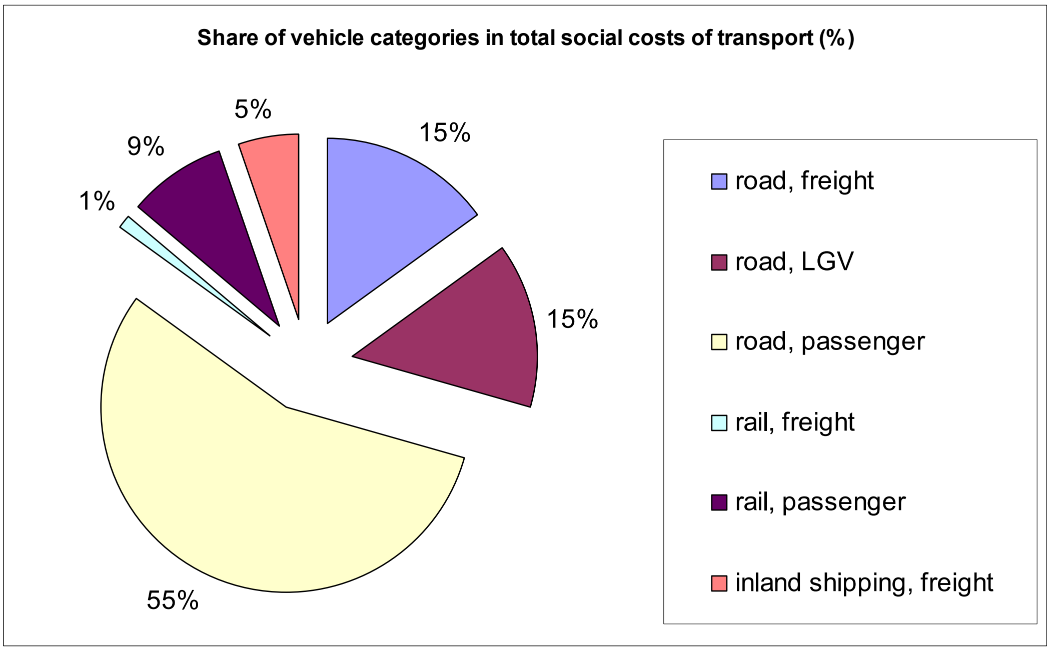
Another difference is in the make-up of the variable social costs, which here derive almost entirely from environmental costs (climate change, but particularly air pollution). The variable costs of accidents and noise are almost negligible. In common with rail freight, again the revenues from standing charges are minimal in comparison with costs.

9.5 Synopsis

In summary we see that, of all the modes of transport investigated in this study, passenger transport on the roads accounts for by far the greatest share of total external costs, again as defined in this study. This is due basically to the huge number of annual vehicle kilometres represented by this segment. At some distance follow light goods vehicles, heavy goods vehicles, inland shipping and passenger rail, with freight rail at the bottom of the list. It makes no real difference to the overall picture whether the costs of railway infrastructure renewal are considered fixed or part-variable (figure 31).

On the most striking results is that the total social costs due to light goods vehicles are the same, in rounded figures, as those for HGVs, i.e. the entire road freight sector. Although per-kilometre costs are higher for the latter, this is entirely offset by the sheer number of LGVs on the roads. Given this observation, and the fact that the LGV segment has been growing more rapidly than any other in recent years, it would seem advisable to focus appropriately on this vehicle category in future transport, mobility and environmental policy.

figure 31 Percentage share of vehicle categories in total social costs of transport in the Netherlands [62]



Despite road transport being responsible for over half of the aggregate social costs identified, it is the mode that best pays its way in terms of the costs being covered by user charges (see figures 32 and 33). As we saw above, in the case of the average petrol car these costs are compensated almost entirely. In these figures, the charges paid by inland shipping and rail freight transport are so fractional as to be non-visible.

---

[62] In this figure we make no distinction between the two variants for the renewal costs of railway infrastructure (fixed vs. part-variable), because the difference involved is so small as to have no significant influence on the overall percentages shown.

figure 32 Total social costs and user charges, principal categories of passenger and freight transport (€ mln/year; costs of rail infrastructure renewal assumed part-variable)

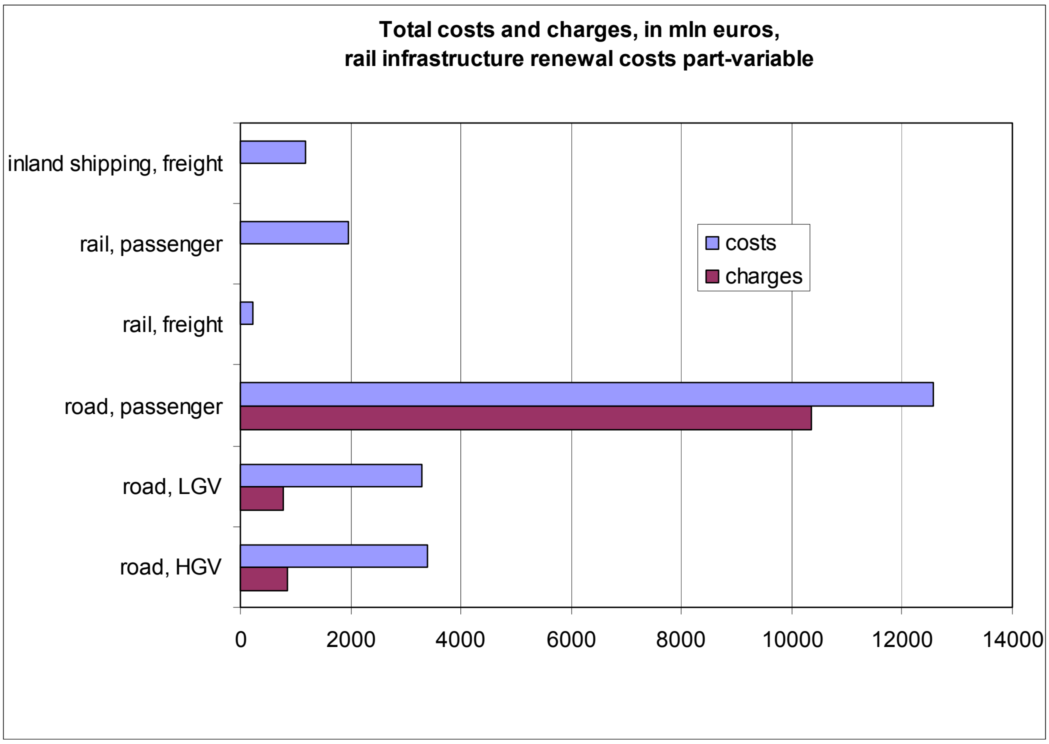
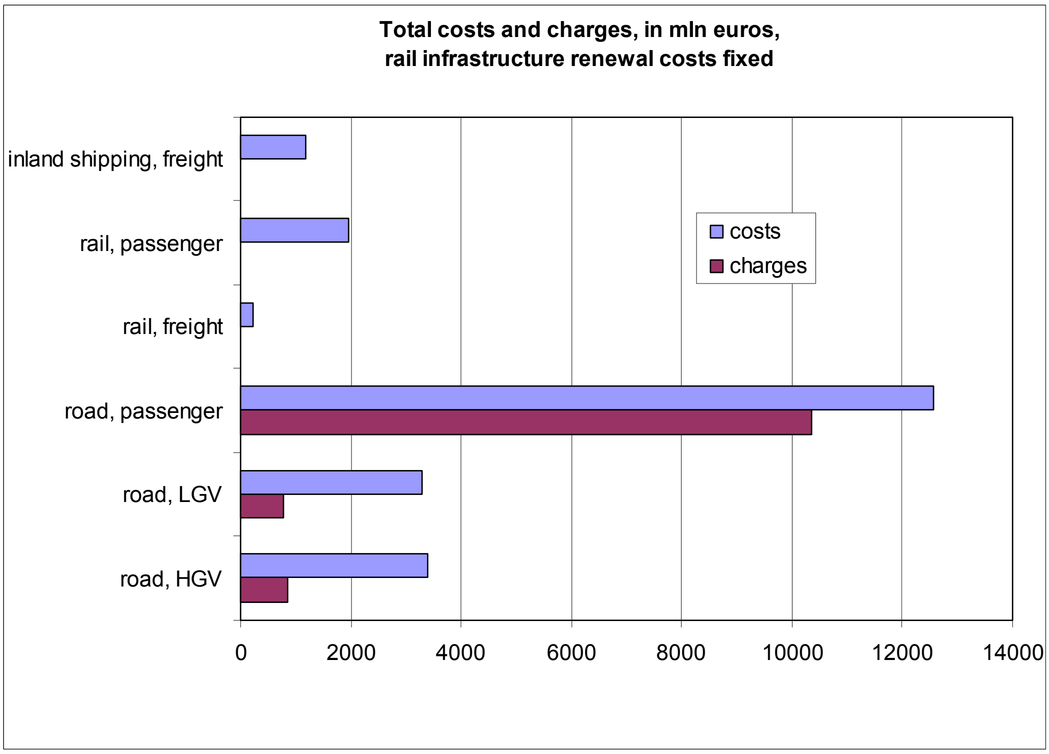


figure 33 Total social costs and user charges, principal categories of passenger and freight transport (€ mln/year; costs of rail infrastructure renewal assumed fixed)



10 Results for the efficiency variant

10.1 Introduction

In this chapter we report the results for the ‘efficiency’ variant of the analysis. The issue we are concerned with here is the extent to which individual users incorporate *variable* costs in their transport decisions. In this variant, then, we compare, the usage-based, variable costs of each vehicle category with the variable charges paid. In the figures presented below, the variable costs are consequently expressed *per vehicle kilometre.*

For any given vehicle category, variable costs and charges are highly dependent on individual vehicle characteristics and the particularities of the traffic situation. In this variant we therefore distinguished a best and a worst case for each transport mode to obtain an idea of the range of costs involved. The parameters of these best and worst case scenarios are set out in section 1.6.3.

The detailed raw data underlying the figures in this chapter are to be found in annex J.

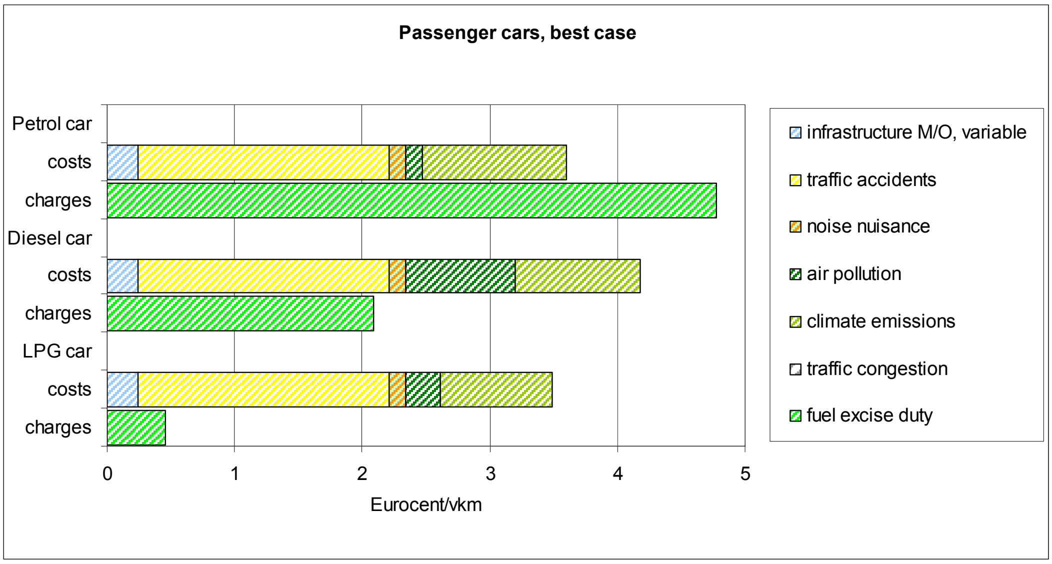
Nota bene!
When reading this chapter, it is important to bear in mind that the figures for the best and worst case scenarios are often presented on different scales, because of the major differences in the sums involved.

10.2 Passenger transport

10.2.1 Passenger cars

With respect to passenger cars, what is immediately striking is the huge influence of congestion costs on the overall picture (figure 35). When congestion sets in (peak-time traffic, worst case), costs per vehicle kilometre increase by a full order of magnitude.

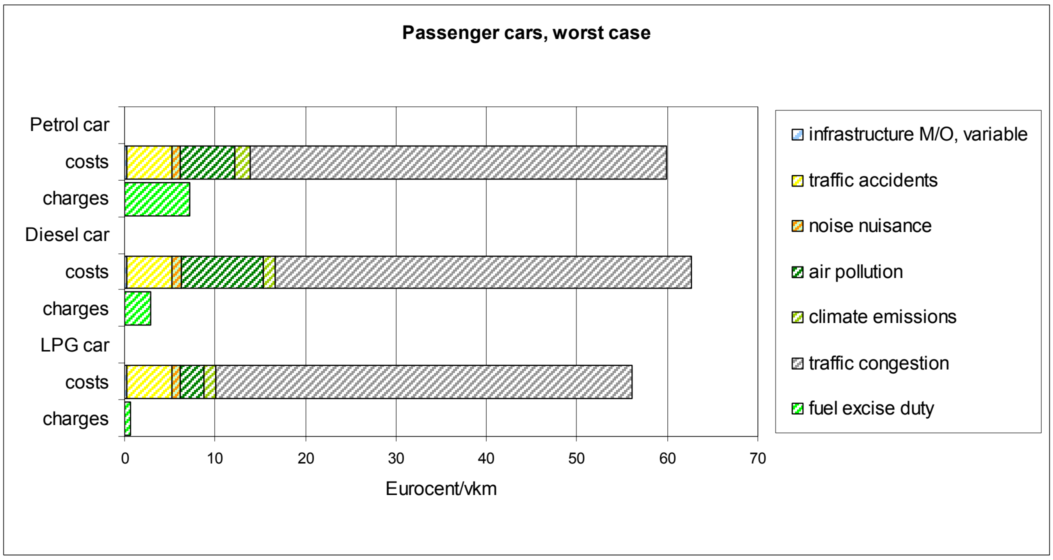
figure 34 Variable social costs and user charges, passenger car transport, best case (€ct/vehicle kilometre)



What we also see, in the best case scenario (figure 34), is that petrol cars more than cover their variable costs by way of fuel duty, while in the worst case there is a deficit, even before congestion is allowed for. As these results show all too clearly, any statement to the effect that petrol cars 'pay their way' with respect to social costs' should be made with due caveats and appropriate nuance.

It can be concluded that cars running on diesel and LPG do not cover their variable social costs. The deficit amounts to some 50-90% in the case of diesel cars and 85-90% for LPG vehicles. The tax benefit to owners of LPG cars (who pay over 90% less duty compared with owners of petrol vehicles) in view of lower pollutant emissions would therefore seem unjustified.

figure 35 Variable social costs and user charges, passenger car transport, worst case (€ct/vehicle kilometre)

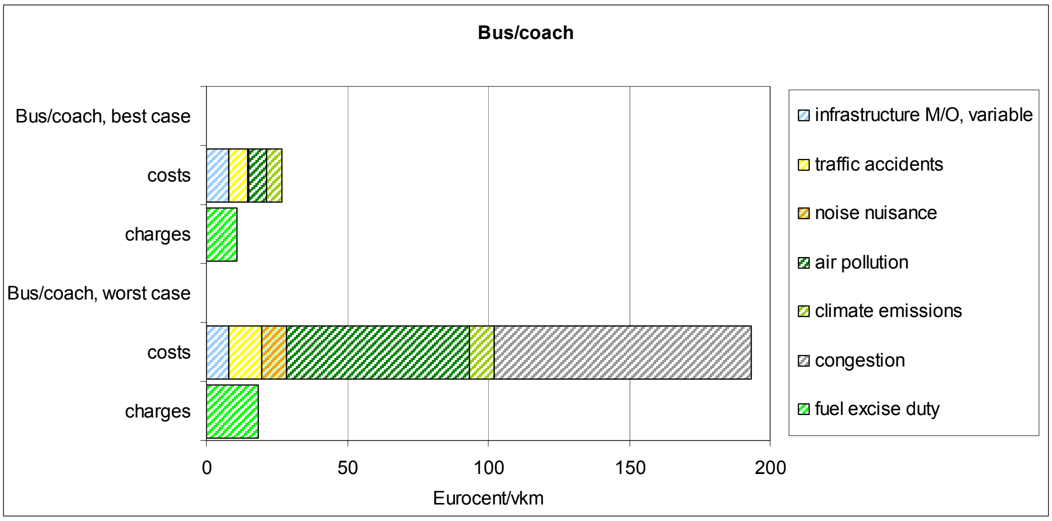


Note that this graph is on a different scale to that for the best case!

10.2.2 Buses and coaches

In the case of buses and coaches, too, congestion costs have a major influence on the overall picture (figure 36). We also see that the costs of air pollution and noise, in particular, are far higher in the worst case scenario. This derives mainly from the fact that the nuisance and health damage due to these two types of emission are far greater in the urban environment compared with rural areas.

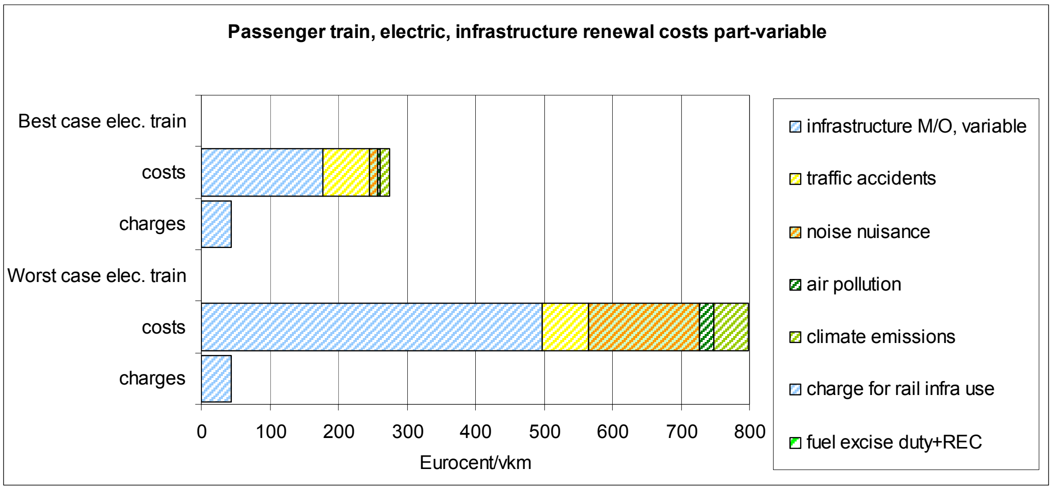
figure 36 Variable social costs and user charges, bus and coach transport, best and worst case (€ct/vehicle kilometre)



10.2.3 Rail

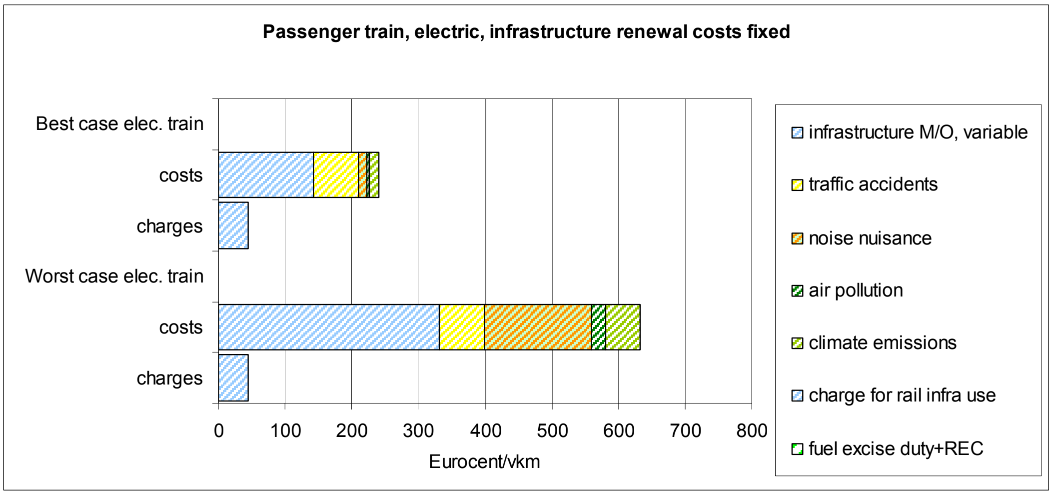
With regard to rail passenger transport, we see that the variable costs associated with *electric* trains are considerably lower in the best than the worst case (figure 37). The difference lies in the different weight of the locomotives involved, a light ‘Sprinter’ in the best case and a heavy Intercity in the worst, with the variable M/O costs of the latter markedly higher. The power consumption of the heavier loc is also greater, pushing up the costs of CO_2 emissions, in particular. It was assumed in the worst case, furthermore, that the Intercity is on an urban line, thus causing comparatively high noise costs in terms of numbers of exposed people. Note, however, that as Intercity trains serve a larger number of passengers, the difference in social costs per *passenger kilometre* is probably far smaller.

figure 37 Variable social costs and user charges, rail passenger transport (electric), best and worst case (€ct/train kilometre; costs of infrastructure renewal assumed part-variable)



If the costs of rail infrastructure renewal are taken as fixed, the variable M/O costs decrease (figure 38).

figure 38 Variable social costs and user charges, rail passenger transport (electric), best and worst case (€ct/train kilometre; costs of infrastructure renewal assumed fixed)

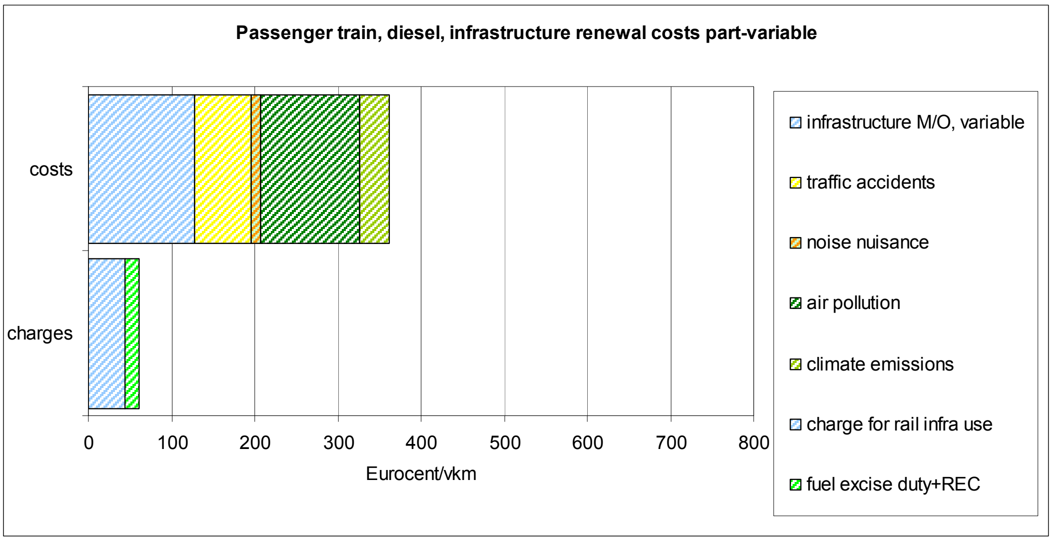


With respect to passenger transport by *diesel* train, variable costs per passenger kilometre are found to be substantially higher than for ‘Sprinter’ trains, which have roughly the same transport capacity (figure 39). The difference derives mainly from the costs of pollutant emissions, which are far higher for diesel traction[63].

---

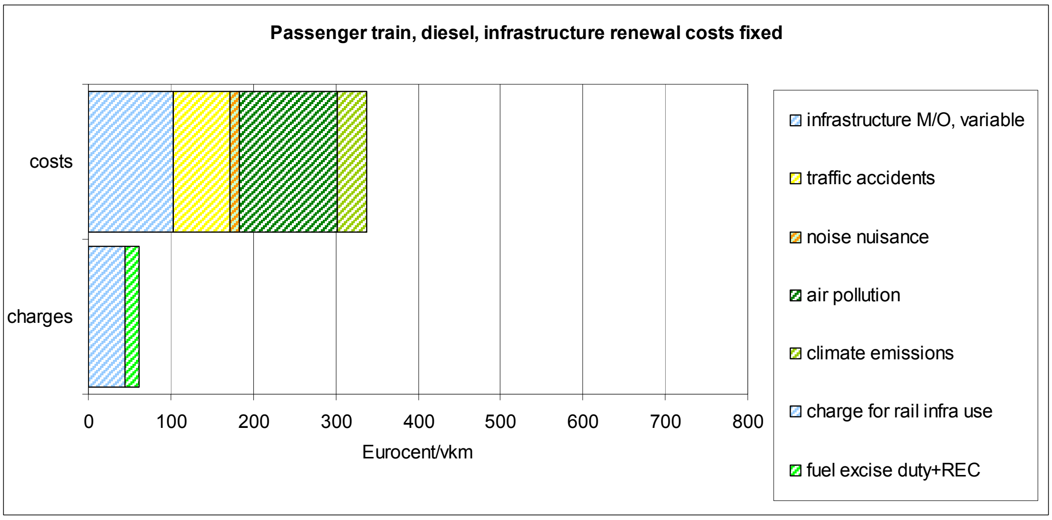
[63] We reiterate that in this study we did not distinguish a best and worst case for diesel passenger trains (cf. section 1.6.3).

figure 39 Variable social costs and user charges, rail passenger transport (diesel) (€ct/train kilometre; costs of infrastructure renewal assumed part-variable)



As with electrical traction for passenger trains, we see a decrease in the variable costs of rail infrastructure maintenance and operation if infrastructure renewal costs are assumed to be fixed (figure 40).

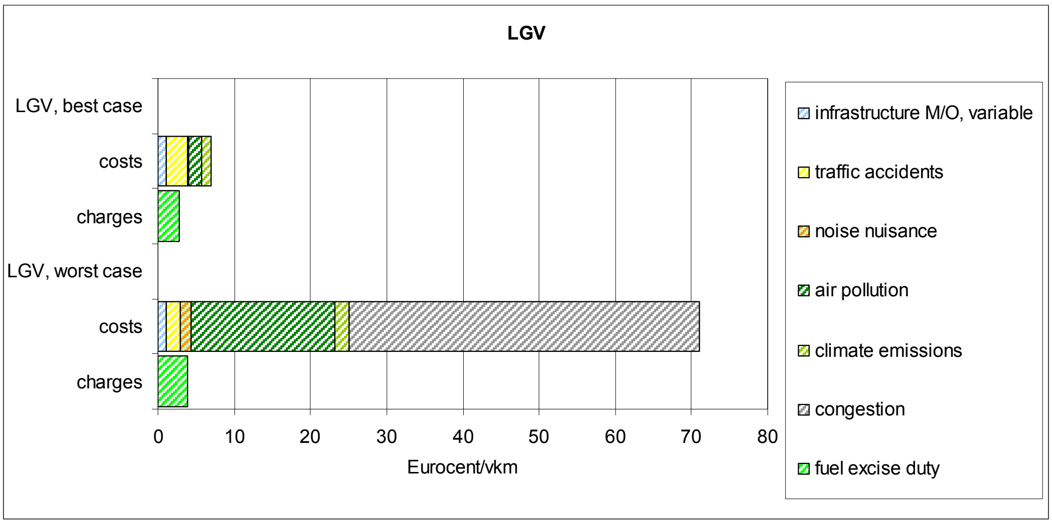
figure 40 Variable social costs and user charges, rail passenger transport (diesel) (€ct/train kilometre; costs of infrastructure renewal assumed fixed)



10.3 Light goods vehicles

The costs of air pollution and climate change are slightly higher for LGVs (figure 41) than for passenger cars (compare figures 34 and 35). This is because vans have a higher engine rating and consequently burn more fuel. In addition, the emission standards in force for LGVs are not as strict as those for cars, and emissions are consequently higher. Noise production is also greater, because of the heavier engine and greater axle load, creating more road-tyre noise.

figure 41 Variable social costs and user charges, LGV, best and worst case (€ct/vehicle kilometre)



In the best case, user charges (i.e. fuel excise duty) cover approximately half the social costs of LGV use. In the worst case, there is less than 10% cost coverage, a similar figure to that for diesel passenger cars, it may be added.

10.4 Freight transport

10.4.1 Road

With heavy goods vehicles, too, we see congestion costs exerting a major influence on the overall picture (figure 42 versus figure 43). In this case, though, the relative influence is less pronounced than for smaller road vehicles, because the other costs are higher. This is particularly true of emission costs but holds for accident costs, too. Because of their far greater weight, HGVs burn more fuel and, in relative terms, cause more traffic casualties among drivers of other vehicles.

Surprisingly, perhaps, the per-kilometre costs of light goods vehicles are not much lower than those of their (far) heavier counterparts. To a certain extent, however, this is due to the high proportion of kilometres driven by vans in urban areas, leading to higher emission, noise and accident costs.

figure 42 Variable social costs and user charges, HGV, best case (€ct/vehicle kilometre)

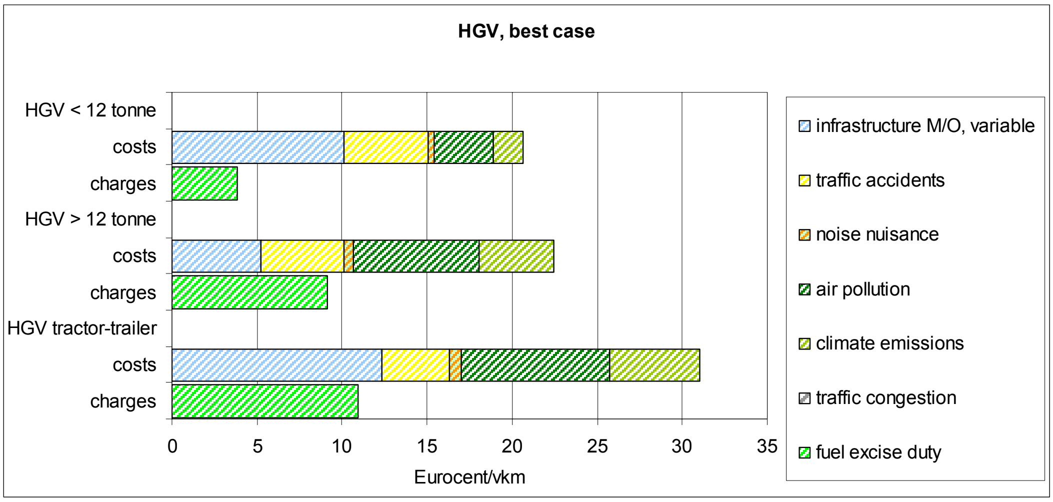
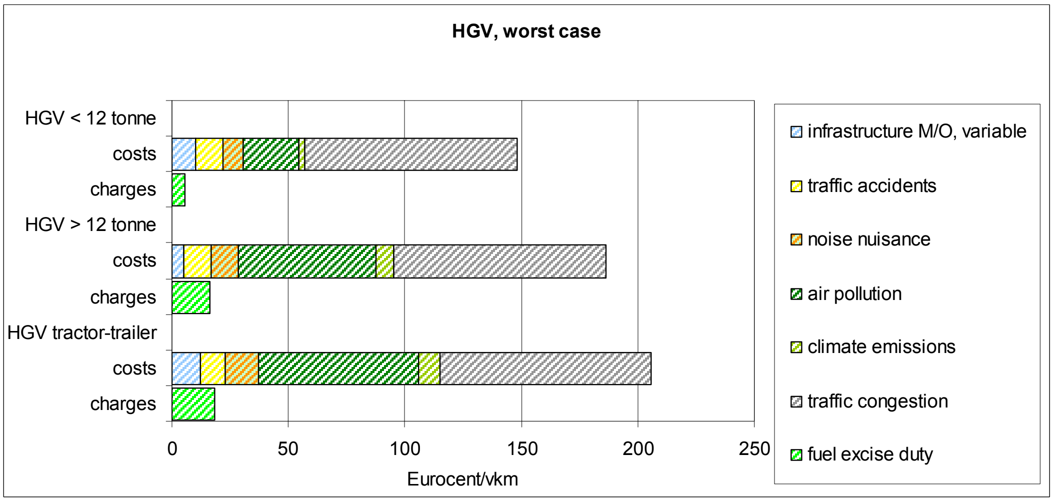


figure 43 Variable social costs and user charges, HGV, worst case (€ct/vehicle kilometre)



Note that this graph is on a different scale to that for the best case!

10.4.2 Rail

With rail freight transport there is an enormous difference in costs between the best and worst case scenarios. The best case (figures 44 and 45) is for an electrically powered, non-bulk freight train running unladen in a rural area. The electrical traction gives rise to virtually no air pollution and because of the relatively low weight, energy consumption is also down, as are the variable costs of infrastructure maintenance and operation (low axle loads causing less wear and tear of the track). Running through a (less populated) rural area, the hypothetical train also gives rise to lower noise costs.

figure 44 Variable social costs and user charges, rail freight transport, best case (€ct/train kilometre; costs of infrastructure renewal assumed part-variable)

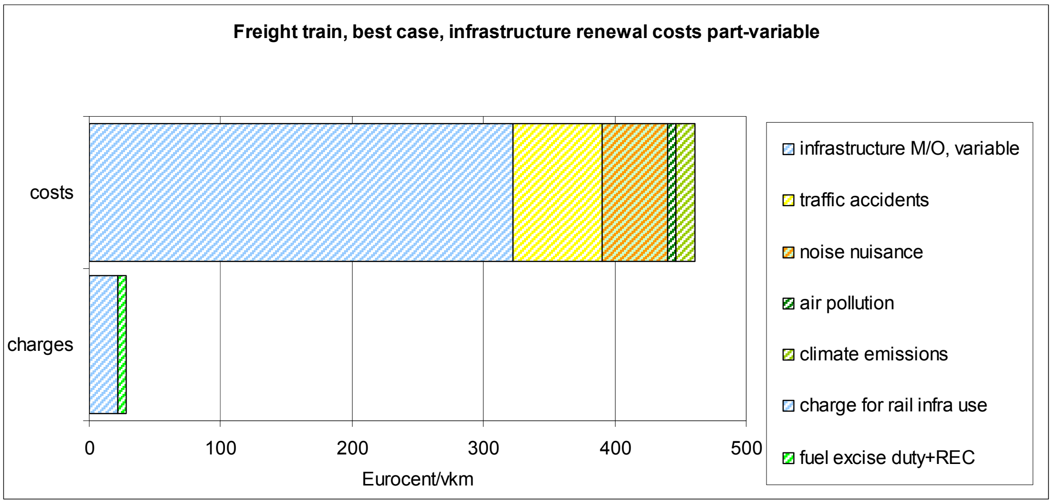
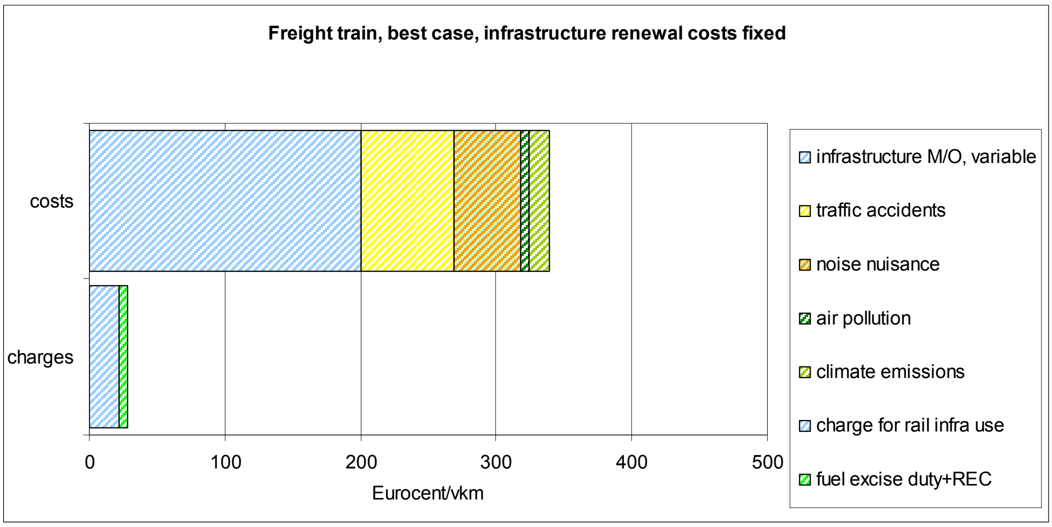
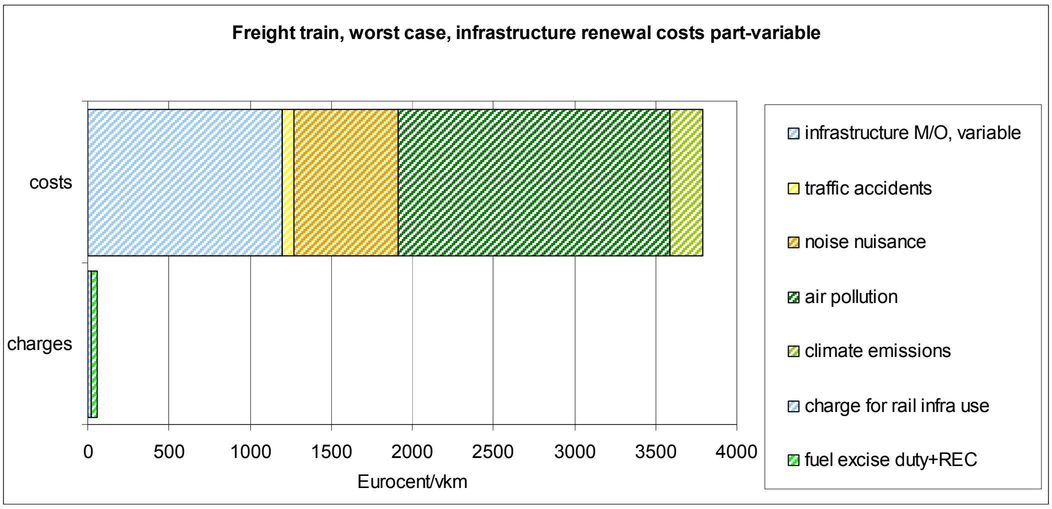


figure 45 Variable social costs and user charges, rail freight transport, best case (€ct/train kilometre; costs of infrastructure renewal assumed fixed)



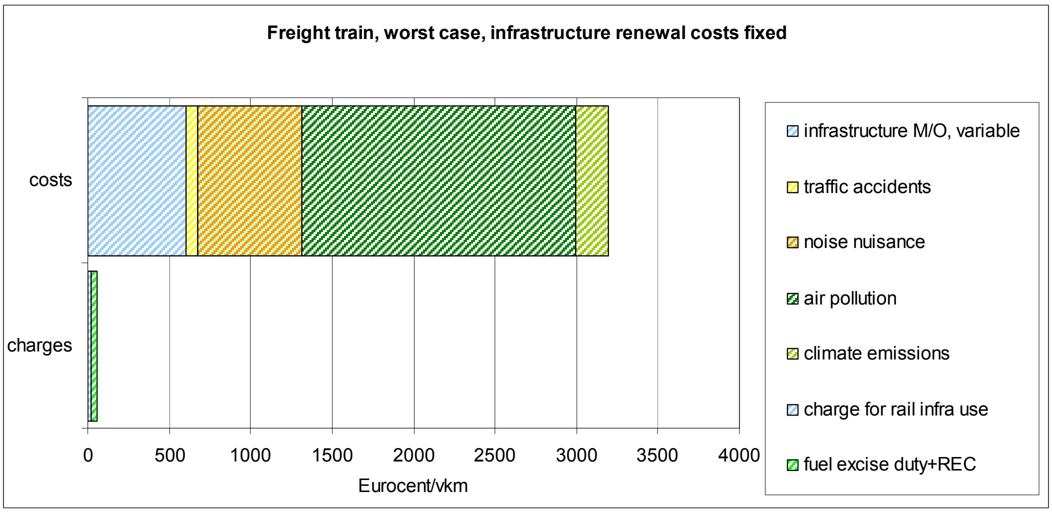
In the worst case (figures 46 and 47) we have a diesel locomotive pulling a fully laden freight train with bulk goods (such as ore) through an urban area. In this scenario, the higher weight causes far more track degradation, reflected in comparatively high variable M/O costs. Diesel traction gives rise to greater pollutant emissions, which are associated with greater health damage, furthermore, because they occur in (more populated) urban areas. The same applies to noise emissions.

figure 46 Variable social costs and user charges, rail freight transport, worst case (€ct/train kilometre; costs of infrastructure renewal assumed part-variable)



Note that this graph is on a different scale to that for the best case!

figure 47 Variable social costs and user charges, rail freight transport, worst case (€ct/train kilometre; costs of rail infrastructure renewal assumed fixed)



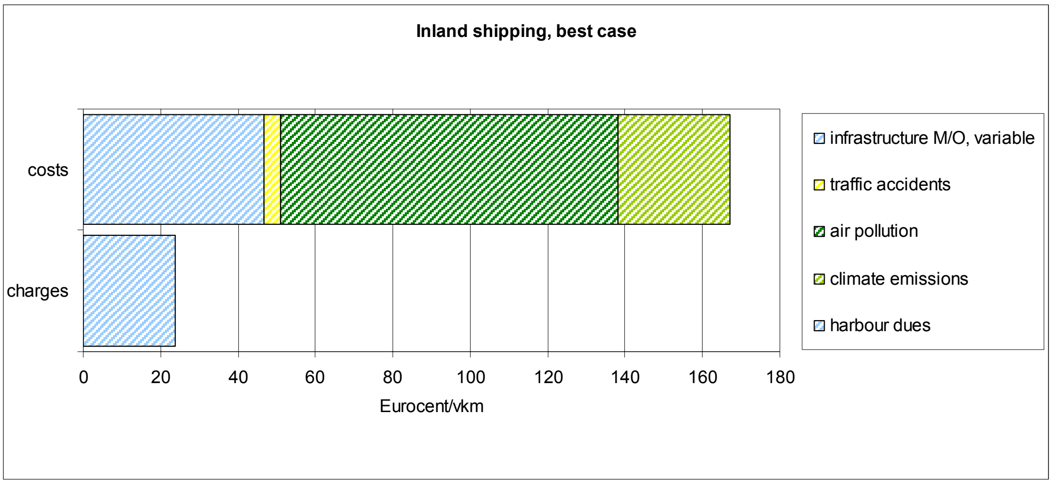
Note that this graph is on a different scale to that for the best case!

Across the board, i.e. from the best to the worst case, usage-dependent charges cover only a fraction of total variable social costs.

10.4.3 Inland shipping

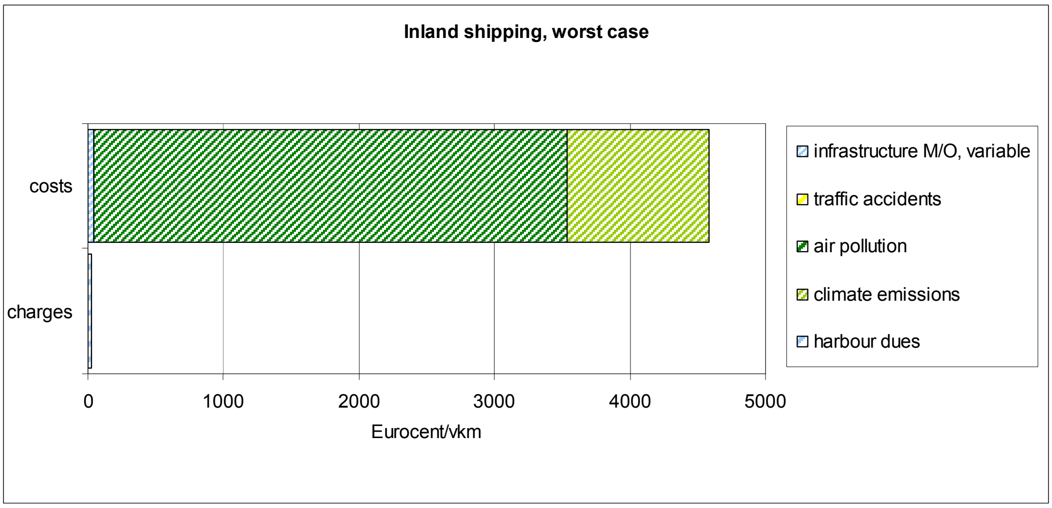
As with rail freight transport, in the case of inland shipping we again see enormous differences. Here the main differences relate to emissions of CO_2 (climate impact) and air pollutants. In the best case (figure 48) we have a small vessel burning approximately 20 times less fuel than the quadruple pushed barge unit of the worst case (figure 49) and weighing in at 350 tonnes loading capacity compared with 8,000 tonnes for the latter type of vessel. In addition, every vessel consumes about twice as much fuel when fully laden (worst case) than when sailing empty (best case). Of less relevance here are river velocity (20% difference) and engine efficiency (15% difference).

figure 48 Variable social costs and user charges, inland shipping, best case (€ ct/vessel kilometre)



The influence of all this on the variable costs of waterway maintenance and operation remains unrecorded here, it may be noted, as we have taken these costs as varying with number of passages rather than vessel kilometres.

figure 49 Variable social costs and user charges, inland shipping, worst case (€ ct/vessel kilometre)



Note that this graph is on a different scale to that for the best case!

10.5 Synopsis

There are a number of conclusions that can be drawn with respect to variable costs:

Road passenger vehicles

- For virtually every category of road passenger vehicle, variable user charges add up to less than the variable costs of infrastructure maintenance and operation and other external costs. This conclusion holds even before the costs of traffic congestion are factored into the equation. Once included, they immediately dwarf all other costs.
- Petrol-driven cars are the only vehicle category of which it *cannot* be said with any certainty that it does not pay its way, in terms of external costs being recovered from user charges. Once congestion sets in, however, cost recovery falls to no more than about 10%.
- In the case of diesel cars, LPG cars and diesel light goods vehicles, variable charges (currently, fuel duty) cover only about half to one-tenth of the variable costs, for diesel and LPG cars, respectively. In this context, it would be wise to use the leverage of fuel duty to recover climate costs (CO_2 emissions), using a different instrument (a kilometre charge indexed to vehicle environmental performance, for example) to recover the costs of pollutant emissions (in particular, NO_X and fine particulates). (We return to this issue in the concluding chapter).

Light goods vehicles

Because of their heavier engines and greater axle loads, LGVs are associated with somewhat higher nose and emission costs than passenger vehicles. The degree of cost recovery is roughly the same as for diesel passenger cars.

Heavy goods vehicles

The situation is much the same for each of the HGV categories distinguished in this study. In each case, the extent of cost recovery is between about half and one-quarter. Cost coverage is greatest for tractor-(semi)trailer combinations, as these vehicles make greatest use of motorways, where the costs of accidents, pollutant emissions and noise are lowest in relative terms. In addition, this category of HGV pays the most fuel duty per kilometre.

Rail

With respect to both passenger and freight rail transport, it can be concluded that variable costs are subject to considerable variation, depending on train weight, type of traction and urban versus rural operation. Across the board, however, only a fraction of the variable costs are recovered in the form of variable charges.

Inland shipping

The conclusions regarding inland shipping are broadly the same as for rail.

11 Conclusions and recommendations

11.1 Conclusions

11.1.1 Regarding total social costs and charges

General

1 In 2002 the total social costs of domestic transportation in the Netherlands, *excluding* aviation, sea shipping, recreational shipping, high-speed rail, cycling and walking, amounted to approx. € 22.5 billion. Over half this figure (about 55%) is due to road passenger transport, followed by HGV (i.e. road freight) and LGV (both approx. 15%), rail passenger transport (approx. 9%), inland shipping (5%) and rail freight (approx. 1%). *Note that these figures do not cover all social costs*, in particular those associated with habitat fragmentation, barrier effects and visual intrusion due to transport infrastructure (see also the Recommendations below).

2 There is not a single category of transport, road, rail or shipping, that is fully charged for all the social costs to which it gives rise. The only potential exception are petrol-driven passenger cars, for which we calculate that the estimated social costs are approximately covered by the user charges paid. Note again, however, that not all social costs were included in the quantitative analysis (see conclusion 1). Note also that the share of petrol-driven vehicles in the passenger car fleet has been declining in recent years and that of diesel vehicles increasing (see conclusion 1).

3 For all the transport modes considered, fixed social costs exceed fixed user charges, with the possible exception of petrol and diesel passenger cars. This does not necessarily mean the fixed charges for these vehicle categories are presently too high, as the social costs of fragmentation, barrier effects and visual intrusion have not yet been factored in. Only after realistic figures have been worked out for these items can it be calculated whether or not current fixed charges are too high and should be reduced for considerations of welfare optimisation.

Road transport

4 In 2002 the total social costs attributable to transportation by LGV (vans) approximately equalled those of domestic road freight carriage by HGV (trucks); given the steady growth of the Dutch LGV fleet, they are now (2004) probably greater. In transport and environmental policy circles, however, there appears to be relatively little interest in LGVs.

Rail transport

5 With rail transport, the fixed costs of infrastructure (maintenance/operation and renewal) predominate. In the case of passenger rail these account for about 75% of total social costs, in the case of freight for over half these costs.

Inland shipping

6 For inland shipping, the fixed costs of infrastructure (maintenance/operation and renewal) account for about 50% of total social costs. Compared with rail freight transport, though, variable M/O costs are proportionally lower, consisting almost entirely of the costs of pollutant emissions (CO_2 and other).

11.1.2 Regarding variable costs and charges

General

7 For all the transport modes considered, with the exception of 'best case' petrol-driven passenger cars, current variable charges are lower than variable social costs. This means that for all these categories of vehicle and vessel, full allocation of variable social costs will lead to an increase in variable costs.

8 A comparison of the results of this study with those of earlier European studies on these issues shows good agreement for all vehicle categories, for both best and worst cases (as detailed in annex L).

Road transport

9 For virtually no category of road vehicle do variable charges cover variable social costs, even if congestion costs are assumed to be zero (these exceeding all other items by far).

10 In the case of passenger cars, besides congestion costs the main variable costs are those due to traffic accidents and air pollution. However, in the best case (new vehicle, rural area) the latter cost item is already significantly lower than in the worst case (10 years old, urban area), an improvement due mainly to the introduction of progressively tighter EU standards for NO_X and fine particle emissions over the intervening 10 years. There is far less difference with respect to CO_2 emissions, for which no European emission standards are (yet) in force.

11 Petrol-driven cars are the only means of transport for which variable charges are not definitely lower than variable costs. If the costs of congestion are included, however, variable charges come to cover only about 12% of variable costs. Ignoring congestion, even in the worst case (10 year-old petrol-driven car, urban environment) variable charges prove to cover only just over half the variable costs. Thus, the conclusion that petrol passenger cars 'pay their way' in terms of covering their social costs is not generally valid, applying only to certain categories of vehicle in an uncongested situation.

12 In the case of diesel and LPG passenger cars and diesel LGVs, variable charges (currently, only fuel excise duty) cover between 50% (diesel car, best case) and 1% (LPG car, worst case) of variable costs. Due allocation of these latter costs will therefore bring user charges for diesel and LPG vehicles more in line with those for petrol vehicles.

13 In the present situation, variable charges for passenger cars are not structurally or directly related to cost drivers. In particular, the influence of such factors as vehicle emission class, safety and noise level, as well as journey time and location – all of which are major factors determining overall variable costs – is not currently reflected in the cost structure at all.

14 For the various categories of HGV the situation is fairly similar, with variable charges covering about half to one-quarter of variable costs. Coverage is greatest for tractor-(semi)trailer combinations, as these make most use of motorways, where the costs of accidents, air emissions and noise are lowest, in relative terms, and pay the most fuel duty per kilometre driven.

Rail transport

15 With rail transport, both passenger and freight, variable costs can vary enormously, depending on aggregate train weight, type of traction and urban vs. rural. In all cases, though, variable charges (and particularly those paid for infrastructure use) are only a fraction of variable costs. Increasing both the capacity and utilisation of the existing rail grid provides a means of achieving greater coverage of variable costs via the infrastructure charge at only a fairly minor increase in cost per passenger or tonne kilometre.

16 In the case of passenger rail, the variable costs of infrastructure maintenance and operation account for about half the total variable costs. In the case of rail freight, variable M/O costs still predominate, but here air pollution (due to the relatively high share of diesel traction) and noise nuisance also contribute significantly.

Inland shipping

17 For inland shipping the picture is broadly similar to that for rail freight, although here there are virtually no variable charges and in the worst case these are lacking entirely.

11.2 Recommendations

1 In this study, the external costs of habitat fragmentation, barrier effects (wildlife) and visual intrusion associated with transport infrastructure were not included in the analysis, for the simple reason that there are currently no methods available for assessing either the magnitude of these impacts or the monetary value to be assigned to them. It is therefore recommended that a method or methods are developed for this purpose.

2 In this study, aviation and sea shipping were also left out of the equation. At the moment there is no way of painting a full picture of the infrastructure costs and other external costs due to sea shipping. The greatest area of uncertainty here relates to the costs of seaport infrastructure. In the first place, seaport administrators are hard pressed to cite solid figures for expenditures on infrastructure (both fixed and variable) over the years and decades. In its White Paper the European Commission also drew attention to this issue. Secondly, it is by no means straightforward to allocate the costs of seaport infrastructure across the various categories of vessel and vehicle making use of these provisions (sea shipping, commercial inland shipping, recreational shipping, rail and road). Before the social costs of marine shipping can be reliably estimated, then, more vigorous research must first be carried out to assess these costs and, above all, agreement reached on an internationally recognised calculation procedure. In the case of aviation, it is comparatively difficult to obtain any solid data at all on (external) costs.

3 We recommend that further research be undertaken to establish the extent to which the costs of rail infrastructure renewal can be taken as variable in the Netherlands (in the present study British data were used). In the European setting, the *Rail charging task force* has been set up by the Commission (at DG TREN) specifically to report on this issue in the near future. The results of that exercise will probably bring an end to the current Dutch debate on whether or not these renewal costs should be booked as fixed or part-variable in this country.

4 There are considerable uncertainties regarding the costs of maintaining and operating locally administered waterways. It is recommended that this issue be investigated more closely.

References

AVV, 2003
EMS-protocol - emissies door de binnenvaart: verbrandingsmotoren
versie 3, 22-11-2003, *Adviesdienst Verkeer en Vervoer* (Dutch Transport Research Centre), Rotterdam 2003

AVV, 2004a
Personal communication, Mr Ernst Bolt, AVV, April-May 2004

AVV, 2004b
AVV basisgegevens voor 2000-2002
Personal communication, Mr Sjef Deckers, AVV

AVV, 2004c
Rapportage Nautische Veiligheid 2000/2001/2002: binnenwateren
(AVV basic statistics)

AVV/CBS, 2002
Nederland en de scheepvaart op de binnenwateren 2002
Nijkerk 2002

BAH, 2000
Usage Costs: Issues raised in the regulator’s consultation
Report to Office of the Rail Regulator, Booz, Allen & Hamilton, London, October 2000

CBS, Statline
Online statistical database: http://statline.cbs.nl

CBS, 1996b
Statistiek van het binnenlands goederenvervoer 1996
Centraal Bureau voor de Statistiek (Netherlands Statistics), Voorburg/Heerlen 1996

CBS, 2003
Financiële Maandstatistiek, Jaargang 9 - november 2003
Centraal Bureau voor de Statistiek, Voorburg/Heerlen 2003

CBS, 2004
Personal communication, Mr T.A. van Tongeren
Centraal Bureau voor de Statistiek, Voorburg/Heerlen 2004

CE, 1999
Efficient prices for transport
CE, Delft 1999

CE, 2001
Benzine, diesel en LPG: balanceren tussen milieu en economie
CE, Delft 2001

CE, 2003a
Efficient geprijsd; een beknopte analyse van verkeerskosten en -heffingen
Policymakers' draft, version 1.0
CE, Delft 2003

CE, 2003b
Efficient geprijsd; een kwalitatieve analyse van verkeerskosten en -heffingen
Policymakers' draft, version 1.0
CE, Delft 2003

CE, 2003c
External and infrastructure costs of road and rail traffic - analysing European studies
CE, Delft 2003

CE/RIVM, 2003
To shift or not to shift, that is the question - The environmental performance of the principal modes of freight and passenger transport in the policy-making context CE/RIVM, Delft/Bilthoven 2003

CE/VU, 2004a
Definities en beprijzingsprincipes; deelonderzoek 1 i.h.k. IBO Gebruiksvergoedingen Goederenvervoer 2004
CE/VU, Delft/Amsterdam 2004

CE/VU, 2004b
Onderhoud en beheer van infrastructuur voor goederenvervoer; Structuur en hoogte van kosten
CE/VU, Delft/Amsterdam 2004

CE/VU/4cast, 2002
Returns on roads : optimising road investments and use with the 'user pays pinciple'
CE Delft 2002

CVB, 1999
Richtlijnen vaarwegen
R.J. Dijkstra, J.U. Brolsma / *Commissie Vaarweg Beheerders, CVB* (Waterway Management Board), Rotterdam 1999

DWW, 2000
Gebruikerskosten
Rijkswaterstaat, Dienst Weg- en Waterbouwkunde (Directorate-General of Public Works and Water Management, Road and Hydraulic Engineering Division), Delft 2000

DWW, 2002
Basisonderhoudsniveau 2001
Expertisecentrum Beheer en Onderhoud, Dienst Weg- en Waterbouwkunde (Maintenance Expertise Centre, Road and Hydraulic Engineering Division), Delft 2002

DWW, 2003
Programma-aanvragen 2005-2009
provided by email

DWW, 2004
Personal communication, Mr W.P. Hoogenboom
Netherlands Ministry of Transport, Public Works and Water Management (Road and Hydraulic Engineering Division)

EC, 2003
Proposal for a directive of the European Parliament and of the Council amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures
Brussels 2003

ECMT, 1998
Efficient transport for Europe; Policies for internalisation of external costs
European Conference of Ministers of Transport (ECMT), Paris, France 1998

ECMT, 2003
Reforming Transport Taxes
European Conference of Ministers of Transport (ECMT), Paris, France 2003

Ecorys (in progress)
Charging and pricing in the area of inland shipping - Practical guideline for realistic transport pricing
ECORYS Transport & METTLE, in progress

HCG, 1996
LMS Basismatrices '94; PAE-factor vrachtverkeer
The Hague (study commissioned by AVV; see above)

HLG, 1999a
Calculating transport accident costs
Final report of the expert advisors to the High Level Group on Infrastructure Charging, 27 April 1999

HLG, 1999b
Calculating transport congestion and scarcity costs
Final report of the expert advisors to the High Level Group on Infrastructure Charging (working group 2), May 7 1999

INFRAS/IWW, 2000
External costs of transport - Accident, environmental and congestion costs of transport in Western Europe
Zurich/Karlsruhe, March 2000

INFRAS/IWW, 2003
External costs of noise - The influence of various reduction measures on the external costs of freight railway noise
Zurich/Karlsruhe, May 2003.

IOO, 1994
De prijs van mobiliteit in 1990
Zoetermeer 1994

IOO, 2002
Parkeren in Nederland: Omvang, Kosten, Opbrengsten, Beleid
Zoetermeer (study commissioned by AVV; see above)

KOAC/WMD, 2001
Onderzoek naar de jaarlijkse onderhoudskosten aan het wegennet, veroorzaakt door overbelading van vrachtauto's in Nederland
Rijkswaterstaat, Dienst Weg- en Waterbouwkunde (Directorate-General of Public Works and Water Management, Road and Hydraulic Engineering Division), Delft

Minfin, 2003
Nota naar aanleiding van het verslag inzake het voorstel van wet houdende wijziging van enkele belastingwetten c.a. (Belastingplan 2004) (29 210) and response to letters from standing committee on Finance (ref. AFP 2003-00774, 28-10-2003)

Nash & Matthews, 2003
Rail infrastructure charges - the issue of scarcity
C.A. Nash and Matthews, B.
University of Leeds, 2003

Navrud, 2002
The state-of-the-art on economic valuation of noise
Final report to the Commission DG Environment April 14th 2002, Navrud, S., Department of economics and social sciences, Agricultural University of Norway

NEA, 2001
Basisgegevens kilometerheffing
NEA, Rijswijk

NEA, 2002
Vergelijkingskader modaliteiten III
NEA, Rijswijk April 2002

NEA, 2003
Vergelijkingskader modaliteiten IIIc
versie 2, NEA, Rijswijk December 2003

Nedtrain, 2001
Spoorwegveiligheidsplan 2001- 2005

NS, 2003
EnergieBesparingsPlan van NS Reizigers 2003 - 2005
Nederlandse Spoorwegen (Dutch Rail), October 2003

ProRail, 2003a
Tariefberekening Gebruiksvergoeding Nieuwe Stijl
2003

ProRail, 2003b,
Verkeersomvang 2002
2003

RAI-BOVAG, 2004
Mobiliteit in cijfers
www.bovagrai.nl

Railion, 2004
Personal communication, Messrs Rebbers and Bouterse

Railned, 2002
Spoorwegveiligheidsplan 2001-2005
Railned rail safety division

RIVM, 2002
Het spoor in model: energiegebruik en emissies door het railvervoer; Beschrijving en toepassing van het model PRORIN
National Institute for Public Health and the Environment, report no. 773002 021/2002, A. Gijsen, R.M.M. van den Brink

RIVM, 2004
Personal communication, Mr J. Jabben

Tebodin/DHV, 1992
Kosten op het spoor: kosten infrastructuur onderzoek NS Goederenvervoer, een afleiding op basis van concurrerende vervoerwijzen
Tebodin/DHV, Amersfoort / The Hague

TKSG, 2003
Jaarverslag van het Ministerie van Verkeer en Waterstaat (XII)
Netherlands Second Chamber, The Hague
28880, no. 26. Annual Reports for 2002, 21 May, 2003

TLN, 2002
Gelijke monniken, gelijke kappen
Transport en Logistiek Nederland, Zoetermeer

Taakgroep V&V, 2004
Methoden voor de berekening van de emissies door mobiele bronnen in Nederland t.b.v. Emissiemonitor, jaarcijfers 2001 en ramingen 2002
Taakgroep Verkeer en Vervoer (Traffic and Transport Taskforce: RIVM, CBS, TNO, RIZA, AVV) February 2004

TNO, 2003
Emissiefactoren heavy duty wegvoertuigen ten behoeve van EmissieRegistratie 2003
TNO (National Institute of Applied Scientific Research), Delft

UNITE, 2000
Valuation Conventions for UNITE
Nellthorp, J., Sansom, T., Bickel, P., Doll, C. and Lindberg, G.
UNITE (UNIfication of accounts and marginal costs for Transport Efficiency) Working Funded by 5th Framework RTD Programme. ITS, University of Leeds, Leeds, April 2001

UNITE, 2002
Deliverable 15: Guidance on Adapting Marginal Cost Estimates
Bossche, M.A. van den, Certan, C., Simme Veldman (NEI), Chris Nash, Daniel Johnson (ITS), Andrea Ricci, Riccardo Enei (ISIS)
UNITE (UNIfication of accounts and marginal costs for Transport Efficiency) Deliverable 15, Funded by 5th Framework RTD Programme, Netherlands Economic Institute (NEI), Rotterdam, August 2002

VROM, 2002
Reken-en meetvoorschrift wegverkeerslawaai 2002
Netherlands Ministry of Housing, Spatial Planning and the Environment

VU, 2002
Infrastructuurkosten van het goederenwegverkeer: Een verkenning op basis van beschikbare gegevens
Department of Spatial Economics, Free University, Amsterdam

V&W, 2001
Risicoatlas spoor
DHV Milieu en Infrastructuur, report for Transport ministry (AVV / DGG), 13 June, 2001

V&W, 2003a
Risicoatlas wegtransport gevaarlijke stoffen
Aviv Consultants Group, report for Transport ministry (AVV / DGG), 24 March, 2003

V&W, 2003b
Risicoatlas Hoofdvaarwegen Nederland
Aviv Consultants Group, report for Transport ministry (AVV / DGG), 20 February, 2003

WHO, 1999
Health costs due to road traffic-related air pollution: an impact assessment project of Austria, France and Switzerland
Prepared for the WHO ministerial conference on environment and health, London, June 1999

Documents also consulted:

CBS, 1979
Veertig jaren verkeers- en vervoersstatistiek
Centraal Bureau voor de Statistiek (Netherlands Statistics), Voorburg/Heerlen

CBS, 1975, 1982, 1992, 1996a
Statistiek der wegen
Centraal Bureau voor de Statistiek, Voorburg/Heerlen 1975, 1982, 1992, 1996

CBS, 2001
Statistiek van het goederenvervoer 2000
Centraal Bureau voor de Statistiek, Voorburg/Heerlen 2000

EC, 1999
Directive 1999/62/EC of the European Parliament and of the Council on the charging of heavy goods vehicles for the use of certain infrastructures
Brussels, 1999

IWW/Prognos, 2002
Wegekostenrechnung für das Bundesfernstrassennetz
IWW & Prognos, Basel / Karlsruhe

TKSG, 2001
Vaststelling van de begroting van de uitgaven en de ontvangsten van het Infrastructuurfonds voor het jaar 2002
Netherlands Second Chamber, The Hague

TLN, 2001
Transport in cijfers
Transport en Logistiek Nederland, Zoetermeer

TNO, 2001
Milieu en Gezondheid 2001:Overzicht van risico's, doelen en beleid
TNO (National Institute of Applied Scientific Research), report no. PG/VGZ/2001.95

VU, 2000
Raming maatschappelijke kosten van ruimtegebruik door het verkeer: efficiënte prijzen voor het verkeer
Department of Spatial Economics, Free University, Amsterdam

CE
Solutions for
environment,
economy and
technology

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

The price of transport

Overview of the social costs of transport

Annexes

Delft, December 2004

Authors: J.P.L. (Joost) Vermeulen (CE)
B.H. (Bart) Boon (CE)
H.P. (Huib) van Essen (CE)
L.C. (Eelco) den Boer (CE)
J.M.W. (Jos) Dings (CE)
F. R. (Frank) Bruinsma (VU)
M. J. (Mark) Koetse (VU)

vrije Universiteit amsterdam

A National road maintenance and operating costs under the ‘Basic Maintenance’ programme

Table 41 shows the budget for the ‘Basic Maintenance‘ programme elaborated by the national Road and Hydraulic Engineering Institute (DWW) as being the level of maintenance required for the Dutch national road grid to remain in optimum condition [DWW, 2002][64]. The costs budgeted in 2002 for the cost categories specified in the first column of the table are reported in the second column. The third column shows what share of the costs can be taken as variable. For many items on the list there is no room for ambiguity, with costs being either entirely fixed or entirely variable. In a fair number of cases, though, costs are part-fixed and part-variable and on most of these, DWW was able to give us an expert opinion as to the percentage of the costs to be deemed variable[65]. Columns 4 and 5, derived from columns 2 and 3, report the variable and fixed costs in absolute terms. Column 4 also shows, for each variable cost item, in what respect it is driven by transport behaviour (see notes at end of table).

table 41 Maintenance and operating costs of Dutch national road network according to ‘Basic Maintenance’ programme [DWW, 2002]; converted from guilders to euros using then-current rate and from 2001 to 2002 price levels using the consumer price index [CBS, Statline]

Cost category	Costs, 2002	% Variable	Variable costs	Fixed costs
Road pavements				
Dense asphalt, slow lane	6.3	100%	6.3 [a]	0
Porous asphalt surfacing on dense asphalt	58.5	100%	58.5 [a]	0
Porous asphalt, slow lane	16.9	100%	16.9 [a]	0
Porous asphalt replacement by ditto	51.5	100%	51.5 [a]	0
Cleaning of porous asphalt	2.9	50%	1.5 [b]	1.5
Sweeping, all roads	4.7	100%	4.7 [b]	0
Patching & minor repairs	23.5	100%	23.5 [a]	0
Repaving	0.9	100%	0.9 [a]	0
Verge sinking	3.1	0%	0	3.1
Drains, gutters, sewers, etc	6.8	0%	0	6.8
Research, etc	1.1	0%	0	1.1
Ancillary works	8.6	50%	4.3 [b]	4.3
Public information	4.7	0%	0	4.7
Subtotal, pavements	**189.5**		**167.9**	**21.5**
Structures				
Viaducts & bridges, concrete	52.3	57%	29.6 [a]	22.7
Tunnels	14.3	7%	0.9 [a]	13.4
Bridges, steel	39.9	33%	13.1 [a]	26.8
Bridges, articulated	5.4	9%	0.5 [a]	4.9
Traffic control measures	10.2	100%	10.2 [b]	0
Overhead sign gantries	7.8	0%	0	7.8
Ferries	11.9	0%	0	11.9
Subtotal, structures	**141.8**		**54.3**	**87.5**

---

[64] We are extremely grateful to DWW for providing these data and for their permission to reproduce them in this appendix. We extend our especial thanks to Messrs Nagtegaal and Van der Vusse for the effort expended on making the data suitable for use in the present study.

[65] For the items under ‘Structures’, absolute costs were available rather than percentages and for the sake of completeness we used these figures to derive a variable fraction.

Cost category	Costs, 2002	% Variable	Variable costs	Fixed costs
Traffic safety & management				
Road lighting	5.3	0%	0	5.3
Crash barriers	8.8	10%	0.9 [d]	8.0
Road markings	16.2	50%	8.1 [b]	8.1
Winter maintenance	15.7	0%	0	15.7
Signposting	5.0	0%	0	5.0
Signs & beacons	5.4	10%	0.5 [b]	4.9
Motorway Traffic Management	31.4	10%	3.1 [a]	28.3
Traffic control centres	9.0	0%	0	9.0
DRIP, RMAS, TFS **	5.8	5%	0.3 [a]	5.5
Cameras, monitoring, reporting	4.9	0%	0	4.9
Incident management	3.3	100%	3.3 [d]	0
Subtotal, traffic safety & management	**110.9**		**16.3**	**94.6**
Landscape and environment				
Verges	13.1	0%	0	13.1
Greenery	7.9	0%	0	7.9
Ditches	8.1	0%	0	8.1
Habitat connectivity	4.2	0%	0	4.2
Noise screens, etc.	11.0	100%	11.0 [c]	0
Waste disposal	7.0	100%	7.0 [b]	0
Management plans	0.9	0%	0	0.9
Weed control	1.2	0%	0	1,.2
Subtotal, landscape and environment	**53.5**		**18.1**	**35.4**
Operating costs				
Administration	9.5	0%	0	9.5
Offices, etc.	12.0	0%	0	12.0
Transport	7.6	0%	0	7.6
Energy to structures & systems	8.1	0%	0	8.1
Communications	5.2	0%	0	5.2
Roadside emergency telephones	3.8	0%	0	3.8
Traffic Info. & Comm. Network	7.0	0%	0	7.0
Mobile Data Information System	3.8	0%	0	3.8
Transport Ministry intranet	11.7	0%	0	11.7
Transfers	1.4	0%	0	1.4
Subtotal, operating costs	**70.1**		**0.0**	**70.1**
Outside scope, estimates				
Network improvements	54.0	**Non-allocated**		
Widening for counterflow	4.7	0%	0	4.7
Preparation of operating plans	9.4	0%	0	9.4
Research & consultancy	18.8	0%	0	18.8
Maintenance administration & consultancy	28.2	0%	0	28.2
Soil rehabilitation	2.3	0%	0	2.3
Negative balance, road accident damages	4.7	100%	4.7 [d]	0
	68.0		**4.7**	**63.3**
Total Basic Maintenance budget [DWW, 2002]	**633.8**		**261.3**	**372.5**

[a] Costs a function of vehicle kilometres and weight.

[b] Costs a function of vehicle kilometres.

[c] Costs a function of vehicle kilometres and noise production.

[d] Costs a function of number and severity of traffic accidents.

** Dynamic Route Information Panels, Regulated Motorway Access Systems, Traffic Control Systems

B Calculation of axle damage factors

This appendix illustrates how axle damage factors are calculated for heavy goods vehicles. It is a slightly modified version of an example provided by the Road and Hydraulic Engineering Institute, DWW[66].

In the Netherlands as elsewhere, road pavements are designed and constructed with the particular contribution of HGVs to pavement distress in mind. One way to quantify this distress, i.e. damage, is by means of so-called axle damage factors. When drawing up pavement specifications, civil engineers express axle loads in terms of an ‘equivalent standard axle load’ of 10 tonnes, assuming in doing so a 4th power relationship between axle load and pavement distress. In a recent DWW report the following equation is used.

Axle damage factor = $\{\text{axle configuration factor} * (A/A_{std})\}^4$

where A is the actual axle load in tones, A_{std} the standard axle load of 10 tonnes and the axle configuration factor a factor representing the influence of axle configuration on the axle damage factor. Table 42 gives the values of the axle damage factor for the various basic HGV axle configurations.

table 42 Axle configuration and value of axle damage factor

Axle configuration	Value of axle damage factor
Single	1.0
Tandem	0.6
Tridem	0.45

Example

As an illustration, consider a 5-axle HGV with the following load on each axle:

- 7 tonnes on axle 1.
- 11.5 tonnes on axle 2.
- 10 tonnes on axle 3.
- 9 tonnes on axle 4.
- 9 tonnes on axle 5.
- Axles 4 and 5 together form a tandem.

---

[66] For which we are grateful to Mr R. van Doorn.

The load exerted on the pavement surface (axle damage factor) by each axle of this vehicle will then be as follows:

- Axle 1: $\{1.0 \times (7/10)\}^4 = 0.24$
- Axle 2: $\{1.0 \times (11.5/10)\}^4 = 1.75$
- Axle 3: $\{1.0 \times (10/10)\}^4 = 1.00$
- Tandem axle 4&5: $\{0.6 \times (2 \times 9/10)\}^4 = 1.36$

The total load exerted by the vehicle as a whole (aggregate axle damage factor) is then: 0.24 + 1.75 + 1.00 + 1.36 = 4.35.

C Use of national waterways

Table 43 provides a synopsis of shipping performance on Dutch national waterways, expressed as number of passages.

table 43 Use of national waterways

Waterway class	Waterway	Waterway no.	No. of passages, inland shipping	No. of passages, recreational shipping
VW1: 'Backbone'	Upper Rhine & Waal[67]	101	168,589	64,276
	Amsterdam Rhine Canal	225	73,523	5,083
	North Sea Canal	233	62,085	49,087
	Eastern Scheldt	138	3,450	40,289
	Volkerak / Zoommeer	129 & 143	212,157	86,972
	Gent-Terneuzen Canal	130	56,759	2,694
Total, VW1			*576,563 (70%)*	*248,401 (30%)*
VW2: Major waterways	Lower Rhine & Lek	102 & 103	34,795	24,077
	Ijssel	84	12,093	10,315
	Twente canals	81	11,969	2,332
	Upper Meuse	150	93,162	53,746
Total, VW2			*152,019 (63%)*	*90,470 (37%)*
VW3: Other waterways	'Border lakes', East	84 & 86	24,093	34,920
	'Border lakes', South	229	7,049	70,014
	Grevelingenmeer	141	1,233	41,108
	Veerse Meer	135	1,422	29,498
Total, VW3			*33,797 (16%)*	*175,540 (84%)*
Total, all classes			*762,379 (60%)*	*514,411 (40%)*

Source: Adapted from [AVV/CBS, 2002]

---

[67] Waterway 101 is the Upper (Dutch) Rhine, part of the waterway category 'Upper Rhine & Waal'. We know of no traffic recording station on the Waal, however. If this were duly corrected for, it could mean inland shipping accounting for a slightly higher proportion of passages.

D Strip-down of M/O costs for inland shipping

For greater insight into our allocation of the costs of waterway maintenance and operation, in the table below we ‘peel off’ the costs to arrive at the portion specifically allocable to commercial.

table 44 Allocation of variable inland shipping costs (mln €) [68]

	M/O	‘Operational’[69]	Total, national government	Total, local government
Total	441.3	55.0	496.3	n.a.
of which: related to waterways	71%	100%	74%	
	313.3	55.0	368.3	118.0
of which: related to inland waterways	80%	90%	81%	81%
	250.7	49.5	300.2	96.2
of which: variable	5.7%	50.0%	13.0%	13.0%
	14.4	24.8	39.1	12.5
of which: allocable to inland shipping (of freight)	65.3%	80.0%	74.6%	16.0%
Total, inland shipping (of freight), variable	9.4	19.8	29.2	2.0

table 45 Allocation of fixed inland shipping costs (mln €)

	M/O	‘Operational’[6]	Total, national government	Total, local government
Total, inland waterways, variable	236.3	24.8	261.0	83.6
of which: allocable to inland shipping (of freight)	94.0%	94.0%	94.0%	66.9%
Total, inland shipping (of freight), fixed	222.1	23.3	245.4	55.9

---

[68] Note that the accuracy of reporting (to 1 decimal place) is no reflection of the major uncertainties surrounding these data.

[69] For a specification of costs under the heading ‘Operational’, see section 2.4.2 of the main report.

E Costs of traffic accidents

E.1 Introduction

This appendix describes the procedure adopted for valuing the external costs of traffic accidents and describes how these costs have been allocated in the case of accidents involving multiple parties, a key issue in the present study.

E.2 Valuation of damage and traffic casualties

The only external accident costs of relevance in the context of our analysis here are those remaining unpaid by transport users themselves or by their insurance companies. There are four categories of cost that can be identified as having an external component[70]:

1 *Transaction and prevention costs*
These are the costs associated with the work of police and fire departments, court hearings, accident investigations, public information and education, and congestion due to traffic accidents. Vehicle safety provisions are designed mainly to protect passengers rather than the outside world and, being internal, are not part of our analysis. The same holds for the costs of driving lessons and vehicle insurance, which have likewise been ignored, because if instruction and insurance markets are operating properly, these costs will be appropriately matched to the degree of traffic risk that individual drivers are held to cause. In this sense, they are already largely internalised. Nor have prevention costs been included in our analysis, because in principle these benefit *all* transport users, who must therefore also pay for them accordingly. The costs of general safety provisions on the road network have been included under the heading of fixed infrastructure costs. The costs of police, accident investigations and public education work fall under infrastructure operating costs. The only external costs remaining, consequently, are those associated with fire departments, court hearings and accident-related congestion, and it is these costs we have allocated across vehicle categories under this heading.

2 *Costs of medical care, return to work and (possibly) taff replacement*
Part of these costs are reimbursed by insurance companies and are consequently internal. The external costs we are concerned with here are the portion over which no compensation is received.

3 *Costs of production losses*
This is the value assigned to a traffic casualty dropping out of the economic production process. Again, it is the portion not covered by insurers that constitutes external costs. In the literature a distinction is made between

---

[70] The external costs of material damages to others are paid for by individual road users by way of compulsory third-party insurance. These costs have therefore already been internalised. Material damages to a driver's own vehicle are internal costs.

gross production losses (lost working years times average future per capita income) and net production losses (gross production losses minus future consumption). Both of these must be converted to net present value.

4 *Costs of accident risk*
The best way to estimate these costs is to estimate the 'willingness to pay' (WTP) for accident avoidance. In earlier studies the costs associated with accident risks were not always included in the analysis, even though they in fact constitute the largest item in this context. On top of that, they were often seen as somehow representing 'the price of a life'. In recent years there has emerged a growing consensus, though, that it is in fact people's perception of risk that is being assigned a value. Today, the measuring rod most frequently used in this connection is the 'value of a statistical life', or VOSL, an approach recommended in the authoritative UNITE study [UNITE, 2000] and the one consequently adopted here.

E.3 Allocation of costs of multiple-vehicle accidents

A study of the international literature provides no clear and unequivocal picture of how the costs of accidents involving more than one vehicle can best be allocated and we therefore examine this issue in somewhat more detail here.
A suitable starting point is the observation that everyone driving a vehicle does so in such a way as to try and guarantee their own safety. A good yardstick for the external costs of traffic accidents is therefore the degree to which (drivers of) the various vehicle categories pose a risk to others. There are three possible approaches to be taken here:

1. Based on *involvement* in accidents.
2. Based on *responsibility* (the person whose behaviour 'caused' the accident).
3. Based on *intrinsic risk* (the person to whom the bulk of the damage arising in an accident can be attributed, regardless of their specific behaviour).

In the case of allocation based on *involvement*, casualties due to multiple-vehicle accidents are allocated equally to all the parties involved. In a two-vehicle accident allocation is therefore 50/50. This means that in a collision between a cyclist and a car or truck (with the cyclist almost inevitably the victim) 50% of the costs are allocated to the cyclist. Obviously, though, the car or truck poses a far greater danger to the cyclist than vice versa, and this form of allocation we therefore rejected.

If allocation is based on *responsibility* for the accident, external costs are attributed to the party 'causing' the accident. Generally speaking, this will be the party that was 'in error'.

We rejected this approach, for two reasons:

1 In the first place, the party 'responsible' for an accident cannot be deduced from the accident statistics.
2 Our second objection is one of principle, viz. that 'responsibility' for an accident, in a causative and moral sense, lies not only with the party 'in error' but may also lie with a party or parties that, legally speaking, committed no error at all. It is, after all, a fact of life that certain activities that undertaken by society bring with them an additional intrinsic risk, even if those performing these activities do not 'err' at all. Thus, transport and mobility, the subject of the present study, are obviously accompanied by a certain intrinsic risk. Even though drivers may comply with traffic and other regulations, they still make society a more dangerous place. In a residential area with children playing on the streets this is self-evident, but the same also holds on a motorway with respect to the mutual danger to which drivers continually expose one another. More specifically, the heavier and faster a vehicle, the greater the danger to which it will expose other road users.
   This 'intrinsic risk' of each vehicle category is reflected in the traffic accident statistics. In a collision between a passenger car and a heavy goods vehicle or train, there is little likelihood of the car driver surviving. By its sheer presence, then, the HGV or train is in a certain sense 'responsible' for the occurrence and gravity of the accident, *even if the drivers of these heavy vehicles themselves make no mistakes.* It is simply a given of society and human nature that people sometimes make mistakes, or even act in a risky fashion.

In this study we have therefore chosen to allocate responsibility for multiple-vehicle accidents to the vehicle giving rise to the 'high-risk' situation, with reference to the *intrinsic risks* of the vehicles involved. This is not only a principle choice, but is also in line with this study's basic goal of anchoring costs where they belong, i.e. where price incentives will lead to optimum socio-economic welfare. In general, a party giving rise to a 'high-risk' situation will be better able to reduce that risk than the average user of the infrastructure in question.

The question now is how the notion of intrinsic risk can be used to derive a key for allocating costs across the various vehicle categories. Here, we have opted not to base the key on vehicle specifications, technical or otherwise, but to derive it directly from accident statistics[71]. After all, the so-called 'conflict tables' in the accident statistics report precisely how casualties are divided across vehicle categories in multiple-vehicle accidents.

In this study we used the conflict tables published by the Dutch Transport Research Centre, AVV, for the years 2000 to 2002. As an illustrative example, these tables show that during this period there were on average 35 fatal casualties a year in two-vehicle collisions between a passenger car and light

---

[71] To allocate costs on the basis of vehicle specifications, the approach taken in many international studies, would mean faster / heavier vehicles being allocated 100% of the costs. A serious problem here is that everything hinges on definitions: how exactly are faster / heavier vehicles to be defined? Is a light goods vehicle faster and heavier than a passenger car? If so, it will be allocated 100% of the costs in a collision between an LGV and a car, and otherwise only 50%. For this reason, we do not consider this method sufficiently robust.

goods vehicle. Of these fatalities, 29 were in the car and 6 in the LGV. In this case, then, we have allocate the fatalities in the cars to the LGVs and the fatalities in the LGVs to the cars.
As expected, this statistical information was in agreement with intuitive estimates of the intrinsic risks of the various vehicle categories. Allocation based on intrinsic risk has also already been (implicitly) adopted In Dutch traffic legislation, given that in accidents involving cyclists or pedestrians, on the one hand, and a motorised vehicle, on the other, liability for any injuries lies entirely with the latter party.

E.4 Rail and inland shipping

Analysis of a report on inland shipping safety for the years 2000 to 2002 shows that on average 1 fatality and 10 injuries a year can be attributed to inland shipping [AVV, 2004c].

Similarly, a rail safety plan published by Railned shows that between 1998 and 2000 there were on average 8 fatalities a year among staff, passengers and passers-by and 143 injuries [Railned, 2002]. These statistics do not include suicides, which we have also left out of the equation.

F Costs of emissions

F.1 Introduction

This appendix provides an detailed account of how figures were established for air pollutant and greenhouse emissions for the various modes of transport under study and how these emissions have been financially valued and subsequently allocated.

F.2 Which emissions?

The principal emissions of vehicles and vessels are CO_2 (carbon dioxide), NO_X (nitrogen oxides), HC (hydrocarbons), PM_{10} (particles with a diameter of less than 10 micrometres), CO (carbon monoxide) and SO_2 (sulphur dioxide). As it is deemed unlikely that transport emissions of carbon monoxide (CO) will pose any serious health or environmental problems in the future, they have been ignored in our analysis.

Table 46 provides a synopsis of the emissions included in the present study, citing the environmental effects of each and whether or not a distinction has been made between urban and rural emissions. . An appropriate decision on this latter point depends on the environmental impacts of the pollutant in question: emissions with a potentially significant health impact require differentiation between urban and rural, because in the former case a greater number of people will be affected per unit emission.

table 46 Synopsis of environmental effects of atmospheric emissions included in this study

	Environmental effect	Urban / rural distinction?
CO_2	Forced greenhouse effect	No
NO_X	Acidification & eutrophication Photochemical smog formation (→ Forced greenhouse effect) Health effects	Yes
PM_{10}	Health effects	Yes
HC	Photochemical smog formation (→ Forced greenhouse effect) Health effects	Yes
SO_2	Acidification Health effects	Yes

It is now accepted that CO_2 is one of the main driving forces behind the forced greenhouse effect, with CO_2 emissions being held responsible for two-thirds of the ‘enhanced’ greenhouse effect due to anthropogenic GHG emissions. For the ultimate environmental impact it makes no difference where on earth CO_2 emissions take place.

The environmental effects of NO_X and HC are complex and both have a regional and an urban component. At a regional level, NO_X emissions cause acidification and eutrophication (i.e. nutrient enrichment of soil and water). Under the influence of heat and sunlight, moreover, above certain concentrations the presence of NO_X and HC leads to formation of photochemical oxidants (ozone), often referred to as 'summer smog'. At the urban level, NO_X and HC cause additional environmental problems. Thus, elevated NO_2 concentrations may lead to respiratory complaints, while various elements of the HC 'cocktail', such as (polycyclic) aromatic hydrocarbons and aldehydes, are suspected of being carcinogens[72].

Particles with a diameter of less than 10 micrometres, known as PM_{10}, are formed mainly during combustion of diesel, gas-oil and fuel oil (as opposed to petrol). The chemical composition of these particles is generally rather complex and a variety of international studies have demonstrated that they may have seriously damaging to human health. This is due mainly to the heavy, carcinogenic polycyclic aromatic hydrocarbons that adhere to the particles of soot emitted by vehicle and vessel engines.

SO_2 causes acidification and in high concentrations can lead to respiratory problems (as in the infamous London 'pea-soup' smog of 1954). The atmospheric concentrations encountered in the Netherlands barely affect human health, however. Given the ongoing desulphurisation of transport fuels under European legislation, transport SO_2 emissions are not anticipated to be problematical in the years ahead, except in the case of marine shipping.

Given the varying effects of these different emissions, in the case of NO_X, HC, PM_{10} and SO_2 (but not CO_2) emissions there must be differentiation as to where emissions occur before valuation can take place. Rural emissions will lead only to regional environmental problems, while urban emissions will lead to both local and regional environmental problems.

F.3 Choice of emission factors and emission data

In this section we first review the emission factors used for road, rail and waterway transport. We then look specifically at emissions that are indexed purely to fuel consumption. Finally, we discuss the emissions associated with oil refineries, which are also to be deemed external.

F.3.1 Road transport

In this study we have used three different emission factors for emissions of the cited air pollutants:

1 Fleet-average data for 2002 (for use in the total cost variant).
2 Emission factors for year of manufacture 1993.
3 Emission factors for year of manufacture 2002.

---

[72] Strictly speaking, these (carcinogenic) substances do not *cause* cancer, but increase the likelihood of contracting it.

The latter two datasets, taken from CBS [CBS-Statline], were used to distinguish worst and best cases, respectively. For freight transport, these emission factors are identical to those published recently by NEA [NEA, 2003]. The fleet-average data are still provisional and are from the Traffic & Transport Taskforce (TTT[73]).

Both CBS and the Taskforce make a simple distinction between vans, trucks and (truck) tractors. In this study we distinguish several categories of heavy goods vehicles Therefore, we had to make several assumptions to derive more specific emission factors.

For LGV we have simply used the published data. For tractor-trailer combinations we have taken the Taskforce's emission factors for tractors, these forming the core element of our category 'tractor-trailer combination' and therefore serving as a good proxy.

The Taskforce gives no emission factors for HGV over 12 tonnes gross vehicle weight (GVW). For this category of vehicle we therefore made an estimate. For HGV > 12 t we took the emission factors for their general category 'trucks'. This is problematical, however, as their category includes trucks of less than 12 t GVW as well as truck/trailer combinations. In all likelihood, however, the respective effects of these two groups on the emission factors for this category cancel one another out, so that we felt justified in adopting the Taskforce's 'truck' emission factors for our category HGV > 12 t.

The Taskforce cites no emission factors for HGV < 12 t, either. Based on the familiar relationship with emission factors for tractors, however, we were also able to establish suitable emission factors for this category of heavy goods vehicle, too.

F.3.2 Rail and inland shipping

Inland shipping

For inland shipping we have used fleet-average emissions for 2002, as derived from the Inland Shipping Emissions Protocol [AVV, 2003]. These cover all emissions from main and auxiliary engines. This protocol has used since 2002 to assess inland shipping emissions for the purpose of national Emission Registration and makes due allowance for technical innovation as well as the evolving structure of the inland shipping fleet, in contrast to the earlier method whereby emissions were calculated from fuel consumption data.

To calculate emissions in the efficiency variant, we employed the model developed by the aforementioned Taskforce (TTT) for the purpose of national Emission Registration. The model was used to calculate energy consumption in

---

[73] A joint taskforce of RIVM (National Institute for Public Health and the Environment), CBS (Netherlands Statistics), TNO (Netherlands Institute of Applied Scientific Research), RIZA (National Institute for Inland Water Management and Waste Water Treatment) and AVV (Dutch Transport Research Centre) set up to produce harmonised Dutch national emissions data.

the best and worst cases. Emission factors for the various years of manufacture were taken from the Emissions Protocol.

Rail
In the case of electric locomotives, analysis must include the emissions associated with power generation. These were calculated from the results of an earlier CE report '*Vergelijking E- en DE-tractie van goederentreinen*', linearly interpolating between results for 1996 and 2010 to obtain a figure for 2002. For CO_2, NO_X and SO_2 emissions per kWh output this yielded figures of 598 g, 0.61 g and 0.22 g, respectively.

Fleet-average emissions for passenger and freight diesel trains for 2002 have been taken from CBS [CBS-Statline].

Because the NEA study '*Vergelijkingskader Modaliteiten*' [NEA, 2003] gives only emission factors for averagely loaded trains, the data from that study cannot be used for deriving costs in best and worst case scenarios (in the efficiency variant). For all diesel trains we have therefore used data from an earlier CE study, 'To shift or not to shift' [CE, 2003].

In the case of electric trains we used the data provided by Dutch Rail [NS, 2003].

F.3.3 Fuel-dependent emissions

Emission factors for CO_2 and SO_2 are far less dependent on the year of vehicle manufacture than those for other air pollutant emissions and have been derived from the energy consumption of the vehicle (category) in question. It is worth remarking here that vehicle energy consumption – to which a vehicle's CO_2 emission is directly proportional – has barely fallen over the past few years because of an increase in vehicle weight (increased comfort, stricter safety regulations) as well as growing use of air conditioning systems and other ancillary equipment. For the energy consumption of the various vehicle categories we derived figures from the road transport emission statistics published by the aforementioned Taskforce.

In the case of SO_2 emissions we followed the Taskforce's methodology report, which gives the sulphur content of the various fuels in 2002 [Taakgroep V&V, 2004].

F.3.4 Refineries

Finally, we included the environmental impacts of transport fuel refining, which are also to be deemed marginal, in the sense of varying in direct proportion to fuel consumption. For emission factors for these refinery operations we based ourselves on analyses carried out by the national energy research centre ECN and published in the TNO/CE/ECN report '*Wijziging brandstofmix*'. To this end we averaged the results for 1996 and 2010 to obtain representative figures for 2002.

F.4 Valuation of NO_x, HC and fine particles

There are two main methods suitable for valuing emissions of nitrogen oxides (NO_X) and volatile hydrocarbons (HC), based on assessing the costs of direct damage and prevention costs, respectively. The costs of health damage are generally higher than prevention costs, the latter being based on the marginal costs of achieving political targets such as the National Emission Ceilings[74]. As a result, and given the recent advances in monetary valuation of health effects, the prevention cost method is being increasingly rejected as a means of valuing emissions.

Over the past few years our understanding of the damage costs associated with air pollutant emissions has improved enormously. In particular, there has been major progress vis-à-vis knowledge of the heath impacts of present-day transport activities. Dose-effect relationships as well as distribution models are now more refined and there is far less controversy about assigning a monetary value to (loss of N years of) a human life. This increased knowledge regarding health impacts has led to:

- A higher monetary value for practically all emissions.
- A better understanding of the spread among reported values, leading to
- Less spread in results (when due allowance is made for the explanatory factors behind that spread).

Increasingly, the focus is on the health effects of fine particles (PM_{10} and smaller, 'ultrafine' fractions). Extensive analysis carried out under the ExternE programme as well as the 1999 study by the World Health Organisation [WHO, 1999] have yielded robust and significant dose-effect relationships. As a result, we now see the costs of road transport-related health effects dominated by the effects of (ultra)fine particles. The next most important pollutants with respect to human health impacts are nitrogen oxides and ground-level ozone.

---

[74] At the economic optimum, the marginal prevention costs associated with achieving sustainability targets with respect to environmental quality are theoretically equal to the marginal damage costs.

The 2001 study ‘Benzine, diesel en LPG: balanceren tussen milieu en economie’ [CE, 2001] goes into the financial valuation of NO_x, PM_{10} and HC in great depth. In the course of that study a great many primary literature sources were consulted and analysed. Based on all our findings, we then made best estimates of the values to be assigned to unit emissions of the respective air pollutants, as reported below in table 47.

Unfortunately, attempts to put a quantitative value on such impacts as loss of biodiversity and damage to forests are lagging seriously behind in comparison with the advances made in the field of health effects.

F.5 Valuation of CO_2 emissions

Prevention cost method
To value carbon dioxide (CO_2) emissions the prevention cost method is generally used. This method derives the value of a unit CO_2 emission from the costs of meeting government emission targets. In doing so, we assume the targets in question are a correct reflection of current understanding of the risks and consequences[75] of climate change, on the one hand, and society’s willingness to spend money on reducing those risks, on the other.

Under the Kyoto Protocol and the allocation of obligations within the EU, the Dutch government has pledged to reduce Dutch greenhouse emissions by 6% between 2008 and 2012 relative to 1990 levels. This pledge is robust and independent of any particular sectoral growth or other (un)foreseen circumstances. This situation implies that the marginal social costs of an additional unit CO_2 emission are not governed by the additional (ecological) damage it causes, for the target and consequently the implied ‘tolerable’ ecological damage have already been fixed. The additional social costs are determined by the costs incurred by society having to adopt additional emission abatement measures, however.
The most important advantage of the prevention cost method is that the valuation of CO_2-emissios can be done relatively easy by determining the cost of the (cheapest) measures that can be applied to reach the emission reduction targets.

The valuation of CO_2-emissions using the prevention cost method is also subject to criticism, however, e.g. from environmental organisations. Their objections are usually not aimed at the method itself, but at the policy targets on which the valuation has been based. These targets are, from that perspective, not ambitious enough. It has become clear indeed, that the Kyoto reduction targets are insufficient to reach a sustainable level of CO_2-emissions. They can merely be regarded as a first step in that direction.

---

[75] We also took into consideration the available data on possible benefits accruing from climate change, such as potentially better farming conditions in areas too cold at present.

Damage cost method
Just as for polluting emissions, their are also attempts to base the valuation of CO_2-emissions on the direct damage (in the case of CO_2 damage of climate change). Given the major uncertainties about the consequences of the forced greenhouse effect to which CO_2 emissions contribute, valuation methods based on direct damages soon become bogged down in uncertainty ranges and 'memorandum items'. These uncertainties are sometimes masked by the fact that many studies yield results in the same basic range. This is merely because they proceed from the same basic assumptions, however.

The need for extreme caution when using direct valuation methods can be illustrated with reference to an example. In many studies (including the authoritative study by Nordhaus, 1991) the maximum loss of welfare due to greenhouse-related damage to agricultural output is estimated at 3% of world GNP, as this is precisely the share of agriculture in global GNP. That this kind of estimate fails to include the higher-order effects of a collapse of world agriculture will be evident, for how could the world (economy) continue to function without food? When it comes to greenhouse emissions like CO_2, however, this example is typical of the major uncertainties involved in assigning any value to direct damages.

Choice
Summarizing this discussion, we conclude that for valuation of CO_2 emissions the prevention cost method is currently leading. However, we remark that with the current CO_2 reduction targets there will still be damage because of climate change which can currently not be valuated properly by the damage cost method.

For the valuation of CO_2-emissions in this study we make a pragmatic choice and adopt the valuation of our study of 1999, which was based on the prevention cost method.

F.5.1 Shadow prices for CO_2

In 1999 we based the shadow price for CO_2 on the range of measures from the policy document *Uitvoeringsnota Klimaatverandering*. In this document the Dutch government has formally specified a basic policy package and an additional policy package for meeting the Kyoto target targets.

Overlooking the complete package of policy measures from the *Uitvoeringsnota Klimaatverandering*, we chose in 1999 an average value for the valuation of CO_2-emissions of € 50 per ton. We adopt this value for this study and correct it for the price level of 2002.

Given the currently expected CO_2-price of about € 10 per tonne within the European emission trading system, as it will start for the industry sector in 2005, the shadow price we use in this study seems relatively high. Choosing this level of valuation, we also have taken into account that the expected CO_2-price just meets the current Kyoto-targets for the EU. As stated before, with this target damage because of climate change is still to be expected. So, the current policy target does not agree with a sustainable level. For this reason, more ambitious CO_2 reduction targets (post Kyoto) are currently subject of discussion within the EU. These targets will push up the price of CO_2.

F.5.2 Synopsis

The following table summarizes the valuation of emissions that have been used in this study.

table 47 Synopsis of financial valuation of atmospheric emissions, urban and rural (for CO_2 in € per tonne, otherwise in € per kg)

Substance	Value of ‘rural’ emission	Extra value of ‘urban’ emission	Total value of ‘urban’ emission
CO_2	56	0	56
NO_X	8	5	13
HC	3	4	7
Fine particles (PM_{10})	78	258	336
SO_2	4	7	11

Source: [CE, 2001]. Values are adjusted to 2002 price level

G Valuation and allocation of noise nuisance

G.1 Introduction

The method most frequently used to determine the external costs of noise nuisance is the revealed preference method. It is theoretically adequate for the purpose and generally takes as its point of departure the noise-related depression of property prices. To the best of our knowledge, no primary studies have yet been carried out in the Netherlands on the external costs of noise nuisance. In this study we have therefore taken an alternative approach, in which we first establish the number of people adversely affected by noise emissions and then apply a monetary value per decibel per person.

G.2 Noise burden

Using the EMPARA[76] model we estimated the total number of people exposed to traffic noise in the Netherlands. The numbers affected in each 5 dB increment are shown in the top two rows of table 48.

table 48 Number of people exposed to noise at various levels (daily average, in thousands) and total valued noise costs based on valuation at € 25 per person per dB per year (€ 2002)

Number of people adversely affected by noise in the Netherlands ('000)							
	0-55 dB(A)	56-60 dB(A)	61-65 dB(A)	66-70 dB(A)	71-75 dB(A)	> 75 dB(A)	Total
Road transport	10,343	3,669	1,484	352	46	9	15,903
Rail transport	14,695	727	333	105	31	11	15,903
Average noise burden, road (dB)		2.5	7.5	12.5	17.5	22.5	
Average noise burden, rail (dB)			2.5	7.5	12.5	17.5	
	Total costs (mln € per annum)						
WTP, road		229	278	110	20	5	641
Health damage				58	86	86	230
Total, road							**872**
WTP, rail			21	20	10	5	55
Health damage				6	9	9	23
Total, rail							**78**

Source: [RIVM, 2004]; [INFRAS/IWW, 2000]

---

[76] EMPARA (Environmental Model for Population Annoyance and Risk Analysis) is used by RIVM for its 'National Environmental Outlook' studies. It is an updated and enhanced version of the former LBV (** *Landelijk Beeld van Verstoring*) model. It is a non-commercial package used only by this institute. The model encompasses all national roads, provincial roads, main local roads, railways, airports and selected industrial estates.

G.3 Valuation

The next step was an international comparison of studies using willingness-to-pay (WTP) methods, in order to establish the damage resulting from exposure to noise in each of the 5 dB classes. From this literature review it emerged that in European studies a wide range of values are assigned to noise (reduction). We opted to take the average value reported in the INFRAS/IWW study published in 2000: 0.1% of GDP per capita, which converts to about € 25 per dB noise reduction per person per year. This figure is also in accordance with the recommendations of the ECMT [ECMT, 1998]. A recent study for the European Commission uses this same value, but now per *household*, making it a considerably lower estimate [INFRAS/IWW, 2000; Navrud, 2003].

In establishing a cut-off level of noise below which no nuisance is experienced we have followed the international literature. A recent European study on valuation of noise nuisance recommends a cut-off point of 55 dB(A), but also stresses that road, rail and air traffic noise cannot simply be lumped together. Other national and international studies, too, report that noise due to rail transport is experienced as being less of a nuisance than road traffic noise. This is because of the lower frequency of the sound and the continuous nature of rail-associated noise. We therefore chose to assign a value of zero to rail noise between 55 and 60 dB(A), in accordance with [TNO, 2003] and [INFRAS/IWW, 2003]. For this reason, in the case or rail transport the average noise burden above the cut-off value is 5 dB lower than for road transport in each of the noise classes (see middle rows of table 48).

Exposure to noise levels above 65 dB(A) can damage a person's health, leading among other things to higher blood pressure and coronary disorders. For this reason the cited monetary values for noise are valid for the lowest noise classes only, from 55 to 65 dB(A). To calculate the costs associated with higher noise levels, we added a 'mark-up' to the WTP. The INFRAS/IWW study provides information on Dutch noise-related health costs in 1995, which we corrected for inflation [INFRAS/IWW, 2000]. It should be added that there is disagreement among economists on whether a correction should be made for health damage, with some holding that such damage is already accounted for in the WTP.

Although inland shipping also gives rise to noise emissions, the nuisance created is relatively insignificant. Few people living in the direct vicinity of waterways are actually affected by the noise of passing vessels. We have therefore taken the external costs of inland shipping noise as zero, in line with other international studies on the external costs of traffic [INFRAS/IWW, 2000].

G.4 Allocating the costs of noise nuisance

Now the total costs of traffic-related noise nuisance have been established, the question remains of how the nuisance is to be attributed to the various categories of vehicle and how it is be divided in terms of the urban/rural split. Because there is no information on the latter issue, we assume, after consultation with RIVM[77], that 80% of all noise nuisance occurs in urban areas.

Studies by ECMT [ECMT, 1998] and [INRAS/IWW, 2000] indicate that the average heavy goods vehicle and motorcycle give rise to 5 to 10 times greater noise costs than passenger cars and light goods vehicle and that goods trains cause about 4 times more noise nuisance than passenger trains.

Allocating total noise emissions using these kind of factors does little justice to reality, however. There is a considerable difference in the (frequency of the) noise produced by a HGV and a motorcycle, and in low-speed traffic with little scope for acceleration (i.e. urban traffic) the proportion of cars to HGV is different from that in traffic travelling at a steady, high speed (i.e. rural traffic). The consortium INFRAS/IWW is currently working on an update of the year 2000 study for the UIC. They have now opted to allocate noise emissions purely on the basis of the share of the vehicle category in aggregate road kilometres, thereby implicitly assuming the same weighting factor for all vehicles. The reason cited is that to do otherwise would mean making too many assumptions[78]. We find it hard to follow this reasoning, because it is all too clear that different categories of vehicle give rise to different levels of noise nuisance.

As the international literature provides little clarity on this issue, we have taken as our point of departure the protocol for calculation and measurement of road traffic noise issued by the Environment ministry [VROM, 2002], which includes reference values (in dB(A)) for noise emissions at various speeds for three categories of vehicle: light, medium and heavy[79]. By converting these reference values to decimal terms – as noise is, by definition, expressed on the logarithmic decibel scale – the ratio between the noise emissions of various vehicle categories at different speeds can be established.

In the case of urban traffic we compared vehicles travelling at 50 km/h. For rural traffic we have assumed that cars average a speed of 100 km/h, heavy goods vehicles 85 km/h and buses 90 km/h. For those vehicles for which no reference value is provided in the cited protocol, we made our own estimate based on the available data and the studies published by ECMT [ECMT, 1998] and [INFRAS/IWW, 2000].

The respective weighting factors for urban and rural traffic are shown in table 49, with the external costs per vehicle kilometre being set as in table 48.

---

[77] Value adjusted relative to the 1999 study, based on talks with Mr H. Nijland, National Institute for Public Health and the Environment (RIVM).

[78] Personal communication, David Schmedding, IWW Karlsruhe.

[79] Light vehicles are taken to mean passenger cars and vans. Medium vehicles are rigid and articulated buses and two-axled vehicles with a single back axle and 4 tyres. Heavy vehicles are articulated motor vehicles with a double back axle, but excluding buses.

table 49 Weighting factors for noise of various vehicle categories and resultant external costs of noise nuisance for each category (€ct/vkm)

	Noise weighting factors		Valuation (€ct/vkm)		Total costs (million €)
Road	Urban	Rural	Urban	Rural	
Car, petrol	1.0	1.0	0.9	0.1	208
Car, diesel	1.2	1.0	1.1	0.1	89
Car, LPG	1.0	1.0	0.9	0.1	24
Long-distance coach	9.8	3.3	8.6	0.4	35
Motorcycle	13.2	4.2	11.6	1.7	141
Moped, scooter	4.0	1.7	3.5	0.5	66
LGV	1.5	1.2	1.3	0.2	138
HGV, single unit < 12 t	9.8	3.0	8.6	0.4	32
HGV, single unit > 12 t	13.2	4.2	11.6	0.6	56
HGV, tr/tr comb.	16.6	5.5	14.5	0.7	84
Total					*872*
Rail					
Passenger train	1		160.4	12.5	58
Freight train	4		641.5	49.9	20
Total					*78*

NB The ‘urban’ and ‘rural’ factors cannot be compared, as in each case the weighting factor is indexed to the noise of a passenger car.
Source: derived from [VROM, 2002]; [ECMT,1998] and [INFRAS/IWW, 2000].

H Road infrastructure funding and land take costs

H.1 The issue of urban land take

In section 6.3.1 we examined the costs of land take for transport infrastructure – comprising land purchase as well as actual construction – and noted several difficulties regarding valuation of *urban* land in this connection[80]. In this appendix we look at the issue more closely, thereby distinguishing between new construction projects on the one hand and redevelopment projects on the other.

H.1.1 New infastructure

Until a few years ago, local authorities developing land for housing, offices and commercial/industrial estates were generally able to recuperate the full project costs from returns on land, i.e. rent, in some cases even generating a substantial profit[81]. More specifically, the proceeds were sufficient to cover the cost of land purchase as well as the full cost of new on-site infrastructure, and in many cases that of access infrastructure too. This meant the latter infrastructure was essentially paid for by the users of the new amenities. In effect, then, all urban infrastructure has in principle been paid for by users at some time in the past, even though this may be a very long time ago. It is fair to say, then, that the costs of existing urban infrastructure are not borne by the present users of that infrastructure, but by those benefiting from the services it provides. In this sense, the costs of urban infrastructure are at any rate borne by parties with a (commercial) interest and it would not then be fair to pass these on once more to a second party, viz. infrastructure users. Between these two parties (those enjoying the services associated with the infrastructure and users) there will be a considerable overlap, moreover, so that there would a form of double payment.

In recent years, however, the role of municipal development corporations has been taken over increasingly by commercial developers. Land rents to municipal authorities are on the decline and the full costs of development projects (land purchase plus construction) are no longer recovered. In the Netherlands, cost recuperation now stands at 75-90%. The shortfall must be made up from public funds and from the perspective of fair allocation these costs, at any rate, may be passed on to infrastructure users. There is no reason to treat land-purchase or construction costs any differently from other development-related costs. For

---

[80] This appendix is based on telephone interviews with municipal development corporations throughout the Netherlands (Almere, Amersfoort, Amsterdam, Breda, Ede, Eindhoven, Enschede, Groningen, Middelburg, Rotterdam, Utrecht, Venlo and Zwolle). While there were obviously differences, the findings were broadly similar across the country. The greatest differences relate to the supralocal infrastructure providing general access. The municipalities of Amsterdam and Rotterdam, for example, keep this kind of infrastructure (including rail infrastructure for public transport) separate from the project budget in their accounts, while Almere, Ede, Groningen and Venlo include these costs in their entirety. Breda, Enschede, Middelburg and Zwolle, in contrast, book only part of the access infrastructure under this heading.

[81] Only rarely (and many years ago) have development projects resulted in financial losses at the municipal level, and most of these were heavy industry projects or housing estates with a high proportion of dwellings at the bottom end of the market.

recent years, then, we feel justified in allocating a limited fraction of these costs to users.

H.1.2 Redevelopment projects

In the case of redevelopment projects, which in the Netherlands generally means conversion of a commercial estate into a housing estate, returns on land are generally far from sufficient to recuperate project costs. There are several reasons for this. In the first place, the overall cost of land purchase is considerably higher in this case, because a fully-fledged commercial estate must be first bought up before work can be started on new housing (etc.). As the companies with premises on the estate will usually have to be compensated for relocation, the effective land price paid will be many times higher than the straightforward sum paid for a rural plot. In the case or redevelopment projects it is therefore hard to put a definite price on the land in question.

Inquiries among municipal authorities in some cases yielded figures within a broad range, from € 130 to € 240 per m^2, say. In other cases the rule of thumb was cited that the total value of the property on the land at the time of purchase will turn up later in the accounts as the overall project loss. Although this rule of thumb is widely applied, it provides no ready route to estimating the price to be put on direct and indirect land take in such cases. The price paid for land for *new* development projects, under the physical planning heading ‘urban expansion’, is not that paid for farmland but that for land zoned for housing, i.e. between about € 20 and € 40 rather than the € 4 tot € 10 paid for farmland[82].

Finally, there may be expenditures on site remediation that increase project costs enormously. These will be offset, to some extent at least, by savings on construction due to the prior existence of infrastructure already paid for by the companies leaving the estate. There will then be less need to build additional on-site infrastructure. That some municipal authorities take the value of the property on the site as a rough indication of future project losses is a sign that these losses cannot really be allocated under the heading ‘infrastructure costs’ (whether as ‘land purchase’ or ‘redevelopment’).

Summarising, we can conclude that in the past the overall costs of new on-site infrastructure (i.e. the costs of land purchase as well as actual construction) were borne by the users of the site in question. This holds true for both new construction and redevelopment projects. As an exception to this situation in which costs are recuperated from local users, we have some portion of the supralocal (access) roads that is covered by public funds or national government subsidies.

---

[82] Note that these prices are for arable land and pasture. For more intensive forms of agriculture such as greenhouse horticulture land prices may be many times higher.

I Valuation of land take for transport infrastructure

I.1 Introduction

In this appendix we first consider several theoretical issues (section I.2). Against this background we then discuss the financial valuation of direct and indirect land take in sections I.3 and I.4, respectively.

I.2 Theory

Generally speaking, we take the ‘cost’ of a given activity to reflect the utilisation of scarce resources for the purposes of that activity. The activity we are concerned with here is the upkeep and maintenance of transport infrastructure and the scarce resource in question is land. Before assigning a monetary value to that land, however, there are three theoretical issues that need to be addressed. The first relates to the concept of marginal costs, the second to the public nature of transport infrastructure and the implications of this for land prices, and the third to the flexibility of physical planning that is often encountered in practice.

I.2.1 Marginal costs

To calculate the cost of a given activity, two situations must be compared: one with and one without the activity. Although this sounds simple, it is by no means always straightforward. To assess the total costs of land take associated with Dutch transport infrastructures by this method would, on this definition, mean comparing the current state of affairs with a situation in which there was zero land take for infrastructure. This is not only impracticable; it would also serve little purpose, for a country without any infrastructure is hard to conceive of. Immediately then, we face a major problem, for if a government wants infrastructure users to pay for the land take for that infrastructure, it is fundamental that a quantitative figure be available to that end.

On a somewhat smaller scale, it may be perfectly feasible to undertake the required comparison of two situations. There is no difficulty imagining some small piece of infrastructure being gone and the freed up land being used for another purpose. One could, for example, envisage plans for a new stretch of motorway being abandoned and the land retaining its current status as farmland. What this approach essentially involves is an assessment of the *marginal costs* of infrastructure land take. In this way, the notion of ‘costs’ gains practical meaning. It has the added advantage, moreover, that economic theory regards these costs as the appropriate indicator of efficient resource allocation.

Using marginal costs in relation to individual items of transport infrastructure suggests it might be possible to calculate aggregate national costs by summing the costs of all the items in question. This would provide a practical solution to the problem of total cost assessment that is workable in practice. It has no theoretical underpinning at all, however, for it is only under exceptional circumstances that simple multiplication of marginal costs by ‘number of items’ yields a valid figure for total costs.

I.2.2 The public nature of infrastructure

Using a marginal cost approach to estimate the cost of infrastructure land take soon leads to that land being valued at market prices. If the land in question would otherwise have been rezoned as farmland, this would be the going price for such land, while if it were earmarked for a new housing project it would be the market price for that category of land.

This approach leads to an overestimate of actual costs, however, because in the Netherlands as well as elsewhere transport infrastructure is generally ‘public property’, i.e. freely accessible to all. One of the main reasons for this is that land is only of any real value after it has been ‘opened up’ by infrastructure. Conversely, land without access will be relatively cheap. The price paid for farmland or for land for new housing (etc.) therefore already incorporates a certain ‘mark-up’ for basic access in the form of transport infrastructure.

To get an idea of the size of this mark-up, imagine a plot of land purchased by a developer and undergoing site development for his activity of choice. We assume the market in question is characterised by perfect competition and that returns to the developer therefore cover no more than basic outlay. His economic activity then consists in site preparation, in the sense of laying on local infrastructure, fencing off parcels of land and so on. The individual parcels are then put up for sale. The area occupied by the infrastructure obviously cannot be sold and if the developer is to break even, the price of the parcels must therefore include an additional mark-up, as explained, for the land take due to infrastructure.

How much of the overall site needs to be devoted to infrastructure will depend on the purpose and nature of the project. If the site is to be used as farmland, parcels will be relatively large with little land set aside for infrastructure. If it is a housing estate that is planned, parcels will generally be small, with a considerable portion of the site being devoted to access roads. For industrial and commercial estates the situation will be somewhere intermediate. In an undistorted market, the total costs of land purchase plus the costs of site development, parcelling out and on-site road-building should equal the total revenue accruing from sale of the plots in question.

If, in this situation, we were to derive the value of the land used for infrastructure from the actual price paid per hectare plot, we would end up with an overestimate. In the case of farmland, the overestimate would not amount to much and might even be negligible. On a housing estate, however, where about half the overall development will consist of infrastructure, it will be fairly substantial.

I.2.3 Physical planning flexibility

A third aspect that needs to be considered is how much flexibility there in fact exists with respect to the rigours of physical planning. In drawing up the plans for a housing estate with a given number of dwellings and a specified plot size, developers still have many options for providing the same standard of overall access. Given these approximately uniform standards, there is no particular reason to adopt one possible configuration rather than another.

This becomes especially relevant when putting a value on indirect land take, i.e. land falling under physical planning restrictions associated with waterway 'sight zones' and those in force along particularly noisy roads or roads on which hazardous goods are transported (see Chapter 6 of the main report). Because of the flexibility that generally exists in the realm of physical planning, there is usually scope for adherence to the restrictions without incurring any major rise in costs. One approach here is to plan parks and greenery in such areas, or other public amenities like a car park.

I.3 Direct land take

For assigning a value to the direct land take of transport infrastructure we can base ourselves simply on current property prices. In urban areas this will be the price paid for farmland that has been reclassified as 'urban' (in Dutch planning parlance, a change from 'green' to 'red'). After all, all the land currently classified as 'urban' was once 'farmland'. Inquiries among 13 municipalities across the Netherlands (see Appendix H) indicated that the going market price is currently between about € 20 and € 40 per m^2. We have therefore taken an average figure of € 30.

For land take in rural areas, i.e. in areas retaining their 'farmland' status, the going price for agricultural land can then be used, with some mark-up to compensate for co-purchase of sheds and suchlike. This means a broader range of values than in the urban situation: from € 5 up to as much as € 20. A figure of € 7 per m^2 seems a suitable average. This is about twice the actual market price for farmland (arable and pasture).

I.4 Indirect land take

In this section we set out the reasoning followed in assigning a monetary value to the indirect land take associated with transport infrastructure. We do so first with reference to shipping 'sight zones' and then for noise zones.

I.4.1 Shipping sight zones

Along waterways there are planning restrictions in force prohibiting or limiting any bank-side development that might pose a hazard for inland shipping, in particular by obstructing the navigational view. This undeveloped 'sight zone' extends 10 to 30 metres on each bank, depending on waterway class and degree of urbanisation.

First, consider the situation in rural areas. In this case, the planning restrictions make no difference to the overall amount of land available for farming and housing, merely altering the physical details of allocation. Whether this gives rise to extra costs depends on the degree of substitutability between the two. If a housing plot along the waterway in question offers a substantially higher quality of life, the restrictions will imply costs. If not, there will be none.

Living near the bank of a river or other waterway may have an appeal precisely because of the waterway, among other things because of the unimpeded view. That extra appeal can then be interpreted as a (positive) external effect of the waterway. That this does not in fact materialise (because of the planning restrictions) does not mean it can be taken as an external *cost* of the infrastructure, however. What might conceivably be considered as a cost driver, on the other hand, is a difference in soil quality, with better-quality soil along the waterway possibly making for lower construction costs. However, it is hard to see why this situation should be any more likely than the opposite case, with poorer-quality soil implying higher costs. Another possible example is someone ideally wanting to build a house close to the road along the waterway. As this is precluded by the sight zone restrictions, additional costs will arise because of the need to provide access to the new house from the public highway. These extra costs could then in principle be attributed to the sight zone. They are not likely to amount to much, however. Many home owners are not keen to live so close to the public highway, even in the absence of sight zone restrictions.

The conclusion of this analysis is that in rural areas there is sufficient flexibility of physical planning for there to be virtually no costs associated with the existence of sight zones along waterways. We have therefore taken these costs to be negligibly small.

In urban areas the situation is not necessarily different. Here too there is a degree of planning flexibility, certainly in the longer term. Rather than building houses directly along the bank of a waterway, a road might equally well be planned. By opting for a spacious design, an attractive canal-side walk could be created while at the same time complying with planning regulations. In this case the additional costs due to the sight zone restrictions are again negligible.

Perhaps the two situations do differ, though. The price of land in and around city centres is higher than elsewhere, because of the benefits of agglomeration. These benefits are specifically due to the central location of the land, making property prices there (far) higher. If there are sight-zone restrictions in force because of a canal running through the city centre, this will mean sub-optimum utilisation of agglomeration benefits, there being less land available for development there. In these circumstances, then, the planning restrictions do generate economic costs. This reasoning need not necessarily be valid, however. It could be argued, after all, that agglomeration benefits are associated first and foremost with the clustering of economic activities and that such clustering may just as well take place 10 to 30 metres further up if there are planning restrictions in force. Here again, then, there might well be sufficient planning flexibility for costs to be negligible in practice.

Because there are no convincing theoretical reasons for adopting either one of these perspectives, we looked at them both a little more closely. If the argument vis-à-vis planning flexibility is valid, additional costs will be (virtually) zero. This means that land within a waterway sight zone is valued the same as the immediately adjacent land. It should be noted, though, that the price of that land may well be determined in part by the fact that the unobstructed view arising from the sight-zone restrictions is enjoyed not only by those sailing the waterway but also by those living near the banks. However, this added value should not be included in the cost of the sight-zone restriction, for if restrictions were removed, the benefit would simply shift elsewhere rather than vanish.

In the Netherlands we estimate the average price of urban land zoned for development to be around € 300 per square metre. This figure is based on a series of telephone interviews with representatives of municipal development corporations throughout the Netherlands and is in good agreement with the value reported in an extensive nationwide parking study [IOO, 2002], which was also based on interviews with a large number of municipal authorities.

As there are no convincing arguments in favour of either of these theoretical approaches, urban land subject to sight-zone planning restrictions has been valued in the present study midway between the respective values suggested, i.e. at € 150 per square metre.

I.4.2 Noise contours

Assigning a value to indirect land take due to noise zoning can be approached from the same two perspectives as for shipping sight zones in urban areas. To a degree, there will be sufficient administrative flexibility for the impact of planning restrictions to be softened at little additional cost. To the extent that unique locations are involved, however, for which few if any alternative uses are feasible, there will be additional costs. Again, we have taken the two scenarios to be equally likely and have worked with the average price.

J Full synopsis of quantitative results

This appendix contains a series of tables showing the detailed data behind the figures presented in the main report, specifying first for the total cost variant and then for the efficiency variant all the individual cost components for each category of vehicle and vessel.

table 50 Total cost variant: costs

Costs (total, mln euro)		*Fixed*					*Variable*				
Mode of transport / vehicle category	Fuel	Infrastructure M/O, fixed	Infrastructure, construction	Parking (incl. land take)	Land take, direct and indirect	Land take, uncertain	Infrastructure, M/O, variable	Accidents	Noise	Air pollution	Climate emissions
Passenger transport											
Car	Petrol	643.05	1,583.03	1,001.01	201.82	110.05	160.83	1,808.23	207.66	651.45	847.43
	Diesel	242.79	597.69	377.94	76.20	41.55	60.72	682.71	89.03	496.06	270.42
	LPG	74.17	182.58	115.45	23.28	12.69	18.55	208.55	23.95	70.60	75.94
Local/district bus	Diesel/LPG	4.80	15.80		1.70	0.50	30.90	52.85	30.93	151.71	39.83
Long-distance coach	Diesel	4.30	15.90		0.20	0.60	18.00	15.61	4.08	31.71	11.91
Train, electric	Electric	556.86	708.42		47.98		237.00	70.09	49.60	4.49	24.44
Train, diesel	Diesel	74.11	101.37		2.28		28.37	10.03	7.10	22.58	4.80
Motorcycle	Petrol	10.40	23.50		9.10	6.90	7.60	152.18	140.77	159.17	18.65
Moped, scooter	Petrol	6.40	63.30		17.80	0.10	5.30	288.24	65.59	198.96	9.63
Freight transport											
LGV	Diesel/LPG	176.40	416.80	585.40	119.50	20.30	198.30	440.39	138.31	894.18	293.23
HGV, single unit < 12 t	Diesel	19.90	46.00		4.20	2.10	88.10	66.13	31.92	69.00	18.48
HGV, single unit > 12 t	Diesel	49.70	144.30		2.90	7.70	105.80	127.01	55.84	311.66	104.11
HGV, tr/tr comb	Diesel	107.00	473.80		2.80	17.10	493.00	183.43	83.91	549.89	225.93
Train, electric	Electric	13.12	18.74		1.82		10.53	1.76	4.99	0.33	1.79
Train, diesel	Diesel	35.52	54.82		0.97		26.07	5.15	14.58	28.95	6.72
Inland shipping	Fuel oil	298.08	285.82		73.36		31.20	2.86	0.00	384.03	118.33
Variant with infrastructure renewal costs assumed 100% fixed											
Passenger transport											
Train, electric		623.80	708.42		47.98		177.65	70.09	49.60	4.49	24.44
Train, diesel		83.69	101.37		2.28		19.87	10.03	7.10	22,58	4,80
Freight transport											
Train, electric		14.81	18.74		1.82		6.63	1.76	4.99	0.33	1.79
Train, diesel		40.44	54.82		0.97		14.68	5.15	14.58	28.95	6.72

tabel 51 Total cost variant: charges

Charges (total, mln euro)		*Fixed*				*Variable*				
Mode of transport / vehicle category	Fuel	Vehicle Circulation Tax	Vehicle Purchase Tax	Eurovignette	Parking fees	Rail infra-structure fees	Harbour dues	Fuel duty + REC	Reduced VAT	Operating subsidy
Passenger transport										
Car	Petrol	1,528.72	2,505.94	0.00	224.68	0.00	0.00	3,586.36	0.00	0.00
	Diesel	728.02	625.33	0.00	84.83	0.00	0.00	581.22	0.00	0.00
	LPG	142.40	143.33	0.00	25.91	0.00	0.00	39.17	0.00	0.00
Local/district bus	Diesel/LPG	2.75	0.00	0.00	0.00	0.00	0.00	79.41	-79.20	-1237.50
Long-distance coach	Diesel	1.24	0.00	0.00	0.00	0.00	0.00	24.55	-89.10	0.00
Train, electric	Electric	0.00	0.00	0.00	0.00	50.01	0.00	0.00	-163.37	-86.86
Train, diesel	Diesel	0.00	0.00	0.00	0.00	7.16	0.00	1.83	-23.38	-12.43
Moped, scooter	Petrol	0.00	0.00	0.00	0.00	0.00	0.00	40.76	0.00	0.00
Freight transport										
LGV	Diesel/LPG	164.00	0.00	0.00	26.28	0.00	0.00	612.51	0.00	0.00
HGV, single unit < 12 t	Diesel	7.53	0.00	0.00	0.00	0.00	0.00	39.72	0.00	0.00
HGV, single unit > 12 t	Diesel	14.36	0.00	23.34	0.00	0.00	0.00	214.53	0.00	0.00
HGV, tr/tr comb	Diesel	31.50	0.00	49.35	0.00	0.00	0.00	465.53	0.00	0,00
Train, electric	Electric	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00
Train, diesel	Diesel	0.00	0.00	0.00	0.00	1.36	0.00	2.56	0.00	0.00
Inland shipping	Fuel oil	0.00	0.00	0.00	0.00	0.00	16.00	0.00	0.00	0.00

table 52 Efficiency variant: costs

		Costs (eurocent per vkm)					
Mode of transport / Vehicle category	Fuel	Infrastructure, M/O, variable	Accidents	Noise	Air pol-ution	Climate emissions	Congestion
WORST CASE							
Passenger transport							
Car	Petrol	0.24	5.01	0.88	6.05	1.69	46.00
	Diesel	0.24	5.01	1.05	9.04	1.37	46.00
	LPG	0.24	5.01	0.88	2.69	1.32	46.00
Local/district bus	Diesel	7.93	11.85	8.58	65.03	8.85	91.00
Train, electric	Electric	497.96	67.79	160.38	21.32	50.57	
Train, diesel	Diesel	127.45	67.79	12.47	118.39	36.04	
Freight transport							
LGV	Diesel	1.05	1.91	1.31	18.98	1.77	46.00
HGV, single unit < 12 t	Diesel	10.12	11.61	8.58	23.96	2.65	91.00
HGV, single unit > 12 t	Diesel	5.21	11.61	11.55	59.01	7.96	91.00
HGV, tr/tr comb.	Diesel	12.35	10.48	14.53	68.73	8.85	91.00
Train, diesel	Diesel	1,200.91	67.79	641.51	1,679.12	200.26	
Inland shipping	Fuel oil	46.65	4.28	0.00	3,487.40	1,053.73	
BEST CASE							
Passenger transport							
Car	Petrol	0.24	1.97	0.13	0.13	1.13	
	Diesel	0.24	1.97	0.13	0.86	0.97	
	LPG	0.24	1.97	0.13	0.27	0.88	
Local/district bus	Diesel	7.93	6.89	0.43	6.18	5.31	
Train, electric	Electric	177.58	67.79	12.47	3.71	12.90	
Freight transport							
LGV	Diesel	1.05	2.78	0.16	1.73	1.33	
HGV, single unit < 12 t	Diesel	10.12	4.92	0.39	3.44	1,77	
HGV, single unit > 12 t	Diesel	5.21	4.92	0.55	7.34	4.42	
HGV, tr/tr comb.	Diesel	12.35	3.94	0.72	8.69	5.31	
Train, electric	Electric	322.58	67.79	49.89	6.06	14.38	
Inland shipping	Fuel oil	46.65	4.28	0.00	87.30	28.75	
Variant with infrastructure renewal costs assumed 100% fixed							
WORST CASE							
Passenger transport							
Train, electric		332.18	67.79	160.38	21.32	50.57	
Train, diesel		103.56	67.79	12.47	118.39	36.04	
Freight transport							
Train, electric							
Train, diesel		603.75	67.79	641.51	1,679.12	200.26	
BEST CASE							
Passenger transport							
Train, electric		143.18	67.79	12.47	3.71	12.90	
Train, diesel							
Freight transport							
Train, electric		200.76	67.79	49.89	6.06	14.38	
Train, diesel							

table 53 Efficiency variant: charges

		Charges (eurocent per vkm)				
Mode of transport / Vehicle category	Fuel	Rail infra-structure fees	Harbour dues	Fuel duty + REC	Reduced VAT	Operating subsidy
WORST CASE						
Passenger transport						
Car	Petrol			7.17		
	Diesel			2.95		
	LPG			0.68		
Local/district bus	Diesel			18.23	-16.00	-250.00
Train, electric	Electric	44.09		0.00	-158.00	-84.00
Train, diesel	Diesel	44.09		17.50	-158.00	-84.00
Freight transport						
LGV	Diesel			3.80		
HGV, single unit < 12 t	Diesel			5.70		
HGV, single unit > 12 t	Diesel			16.41		
HGV, tr/tr comb.	Diesel			18.23		
Train, diesel	Diesel	22.04		34.91		
Inland shipping	Fuel oil		23.93	0.00		
BEST CASE						
Passenger transport						
Car	Petrol			4.78		
	Diesel			2.09		
	LPG			0.45		
Local/district bus	Diesel			10.94	-16.00	-250.00
Train, electric	Electric	44.09		0.00	-158.00	-84.00
Freight transport						
LGV	Diesel			2.85		
HGV, single unit < 12 t	Diesel			3.80		
HGV, single unit > 12 t	Diesel			9.12		
HGV, tr/tr comb.	Diesel			10.94		
Train, electric	Electric	22.04		6.40		
Inland shipping	Fuel oil		23.93	0.00		

K Passenger transport: total costs and charges per passenger kilometre

At the express request of the project principal, the Dutch Ministry of Transport, in figures 50 and 51 we provide an additional review of the total costs and charges associated with passenger transport, with data expressed *per passenger kilometre*. The figures were derived by dividing the total user costs and charges calculated in Chapter 9 by the annual transport performance of the respective vehicle categories in 2002, in passenger kilometres, as reported in OVG [CBS, Statline]. In the case of rail transport, the costs and charges of electric and diesel trains have been lumped together.

The data presented in the bar charts are specified in table 54, at the end of this appendix.

figure 50 Total costs and charges per passenger kilometre (€cent). Public transport operating subsidies for bus and train are *not* included in this figure; costs of railway infrastructure renewal assumed part-variable

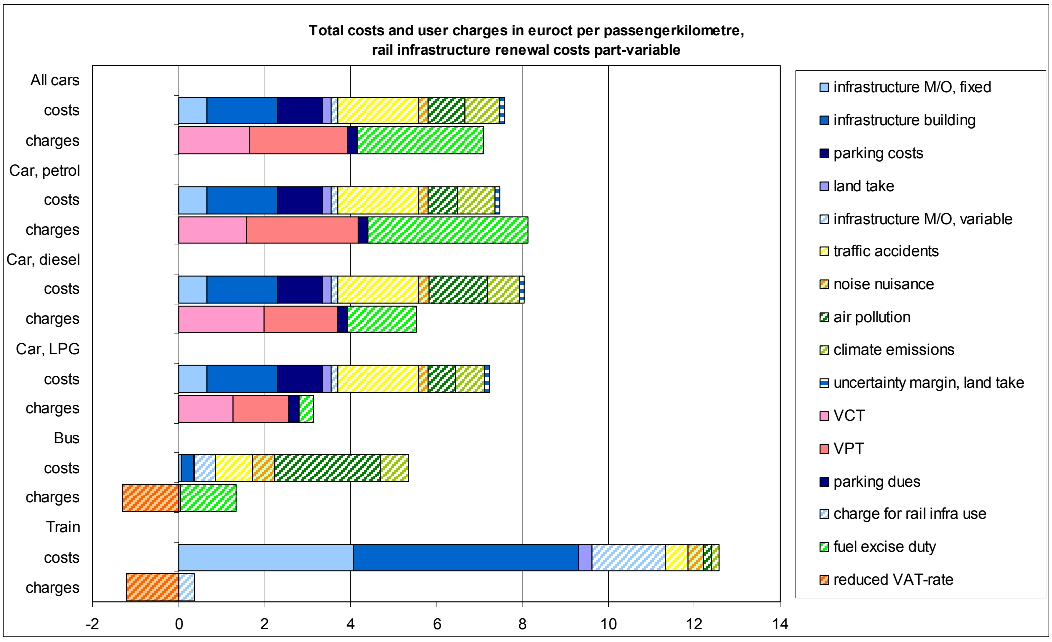


figure 51 Total costs and charges in €cent per passenger kilometre, rail infrastructure renewal costs fixed

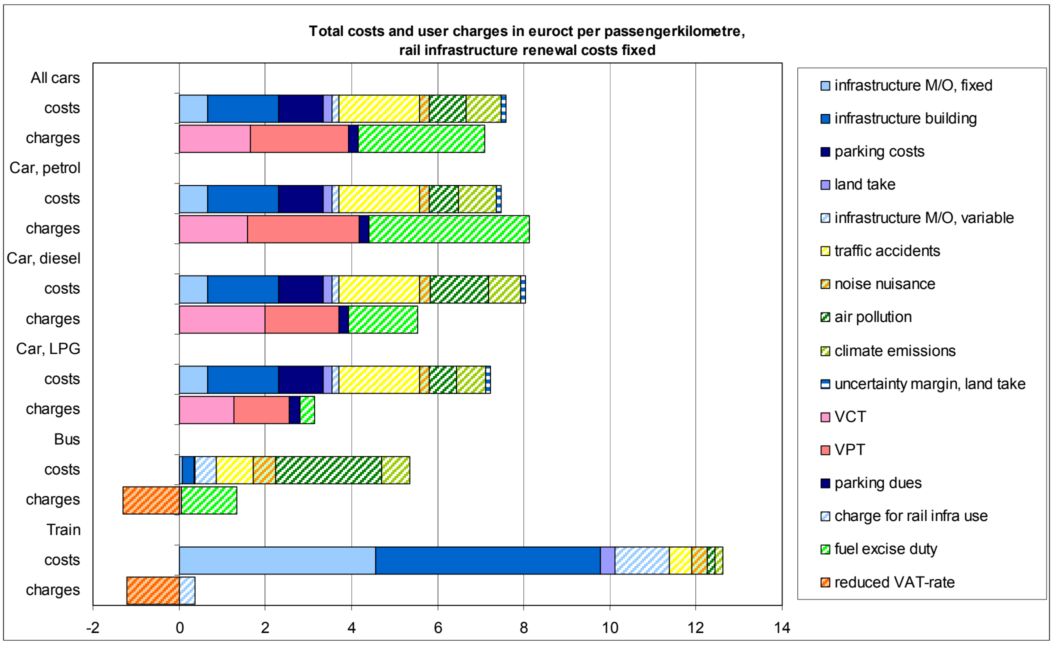


table 54 Total costs per passenger kilometre (costs and charges)

Costs (eurocent per pkm)		*Fixed*					*Variable*				
Transport mode / Vehicle category	Fuel	Infrastructure, M/O, fixed	Infrastructure, construction	Parking (incl. land take)	Land take, direct and indirect	Land take, uncertain	Infrastructure M/O, variable	Accidents	Noise	Air pollution	Climate emissions
Car	All	0.67	1.64	1.04	0.21	0.11	0.17	1.87	0.22	0.84	0.83
	Petrol	0.67	1.64	1.04	0.21	0.11	0.17	1.87	0.21	0.67	0.88
	Diesel	0.67	1.64	1.04	0.21	0.11	0.17	1.87	0.24	1.36	0.74
	LPG	0.67	1.64	1.04	0.21	0.11	0.17	1.87	0.21	0.63	0.68
Local/district bus	Diesel	0.08	0.26	0.00	0.03	0.01	0.50	0.86	0.50	2.47	0.65
Train	All	4.07	5.22	0.00	0.32	0.00	1.71	0.52	0.37	0.17	0.19
Variant with railway infrastructure renewal costs assumed 100% fixed											
Train	All	4.56	5.22	0.00	0.32	0.00	1.27	0.52	0.37	0.17	0.19

Charges (eurocent per pkm)		*Fixed*			*Variable*						
Transport mode / Vehicle category	Fuel	Vehicle Circulation Tax	Vehicle Purchase Tax	Parking fees	Rail infra-structure fees	Fuel duty + REC	Reduced VAT				
Car	All	1.66	2.27	0.23		2.92					
	Petrol	1.58	2.59	0.23		3.71					
	Diesel	2.00	1.71	0.23		1.59					
	LPG	1.28	1.29	0.23		0.35					
Local/district bus	Diesel	0.04	0.00	0.00		1.31	-1.29				
Train	All				0.37	0.01	-1.20				

L Brief comparison with results of earlier studies on the social costs of traffic and transport

The report *External and infrastructure costs of road and rail traffic - analysing European studies* [CE, 2003c] reviews the results of a wide range of European studies on the social costs of road and rail traffic. On the basis of that study, in this appendix we report how the results of the present study compare with those of earlier studies in the field, restricting this brief analysis to the efficiency variant for road and rail.

The cited report makes a distinction between transport in urban and rural areas and in table 55, below, we compare the lower limit for 'rural' and the upper limit for 'urban' with our best and worst case, respectively.

Most studies make the urban/rural distinction, but do not distinguish a best-case and worst-case scenario. The figure in the table should therefore be interpreted with due caution, as the studies in question sometimes used very different assumptions and methods (mode of allocation, valuation, Euro-class of vehicles, etc.).

For all vehicle categories, the best and the worst cases are both in good agreement with the results of earlier studies. The one exception, the worst case scenario for rail freight, is due to the relatively high load taken for this case.

tabel 55 Comparison with results of earlier studies on the social costs of transport and mobility (€ct/vkm)

Vehicle category	**Results of this study**		**Range of major European studies**	
	Best case (rural)	*Worst case (urban)*	*Low values (rural)*	*High values (urban)*
Passenger car, petrol	3.6	13.9	3.0 **)	10.2 or 9.9 (excl. M/O costs)
Passenger car, diesel	4.2	16.7	4.5 **)	14.2
Passenger train	274 *)	798	163 (excl. M/O costs)**)	576
HGV, small (<12 t)	20.6	56.9	8.1	58 (excl. M/O costs) **)
HGV, large (>12 t)	22.4	114.9	12.3	82 **)
Freight train	461 *)	3,790	278 (excl. M/O costs)**)	1,337

*) With renewal costs 100% fixed the best cases for passenger and freight are 240 and 338 €ct/vkm, respectively.

**) The highly anomalous results of one specific UNITE case study have been omitted here.