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Road infrastructure cost and revenue in Europe

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Executive Summary

The estimation and internalisation of the external costs of transport have been important issues for European transport research and policy development for many years. In the light of Article 1(9) of the Eurovignette Directive 2006/38/EC (amending Article 11 of the previous Directive 1999/62/EC), the central aim of the IMPACT study is to provide an overview of approaches for estimating and internalising the external costs of transport. The results are presented in the separate deliverables of the IMPACT project, Deliverable 1 and Deliverable 3 respectively. These deliverables cover environmental, accidents and congestion costs.

The internalisation of these various types of external costs is strongly related to the charging for the use of transport infrastructures. Within the framework of the IMPACT project, the Commission therefore also requested an analysis of infrastructure cost. Contrary to the other deliverables of IMPACT, the scope of this work is limited to road transport.

Deliverable 2 of the IMPACT study summarises the current cost structures and revenues of European road infrastructure. It extends the External Cost Handbook (IMPACT Deliverable 1), which does not cover infrastructure costs, and provides direct input to the pricing scenarios defined and analysed in IMPACT Deliverable 3. The cost structures include discussions of total costs and their variability with region and traffic characteristics, average costs by vehicle type as well as the marginal social infrastructure costs. Revenues associated with road transport are classified by type and variability.

Estimating the economic costs of transport infrastructure including depreciation and interest on capital and running costs can be done using the Perpetual Inventory Method (PIM) or the Synthetic Method. Each of these accounting philosophies has its own strengths and weaknesses. Having conducted a thorough check of each of the arguments, we recommend the Synthetic Method for infrastructure accounting purposes. This method is considered superior if there is no tradition of calculating infrastructure costs with the PIM approach due to the better availability of the required data, the reflection of current infrastructure quality and the relation of cost accounting to existing physical objects of the road network.

Total costs have been derived by analysing the results of recent studies. The UNITE country accounts and the national studies for Germany, Switzerland, Austria and the Netherlands were the most important ones. The unit costs per road kilometre by road class were derived from these sources. Data quality is considered to be detailed for six and general for ten countries, while no sufficient data was found at all for thirteen countries.

There are similarities of cost levels and cost structures between the big Western European countries. For these countries we found values between € 600,000 (Austria, Germany, Italy, Spain) and € 800,000 (France) per motorway kilometre.
The main findings were that unit costs for motorways are roughly ten times higher than for trunk or urban roads. Only motorway costs showed some, but very limited, co-linearity with the price index for construction services across countries.

Regional results for Austria and Switzerland reveal that the running costs are 20 to 50% higher in mountainous areas than in relatively flat regions. Results for capital costs are not available, but it can be suspected that the need for more bridge and tunnel constructions pushes up construction costs in mountainous areas considerably.

Average costs are derived by dividing the total costs by the traffic volume (in vehicle kilometres). The level of average costs is thus not only driven by construction prices, running costs and accounting methodologies, but to a large extent by traffic density. Accordingly, the remote countries (Sweden, Finland, Ireland) show much higher values than the central transit countries. For HGVs on motorways, the specific average costs have been found to vary considerably with vehicle weight from 4 €-ct/vkm for a 5.5t lorry to 19 €-ct/vkm for a 40t truck and trailer combination.

The GRACE case studies indicate that variable average costs may be a good proxy for the marginal costs of infrastructure use. For motorways in the six countries with detailed accounting information, the share of variable costs across all vehicle categories is 22%. For all other countries and road classes, the share of variable infrastructure use costs is 26%. Pure marginal infrastructure cost pricing would thus lead to a deficit of more than 74% of total infrastructure costs.

For the six countries with detailed accounting information, the marginal costs for light lorries (3.5t to 7.5t) range between 0.20 €-ct/vkm (France and Italy) and 51 €-ct/vkm (Switzerland). For HGVs above 32t, the range is from 5.57 €-ct/vkm for Austria to 52 €-ct/vkm for Sweden. These extreme ranges make it questionable, whether the proxy of average variable costs for marginal infrastructure use costs remains valid.

Marginal costs appear to be considerably higher on secondary roads than on motorways in countries with dense motorway traffic. The ratio between trunk roads and motorways was above six for Italy and 0.7 for Sweden. In the EUR-29, the average marginal costs on trunk roads are roughly double the costs on motorways for 40t HGVs.

The study reviewed several sources on national taxes and charges to estimate total and average revenues. The comparison with infrastructure costs shows that, when considering all transport-related taxes and charges, HGV traffic on motorway roughly covers its infrastructure costs, but does not contribute to public budget financing. If the tax share which is not earmarked for transport purposes is removed, the cost coverage drops to 60%. Comparing variable taxes and charges with variable costs shows that countries with road user charge systems considerably overprice lighter HGVs.

It can be concluded that a rough computation of road infrastructure costs for all European countries is possible using simple value transfer rules. But in order to obtain reliable information, national studies per road type are inevitable. Further additional research on the development of investment, running, average and marginal costs is required which takes regional characteristics into account.

This report contains a set of indicative figures on the total costs and total revenues for twenty-seven countries, nine vehicle classes, three road classes and variability. The figures obtained can in no way replace detailed national studies.

1 Introduction - formulating the challenge

1.1 Background and aim of the IMPACT project

The estimation and internalisation of the external costs of transport have been important issues for European transport research and policy development for many years. The European Commission has raised the issue of internalising the external costs of transport in several strategy papers, such as the Green Book on fair and efficient pricing (1995), the White Paper on efficient use of infrastructure, the European Transport Policy 2010 (2001) and its midterm review of 2006. The issues of external cost estimation and internalisation have also been extensively studied in a number of European Framework Programme projects (e.g. UNITE, PETS, ExternE, IMPRINT, REVENUE, MC-ICAM, TRENEN, GRACE).

With the amendment of Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures the subject has come to the forefront of attention. Article 1(9) of the Eurovignette Directive 2006/38/EC (amending Article 11 of the old Directive 1999/62/EC) requires the Commission to present a generally applicable, transparent and comprehensible model for the assessment of all external costs (including those caused by non-road modes). This model is to serve as the basis for future calculations of infrastructure charges. The model must be accompanied by an impact analysis on the internalisation of external costs for all modes of transport and a strategy for a stepwise implementation.

The aim of the IMPACT study is to provide a comprehensive overview of approaches estimating external costs, and an analysis of internalisation strategies, including an assessment of the impacts of various alternatives. The results of IMPACT, based on the enormous amount of material available on these issues, should help the Commission with the development of a Communication as requested by Directive 2006/38/EC.

The issue of internalising external environmental, accidents and congestion costs is strongly related to charging for infrastructure costs. Within the framework of the IMPACT project, the Commission therefore also requested an analysis of infrastructure costs. Contrary to the other work within IMPACT, the scope here is limited to road transport.

In brief, the results of the IMPACT study are laid down in three deliverables:
1 Deliverable 1 - Handbook on external cost estimates.
2 Deliverable 2 - Report on road infrastructure costs, taxes and charges.
3 Deliverable 3 - Report on internalisation strategies.

This report constitutes the second deliverable. It extends the External Cost Handbook (IMPACT Deliverable 1) which does not cover infrastructure costs. In addition, the quantitative results of this deliverable (estimating road infrastructure

costs and revenues of road transport taxes and charges) have been used in the impact assessment of Deliverable 3.
Deliverable 2 focuses on the estimation of infrastructure costs. It does not discuss the various options for charging these costs. This issue is touched upon in Deliverable 3 to the extent that it is related to internalisation approaches, which are the core subject of that deliverable.

1.2 Scope of this report

Given the importance of the road sector in the transport pricing debate, this deliverable seeks to quantify a number of key cost and revenue figures for the European road network. This report aims:

1. To provide an overview of the full economic costs of the European road network by network type, country, user group and cost variability.
2. To derive appropriate levels of user costs related to the investment, wear and tear and operation of the road network.
3. To analyse current tax and charge levels by type, country, road class, user group and variability.
4. To benchmark average costs, marginal costs and revenues against each other to identify equity and financial viability issues.

The scope of this study is the extended European Union (EU-27) plus Norway and Switzerland. Data is provided for the year 2005 for three road classes: motorways, other trunk roads and local streets. Costs and revenues are further broken down into 10 vehicle classes according to the TREMOVE classification. These are:

1. Small cars including station wagons.
2. Big cars including SUVs.
3. Motorcycles.
4. Bus and coach.
5. Light duty vehicles (LDVs) <3.5t, incl. delivery vans.
6. Heavy goods vehicles (HGVs) 3.5 t-7.5t.
7. Heavy goods vehicles (HGVs) 7.5 t-18t.
8. Heavy goods vehicles (HGVs) 18t -32t.
9. Heavy goods vehicles (HGVs) >32t.

In the end, cost elements are assigned to fixed and variable cost blocks as a starting point for deriving marginal costs. Variable cost elements in the framework of this study refers to a medium time horizon, including the life expectancy of major road infrastructure assets. This is commonly 30 to 40 years, but differs between assets.

1.3 Framework and purpose of this report

Current EU legislation encourages Member States to charge vehicles for the use of transport infrastructure by levying average or marginal infrastructure costs. While Directive 2006/38/EC requires the road user charges on the trans-European networks to be based on weighted average infrastructure costs[1], i.e. to charge weighted average tolls, the Commission's vision for a fair and efficient transport system laid down in the 1998 White Paper and its implementation in the second railway package by Directive 2001/14/EC recommend marginal social cost based tariffs (paragraph (3-4)) and a system of mark-ups to recover total costs (paragraph 8 (1)). The term 'weighted average' tolls in the Eurovignette Directive means that tariffs may be differentiated by various criteria (vehicle weight, emissions, time of day, etc.) as long as the total revenues meet the total costs for operating, maintaining, renewing and financing the road network. Thus, both types of charging systems need to be taken into consideration. Although the Eurovignette Directive permits Member States to set weighted average tolls below weighted average infrastructure costs, the coverage of total costs by transport pricing revenues will remain an important aspect in European transport policy for the coming decades due to the public budget considerations of the Member States and given the growing interest in Public Private Partnerships (PPP) to finance transport infrastructure.

Covering total costs can be achieved by setting average cost-based infrastructure prices, by imposing various types of mark-ups on marginal infrastructure costs or by fine tuning a system of marginal infrastructure and congestion costs, which includes the thorough consideration of incentive and intermodal and interregional cross-funding schemes. The decision criteria for selecting one of these options include the dominance of fiscal rules, the expected predictability and robustness of costs and revenue flows, technical options, transaction costs and of course network and demand structures.

Against this background, Deliverable 2 of the IMPACT study summarises the evidence on the current cost structures and revenues of the European road infrastructure. Cost structures include discussions of total costs and their variability with regional and traffic characteristics, average costs by vehicle type as well as the marginal social costs of infrastructure use.

The *marginal* infrastructure costs presented in this study are relevant from the perspective of marginal social cost pricing, which is the benchmark of pricing schemes under ideal conditions. They have been based on estimated average costs and on the ratios between marginal and average infrastructure costs following the elasticity approach proposed by the GRACE project (Lindberg, 2006).

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[1] Paragraph 1 (2e) amending §7 (9) and (10) of Directive 1999/62/EC and Annex II, Section 2 amending Annex III of DIR 1999/62/EC.

In addition to the marginal infrastructure costs, estimates for *total (full) and weighted average* infrastructure costs are presented as well as including capital costs due to investment activities. These figures are relevant for several reasons:

1 Weighted average costs by type of activity (investment, renewal, maintenance, operation) are used in this report for calculating marginal social infrastructure costs.
2 Even under a marginal social cost pricing regime, the recovery of total infrastructure costs remains a politically relevant issue. Data on full or average infrastructure costs help to understand whether and under which conditions a marginal infrastructure cost based pricing scenario could meet the total budget requirements of transport network providers. Total or average infrastructure cost levels may, for instance, help in setting politically acceptable caps on congestion charges.
3 Under prevailing legal conditions, weighted average infrastructure costs are the basis for setting maximum levels of road user charges as permitted by the Eurovignette Directive 1999/62/EC (Annex III) and its current amendment (Directive 2006/38/EC). Without actually preventing Member States from setting lower charges, the Directive does recommend that toll revenues should meet total infrastructure costs. The German Governmental Commission on Transport Infrastructure Financing (Paellmann, 2000) advocates a decoupling of transport financing from fluctuating public budgets in this respect with limited cross-financing between modes.

In addition to road infrastructure *costs*, this study also presents *revenues from the taxes and charges* associated with road transport. These revenues are classified by type and variability. Cost and revenue figures are generated for all 27 EU Member States plus Switzerland and Norway for the year 2005. Missing data are estimated in order to provide a complete and consistent data set across Europe, covering all cost and revenue categories.

It should be noted that road infrastructure costs and revenues are regarded in a European perspective. Limitations in the project resources may cause deviations of the reported figures from the transport account statistics for individual countries. The figures presented here give a well balanced picture of road infrastructure costs across Europe, but may not be used to benchmark national pricing systems. Local studies are required to do so.

1.4 Incorporating the results into the IMPACT scenarios

Five scenarios, including seven different variants, were defined for the impact assessment (see IMPACT Deliverable 3). These scenarios with strategies for internalising the external costs of all modes of transport throughout the EU consider two alternative treatments of road infrastructure costs:

- Existing charge systems remain in place.
- Replacing the current infrastructure charges by a system of tariffs based on marginal infrastructure costs, to some extent with added marginal social congestion charges.

The scenarios differ in the way internalisation is pursued, and also in their ambition level regarding internalisation. It should be noted that another option, namely charging for average infrastructure costs across the entire European road network with added measures for internalising external costs, has not been assessed. The reason for this is that the scenarios (selected in consultation with the Commission services) focus on approaches for internalising external costs (being the subject of the study) rather than on variants for charging infrastructure costs. An overview of the parts of the scenarios that are related to road transport[2] is given in Table 1.

Table 1 Summary of IMPACT scenarios (measures for road transport)

Scenario	Infrastructure charges (tolls)	Circulation tax	Fuel tax	Bottleneck /cordon charges
1 Reference	Existing tolls + for HGV at level of fixed charges (revenue neutral)	Current purchase + circulation taxes, CO_2 based	EU minimum where national rates are lower; elsewhere current rates	-
2 Internalisation through fuel taxes	As (1)	As (1)	EU minimum + external costs (accidents, air, noise)	
3 Internalisation through km-charges	As (1) + circulation taxes (1) for cars + externalities (accidents, air, noise) for all vehicles, all roads	Non for cars, as (1) for HGVs	EU minimum	
4A Smart charging with minimum fuel tax	Marginal infra costs + externalities (air, accidents, noise) for all vehicles	Non for cars, as (1) for HGVs	As (3)	Congestion (selected modes only)
4B Smart charging with current fuel tax			As (1)	
5A Pragmatic, HGV charges on all roads	As (1) for cars, marginal infra costs + externalities (air, accidents, noise) for HGVs on all roads	As (1) for all vehicles + externalities (noise, air, accidents) for cars	As (1) for all vehicles, reduction according to increase of other taxes (not below minimum) for HGV	As (4)
5B Pragmatic, HGV charges on motorways	As (5A) with HGV charges on motorways only			

Note: EU minimum = minimum excise duty rates as foreseen by the commercial diesel proposal.

2 Note that the internalisation scenarios cover all modes of transport. The full scenario descriptions can be found in IMPACT Deliverable 3.

1.5 Structure of the report

In addition to this introduction, the report consists of six chapters. Chapter 2 discusses selected theoretical issues related to the pricing of infrastructures. It thus paves the way for the compilation of the cost and revenue database.
Chapter 3 presents the approach, the data sources and the results of estimating the total and average infrastructure costs for all European countries, road types and vehicle classes. It therefore contains a section on road traffic demand which is used in other sections, too.

Chapter 4 presents the available evidence on the marginal costs of road infrastructure and allocates them to the various countries and road classes. With this information the chapter accomplishes the road cost database building on the work of the previous section.

Chapter 5 describes the process and the results of collecting road transport related revenue data. Chapter 6 compares average costs, marginal costs and revenue using various characteristics. The emerging policy conclusions are finally discussed in Chapter 7.

2 Total and average road infrastructure costs for Europe

The introductory chapter emphasised the importance of total and average cost estimates for deriving marginal cost figures and setting the IMPACT scenarios in relation to road network (re)financing needs. Accordingly, this chapter aims at building up a quantitative database on total road infrastructure costs for all 29 countries considered and all road classes. By allocating these costs to cost categories and to vehicle types, weighted average road infrastructure costs are obtained, where the weights are set according to vehicle characteristics which impact the costs of road construction, renewal, maintenance and operation. Environmental and safety aspects are disregarded in this report.

Due to the poor data situation of European road accounts, the figures were mainly generated using a limited number of country studies, which were extrapolated to all 29 countries. The results of this report can thus in no way replace national studies when designing local pricing policies.

According to the mandate, this report is restricted to road infrastructure. However, rail and aviation infrastructure, where a high degree of privatisation has occurred over the last decades, were also briefly considered while reviewing the studies. The insights gained from this include the following:

1. The data situation for rail transport appears to be even worse than for roads. This is due to the still strong presence of the public sector in network management combined with the privacy rules of new market structures enforced by the railway packages of the EC. The management of railway networks is still dominated by the decision power of small regional units; central planning systems are established only slowly.
2. In aviation, local and municipal authorities play a big role in financing airport infrastructure as airports are expected to be catalysts for economic development. Thus, the sector is granted considerable subsidies which are commonly hidden in other public budget titles. Moreover, airports are generally a mixture between transport and commercial (retail) infrastructure. Separating investment grants or running expenditures for the transport sector appears to be difficult or extremely arbitrary.
3. The data availability for rail and aviation facilities is even worse than for roads on account of the privacy status of railway undertakings after the liberalisation of European rail markets and the partly private status of many airports. Thus, it will hardly be possible to establish a comparably comprehensive cost database as was able to be done within the scope of this study for the road sector.

2.1 Overview of accounts

Accounting for the economic costs of road transport is a tradition mainly in the German speaking countries. The following international studies were analysed:

1. Doll (2005): Results of European road accounting studies new approaches to allocate common costs.
2. UNITE (2003): EC project determining infrastructure and external cost accounts for 18 European countries, all modes and three years (1996, 1998, 2005). Moreover, the project has carried out several case studies on the marginal costs of different cost categories across Europe.
3. GRACE (2007): EC Study quantifying the variation of marginal costs of all modes and categories with traffic and exogenous parameters on the basis of several European case studies.
4. ASECAP (2007): Statistics on revenues and traffic performance on European toll roads.

On a national level, the following accounting studies were used:

5. ProgTrans/IWW (2007): Succeeding Prognos/IWW (2002): Calculation of the tariffs of the German HGV motorway charge according to the provisions of Directives 1999/62/EC and 2006/38/EC on behalf of the German Ministry for Transport, Building and Urban Development (BMVBS).
6. Herry/IWW/NEA/Sniezek (2002): Study for the Austrian Motorway and Express Roads Financing Society (ASFINAG) on calculating the tariffs for the national HGV motorway charging system in Austria.
7. ITS (2001): Study quantifying the external costs of transport for the UK in 1998.
8. BFS (2007): Swiss road accounts for 2005. Methodology and results of costs and revenues of the Swiss road sector.

The subsequent elaborations use key values and findings from these studies updated for the year 2005.

2.2 Review of methods and options

2.2.1 Expenditures vs. economic costs

Accounting for the total resources consumed by the construction, maintenance and operation of long life infrastructures can either be done by simply summing up expenses or by using real economic accounts. The latter take into account the direct expenses plus the financing costs or - regarded from a different point of view - the opportunity costs for not spending the resources for more profitable purposes. Financing and opportunity costs are expressed by the interest on capital, where the interest rates vary with the legal status of the investor. Private investors expect greater profits and account for more profitable, alternative forms of money spending than public bodies and thus assign higher interest rates to the computation of capital costs.

As financing and budget allocation are issues for public bodies as well as for private investors, full economic accounts are preferred to summing up expenditures in all cases. Further, the examples of road expenditures given in the tables below demonstrate that these figures may vary widely by year and area. This is due to the long planning and construction phases of big projects, varying quality standards, local conditions and budgetary reasons. The examples show the expenditures for new and enlargement projects (Table 2) and the expenditures for maintenance (including reinvestment and rehabilitation measures) for selected countries and years relative to the length of the respective networks.

Expenditure accounts can help to compare cost structures among countries, provide the basic data for deriving economic costs and transfer economic accounts between countries. By consulting national statistics, the following figures were collected for new construction, for investment and routine maintenance and for the operation and management of the highway networks in Austria, Switzerland and Germany. The data have been normalised to road kilometres expressed in Euros re-indexed to the year 2005 to allow comparison among countries.

Table 2 National expenditures for new road construction, maintenance and operation in selected countries

Country	Network	Capacity enlargement	Investive maintenance	Routine maintenance	Operation, management & finance	Total
		Euro (2005 prices) per km of total network length				
Austria [1)]	ASFINAG network	331,134	197,917	108,406		637,456
Switzerland [2)]	National roads	783,502	288,239	78,867	99,053	1,249,661
	Canton roads	32,035	9,634	20,902	17,124	79,695
	Municipal roads	7,403	2,325	14,831	4,589	29,148
Germany [3)]	Federal motorways	197,528	83,826	39,383		320,737
	Federal trunk roads	23,410	21,173	11,576		56,159

1 ASFINAG (2007), annual expenses of ASFINAG for motorways and express roads 2006.

2 BFS (2007), preliminary values for 2005.

3 BMVBS (2006), expenses of the federal Government 2005, general road network expenses are allocated 50% / 50% to motorways and federal roads, respectively.

The data shows big differences across road classes and across countries. Motorway maintenance and operation costs range between 178,000 €/km in Switzerland and 40,000 €/km in Germany. But, according to BMVBS (2006), the German figures only contain direct federal government expenses and ignore the costs to federal states and the costs of enforcement (traffic police) and operation of the road network. These costs are contained in the Swiss road accounts (BFS, 2007) and in the ASFINAG balance sheets (ASFINAG, 2006).

It is not possible to compare new capacity provision costs between countries or maintenance costs as all the figures relate to the length of the existing network and are thus driven by unit construction costs and the volume of new construction or extension projects. Furthermore, extension projects also contain elements of renewal in the case of added traffic lanes.

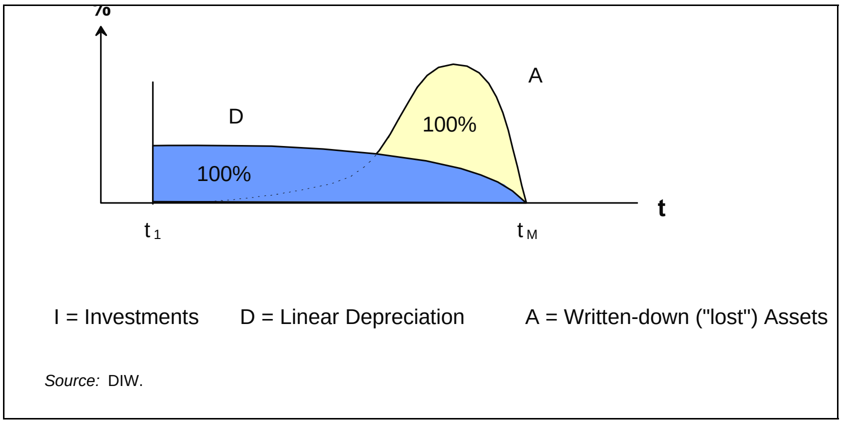
Economic accounts can either be based on the capitalisation of historical expenditure data (Perpetual Inventory Method - PIM) or on the assessment of the future financing needs of the present network (Synthetic method). These two options are described and compared below.

2.2.2 The Perpetual Inventory Method

The Perpetual Inventory Method (PIM) builds on long time series of infrastructure expenditure data which are classified into types of activity: Investment and operation. As a rule, both are further distinguished in sub-categories specifying the type of asset and the nature of management and operation activities (see section 2.2.5). The distinction into expenditure categories is required because individual cost blocks react differently with varying investment and maintenance levels, changing traffic volumes and over time.

For each category of investment expenditure, the PIM calculates the annual depreciation costs by distributing the initial investments over the asset's lifetime. Costs are not necessarily distributed evenly across years. The most recent infrastructure cost studies use probability functions to describe the statistical distribution of the maximum life expectancy of construction elements of transport infrastructure. These may be defined on the basis of statistical analyses (UNITE, 2002), experiences of road administrations (Herry, 2002), or engineering considerations (ProgTrans/IWW, 2007).

Figure 1 General scheme of end-of-life probabilities and annual depreciation levels for longlife infrastructures



Source: UNITE (2000).

The sum of the investment costs which are not fully written off at the period of accounting equals the gross asset value of the network in question. Commonly, the historical investment costs are adapted to the current price level using construction price indices. Subtracting the annual depreciation in current prices from the gross asset value yields the net asset value. The ratio between the gross and the net asset value can be regarded as a measure of the average age or modernity of the network.

Interest costs express a variety of real and imputed cost blocks borne by the infrastructure owner or concessionaire. They are computed by multiplying the net asset value by an appropriate interest rate. Interest rates depend on the legal status of the infrastructure owner, the valuation of assets and the selected depreciation model. The latter two drivers in particular determine whether to apply real (excluding inflation) or nominal (including inflation) interest rates.

Capital costs equal the sum of depreciation and interest costs. In contrast all those expenditure elements with a lifetime below one or two years (operation, management, energy supply, minor repairs) are not capitalised. These running costs are taken directly into account when computing total infrastructure costs. Total annual costs thus equal the sum of annual capital costs plus annual running costs (or expenses). The historical expenditure series may either be taken as they are (in current prices) or may be transformed into reinvestment values by applying appropriate price indices.

Besides expenditure time series, the most important parameters driving total costs in the PIM model are thus (see details in section 2.2.5):

- The assessment of investment value (historical expenses vs. replacement values).
- Functions of life expectancy.
- Interest rates (real or nominal, cost elements included).

Finally, the average costs by vehicle category are strongly dependent on the cost allocation procedure applied. Different types of assets are affected differently by certain vehicle characteristics, but the uncertainties associated with quantifying these impacts are huge. Available cost allocation models are presented in section 2.2.7.

Current PIM applications abstract from physically existing networks, which means that investment expenditures which are fully written down according to the time series may still exist and cause future reinvestment activities. Thus, the pure price adjustment is not equivalent to a full prediction of future financing needs of the existing infrastructure network. The results of PIM models reflect the depreciation of historical expenses rather than physical assets.

The advantage of the PIM approach is that it is compatible with the common accounting philosophies of public budgets. In compliance with the doctrine of the system of national accounts it expresses the economic costs which past investment decisions and the existence of the infrastructure networks cause in the accounting period. It is thus more a statistical convention than a basis for predicting future maintenance costs and reinvestment needs.

2.2.3 The Synthetic Method

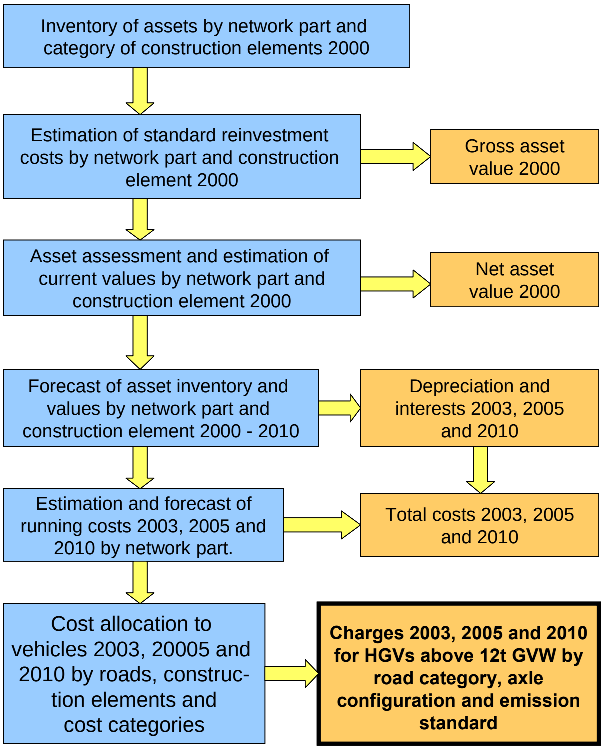
The UNITE accounts revealed that the data requirements of the PIM approach can only be met by a limited number of countries. In particular, the Southern and Eastern EU Member States do not possess long time series of road expenditures with a sufficient level of detail. Enquiries made for this study at the national statistical offices of the 29 countries in February 2008 confirmed this finding.

An alternative approach is provided by the Synthetic Method of calculating infrastructure costs, which starts from a complete inventory of assets in the accounting period. It thus reacts to two weaknesses of the Perpetual Inventory Method (PIM) as it explicitly refers to physically existing assets and abstracts from historical records of road expenditures. For each type of asset, a replacement cost value is estimated, reflecting its dimensioning, load, location and the latest technical standards and specifications. The historical investment expenditures do not matter. However, the Synthetic Method does require minimum information concerning the age of each asset and - if available - its physical condition. The data contained in such an inventory may well exceed the data requirements of the PIM approach, but it can be easily generated by each country through observation or should be readily available in infrastructure managers' asset management systems.

Considering the age and - depending on the type of depreciation model used - past and projected traffic loads and the physical condition of the asset, depreciation and interest costs are calculated similar to the PIM approach. Contemporary studies applying the Synthetic Method (ProgTrans/IW, 2007; Herry et al., 2002) use statistical life expectancies. The relation to physical objects makes it possible to apply much more detailed and advanced depreciation models. Table 5 presents average depreciation periods and section 2.2.6 discusses some selected models applied in the literature.

Running expenses are usually taken from national accounts and thus do not differ from the PIM approach. The same holds for cost allocation procedures, which appear to be the same for both accounting methods. The structure of the Synthetic Method is shown in Figure 2.

Figure 2 Structure of the Synthetic Method for infrastructure accounting



2.2.4 Comparing the PIM approach to the Synthetic Method

The Synthetic Method is much more of a decision support tool than the PIM approach as it indicates the sum of money to be raised in order to maintain the quality of the network at a certain level. Outputs of cost accounting are thus influenced by the discretionary choice of quality. Prognos/IWW (2002) and Herry et al. (2002) have thus shortened depreciation periods in order to reflect observed investment backlogs.

The targeted quality standard can be adjusted by changing the length of depreciation periods in the accounting system; long periods indicate that reinvestment measures will be postponed and accordingly worsening infrastructure conditions will have to be accepted with ageing assets. The Synthetic Method can in principle be applied within traffic models and thus can react dynamically to different future scenarios of traffic demand development.

Both models comply with the provisions in the Eurovignette Directive and its amendment of 2006. But only the PIM approach complies with the System of National Accounts (SNA) and common public accounting considerations.

With regard to data requirement both methods are demanding. While the Synthetic Method requires excessive information on physical assets and their current condition, the collection of expenditure data assigned to the transport networks to be assessed and their allocation to cost categories for the PIM approach may demand excessive and resource-consuming surveys of public budget records. For a number of countries the latter information is not available at all. In these cases, the application of the PIM method will not lead to reliable results. Data gaps in the Synthetic Method can be bridged more easily by using standard values than is the case for the PIM approach, which makes the Synthetic Method applicable to more cases and gives it more flexibility towards different budgets for infrastructure cost estimation surveys.

In the end, the decision whether to apply the PIM approach or the Synthetic Method depends on the objective of the cost accounting scheme. If the objective is to account for the present value of historical activities, e.g. the expenses of tax payers, then the PIM approach should be applied. This objective is more for documentation purposes, e.g. for an intermodal comparison of public expenses, than decision support.

In a private sector dominated environment, the revenues from an infrastructure pricing scheme should suffice to maintain the infrastructure at a particular quality standard. In this case, past (sunk) expenses are irrelevant. Further, the long and broadly distributed lifetimes of transport infrastructure assets call for the application of open (flexible) depreciation procedures. It can thus be concluded that a private operator will apply the Synthetic Method rather than the PIM approach.

Table 3 compares some features of the accounting approaches.

Table 3 Features of the PIM and the Synthetic Method

Criterion	Perpetual Inventory Method	Synthetic Method
Data requirements	Long investment expenditure time series by category of assets	Detailed inventory of assets with information on dimensioning, age, physical condition, location and traffic load
Regional differentiation	Generally difficult, depending on how expenses are recorded in public budgets	Inherent, depending on structure of asset inventory
Accounting objectives	1 Record of capital bound by historical investment decisions (according to System of National Accounts) 2 Replacement costs: possible but difficult as no relation to actual existing assets	1 Replacement costs: natural application due to direct relation to the physical network 2 Account of capital bound: possible but not conform with SNA
Maintenance strategies	Rather artificial as no link between varying replacement intervals and reinvestment needs is provided by the PIM structure	Easily possible due to the local and asset-related structure of the method
Open depreciation schemes	Not applicable, requires tracking of asset quality standards over time	Applicable due to availability of physical asset inventory
Level of costs	Reflects the actual expenditure practice of infrastructure managers/owners, no relation to investment needs	Reflects the theoretically required investment level; desired network standard to be adjusted by life expectancy function per type of asset

Given the huge amount of historical data required for the PIM approach and its limitations in setting correct price signals for future investment activities, the Synthetic Method is recommended with a thorough selection of reinvestment cost values per cost component.

As concerns capital and running costs, both methods suffer from a large degree of uncertainty. This is caused more by the complex structure of financial flows in public accounting systems than by the cost calculation method itself. Of particular importance are the expenses of local entities and the hidden costs of public planning and administration. There is no clear indication as to which method leads to higher costs since, on the one hand, the PIM might double count measures succeeding each other at a particular infrastructure object, and, on the other hand, the Synthetic Method accounts for the calculated costs of delayed reinvestment measures. Thus, under optimal road maintenance conditions, the PIM is expected to lead to higher capital costs, while under the conditions of constrained investment budgets, the results of the Synthetic Method should be higher.

Comparative results are available for Austria in Herry (2000), Germany (Doll, 2005) and Sweden (UNITE, 2002c). The results of the Synthetic Method for the gross capital value of German motorways appear to be roughly 10% above those of the PIM, while the net asset values of the Synthetic Method are 10% lower. Given the shorter depreciation periods and higher interest rates applied by the Synthetic Method, Prognos/IWW (2002) arrives at 13% higher capital costs and, due to different assumptions about running and administrative costs, at 16% higher total costs per road kilometre than the PIM method applied in UNITE (2002a). The comparison of net asset values for Austrian roads in Herry (2002) also reveals 14% to 20% higher results for the PIM model. In contrast, the comparison of the Business and the PIM accounting for Swedish national roads in UNITE (2002c) shows a 17% lower net capital asset value, but 11% higher total costs.

Table 4 Ratio of accounting results using the Synthetic Method to PIM in various studies

	Germany (Motorways)	**Sweden** (all roads)	**Austria** (all roads)
	Unite (2002a) and Prognos/IWW (2000)	UNITE (2002c)	Herry (2000)
Gross capital value	+10%	-	-
Net capital value	-12%	+17%	-14%
Capital costs	+13%	-31%	-
Total costs	+16%	-11%	-

The three cases indicate that practical asset lifetimes on average exceed the depreciation periods assumed in the accounting models. The rather mechanistic PIM approach thus gives an inaccurate picture of the current state of the infrastructure. This is presumably why the Synthetic Method is applied by the only two countries in the EU, namely Germany and Austria, which justified road user charges by economic cost accounts. The huge number of country studies computed with the PIM approach dates back to computations of the German Institute for Economic Research (DIW) in the UNITE project. Real national approaches are only available for Germany and Switzerland.

Recalling the chain of arguments above, the PIM method is more closely related to the philosophy of public accounting, but may face difficult data situations and lacks the flexibility to depict the current state of infrastructure networks. We thus recommend the Synthetic Method as the first best approach for setting road user charges. However, care must be taken to accurately define replacement values and net asset values based on asset quality indicators.

2.2.5 Cost categories

Depending on data availability, studies distinguish between different cost categories. A systematic comparison of studies concerning the impact of specific categories on total costs is difficult because the results are usually presented in aggregated form. However, there are some exceptions which include a detailed presentation of total costs by category. These are the German accounts (Prognos/IWW, 2002 and ProgTrans/IWW, 2007), the Austrian Infrastructure cost study (Herry et al., 2002) for ASFINAG and the US Highway Cost Allocation Study 1997 (FHWA, 1997). A common structure of cost categories is:

Investment expenditures:

1 Planning and surveying.
2 Land purchase/right of way.
3 Earthworks (ground preparation, drains, etc.).
4 Substructures (base and frost protection course).
5 Superstructures (binder and surface courses).
6 Engineering works (bridges, tunnels, etc.).
7 Equipment (traffic signs, etc.).
8 Park and rest facilities.

Running costs

1 Repair measures.
2 Operation (winter maintenance, green cutting, etc.).
3 Traffic police.
4 Administration.
5 Toll collection.

The scope of cost categories differs slightly between the studies: While Prognos/IWW, 2002 explicitly excludes park and rest facilities, other studies (including the succeeding study by ProgTrans/IWW, 2007) take this (minor) cost category into consideration. Alternatively, cost categories could be grouped by function, e.g. into capacity enlargement, maintenance investments, routine maintenance, operation and management (see section 2.5.1).

Table 5 Average depreciation periods by construction element reported by selected studies (in years)

Asset category	Germany			Austria
	FGSV (1997)	Prognos/IWW (2002)	UNITE (2000)	Herry et al. (2002)
Substructures of free lanes		90	116	65
- Land purchase/right of way				
- Earthworks	100			
- Draining	75			
Superstructures of free lanes			35	
- Main course	50	50		23
- Surface course				15
- Asphalt surface				
- Binder course	25	25 [4]		
- Asphalt surface layer	12.5	12.5 [4]		
- Concrete surface layer	25	25 [4]		
Equipment of free lanes		18	18	
- Equipment	10			14 - 23 [5]
- Noise protection	25			18
Engineering works of free lanes and intersections			68	
- Bridges	50	65		73
- Tunnels	50	90		95
- Other engineering works	50	50		73
Nodal points (intersections)				
- Earthworks		90		
- Road surfacing		ca. 20 [3]		
- Equipment		50		
Operating facilities		18	18	
- Real estate	10			68
- Machinery	25			11

1 Reinvestment as concrete surface.
2 Not relevant as next reinvestment wave starts from 2050 on.
3 Average composition of surface types according to free lane.
4 Valid for average traffic loads 1997; respective shortening with increasing volumes.
5 Including equipment for bridges (23 years) and tunnels (16 years).

Among the running costs, two items are of specific interest: the costs of planning, public administration and toll collection.

Administrative costs are particularly difficult to estimate as they are commonly hidden in various titles of state accounts and cannot be easily attributed to particular modes, road categories or activities. While high estimates of public administration costs range above 50% of gross capital costs (Wirtschaftsrat, 2007), more conservative estimates by ProgTrans/IWW, 2007 assume a value of 15% of total infrastructure costs based on the experiences of German federal states and of the DEGES (German Unity Motorway Planning and Construction Company).

The costs of the toll collection system depend on the technology applied. While the Austrian, French, Italian, Spanish and Portuguese systems ‘cost’ roughly 5% of infrastructure costs, the satellite based German system eats up 20% of toll income.

2.2.6 Interest rates and depreciation models

Investment related cost components have a particular life expectancy, which may vary between 10 to 15 years for equipment, 90 to 100 years for earthworks or tunnels up to infinity for land purchases. Within this depreciation period the assets lose a certain share of their original (gross) investment value, which may be linear or depend on traffic loads.

Contemporary cost models assume that depreciation periods are not constant, but are distributed according to statistical probability functions (UNITE, 2003; Prognos/IWW, 2002; Herry et al., 2002; ProgTrans/IWW, 2007). Prognos/IWW, 2002 suggest that 'open' depreciation models should be applied due to the long and uncertain life expectancies of transport infrastructure assets. These would determine the actual depreciation by comparing the asset's condition at the beginning and at the end of the accounting period. This would make statistical distributions of lifetimes obsolete, but would require regular account and quality measurements to be made separately for single assets.

The statistically remaining value of the asset in the year of accounting reflects the capital commitment which needs to be financed on the capital market. The assessment of assets (historical or reinvestment costs) and the depreciation model applied determine whether interest rates are expressed in real terms (with inflation correction) or nominal terms. If price effects are already considered in the assessment and depreciation then the interest costs must be computed with real rates (compare Table 6).

Table 6 Depreciation models and interest rates

Depreciation model	Interest rates	Application cases
Regular depreciation of historical costs	Nominal	BFS, 2003
Regular depreciation of replacement costs	Real	UNITE, 2002; Herry, 2000
Open depreciation of replacement costs	Nominal	Prognos/IWW, 2002; ProgTrans/IWW, 2007

Across all the cost assets in an infrastructure network, the capital costs are thus determined not so much by questions of asset valuation and depreciation models, but more by the level of the real interest rate. Real interest rates are determined by the enterprise fiction behind the accounting framework. If the infrastructure is operated by a public authority, real interest rates between 2% and 3% have been applied by past studies, referring to the long-term public loans in Western Europe. However, social interest rates might well be higher in high interest periods or outside the EU. Real interest rates are also higher if private capital is involved as the interest costs contain elements of risk beyond public sector guarantees and profit margins.

2.2.7 Cost allocation procedures

In order to calculate weighted average cost charges or revenue cost ratios from full cost accounts, total costs need to be attributed to single vehicle classes or user groups. Transport infrastructure consists of a high share of fixed costs, which do not or only partly vary with traffic demand. It renders this allocation process difficult and somewhat arbitrary. To find fair and objective solutions, three different types of cost allocation have been developed and applied in recent cost allocation studies:

1 The **equivalency factor method** defines certain proportionality factors for each vehicle class and cost category which express the responsibility or the causation of the vehicles for the level of total costs. Very significant equivalency factors for instance are Equivalent Standard Axle Loads (ESAL), which derive from the results of the AASHTO road test in the US and increase with the 4th power of axle loadings. These are applied to damage sensitive surface layers. Capacity related costs are distributed by Passenger Car Equivalents and fixed cost blocks are assumed to be linear to pure vehicle movements. Major problems arise from the inter-dependency of asset dimensions, from weak empirical data and from high levels of data aggregation. Accordingly, the results of different equivalency factor applications may diverge widely. The method is the most frequently applied approach to allocate total costs in road infrastructure accounts; it is applied in UNITE, 2002; BFS, 2007 or ProgTrans/IWW, 2007. The equivalency factor method is compatible with common planning tools which determine the width and thickness of roads and the design of curves, gradients and junctions depending on projected traffic loads, their composition and the general function of the road.

2 The **econometric approach** is solely applied by the Austrian infrastructure cost study (Herry et al., 2002). It relates cost data to traffic flow information across links and over time. The regression coefficients then provide cost shares for the different vehicle types. The method, in principle, is more objective than the equivalency factor method, but in practice, the significance of results is low due to high co-linearities of flow data among different vehicle classes. The results range around the upper limit of applied equivalency factor methods.

3 Doll, 2005 proposed a **game theory application** to link the engineering knowledge of equivalency factor methods with a scientifically sound and objective allocation scheme. The approach uses the design and construction principles of roads to construct a ‘characteristic cost function’, which is then applied to a continuum of players (road users). The result of the co-operative game is that all users negotiate a fair share of total costs for themselves. The procedure was not applied to complete road networks, but example calculations support a rather cautious approach by allocating lower costs to heavy traffic as applied by ProgTrans/IWW, 2007. Some elements of the approach were also applied in the US Federal Highway Cost Allocation Study 1997 (FHWA, 1997).

Although cost allocation procedures do not affect total costs, they have a huge impact on the unit costs for single vehicle categories, e. g. road user tariffs. In this study, not the methodologies, but the results of the above cost allocation procedures are used to assign total costs to types of vehicles. By treating the different elements of total costs separately according to their specific characteristics in cost development, the basic concept of the game theory approach is linked to techniques of standard equivalency factor allocation. Eventually, the objective of this study is to apply a commonly acceptable and simple method of cost accounting and cost allocation rather than to promote completely new methods.

2.3 Studies and results

Economic accounts of transport infrastructure have been done by a number of countries and by the EC funded research project UNITE (2000 to 2003). National studies are available for:

1 Germany (ProgTrans/IWW, 2007; Prognos/IWW, 2002 on behalf of BMVBS).
2 Switzerland (Bundesamt fuer Statistik, 2007).
3 Austria (Herry et al., 2002 on behalf of ASFINAG).
4 The Netherlands (CE, 2004).
5 The United Kingdom (ITS et al., 2001).

UNITE has carried out national accounts with varying scopes and levels of detail for Germany, Switzerland, Austria, Denmark, Spain, France, the Netherlands, the UK, Belgium, Finland, Greece, Hungary, Italy, Luxemburg, Portugal and Sweden. The results of selected studies are presented in Table 7. These were made comparable by relating total costs in 2005 Euro to network lengths. The resulting unit cost values diverge greatly between studies; the only general trend is that motorways appear to be far more costly than other roads. The data does not show any relation between the geographical structure of a country and the infrastructure costs, but does seem to suggest that road construction in arctic regions with harsh winters is more demanding than in mountainous topographies. The different levels of aggregation for the various road classes in the studies, however, makes a clear analysis difficult.

UNITE and BFS, 2003 use the PIM approach for total cost allocation, while Herry, 2002 and ProgTrans, 2007 apply the Synthetic Method. A comparison of the results in TC, 2005 and Doll, 2005 shows that the Synthetic Method leads to 16% higher capital costs when applied to roughly the same networks in Germany but with slightly different assumptions on interest rates and depreciation periods, while Herry (2000) found that the Synthetic Method generated lower capital costs under the same conditions. Most studies (UNITE, 2002; ProgTrans, 2007; BFS, 2003) apply the equivalency factor method for cost allocation while only Herry, 2002 develops and uses the econometric approach. The latter is, however, also used in GRACE, 2006 for estimating marginal costs per vehicle class.

The far right column in Table 7 shows the share of costs attributed to heavy traffic. The different shares, in particular for the two German accounts, demonstrate the strong impact of cost allocation rules on the structure of cost based user charges.

Table 7 Comparison of annual infrastructure cost estimates by selected studies

Source	Country	Price basis	Network	Total costs million €	Unit costs 1,000 €/road-km	Heavy traffic share
ProgTrans/ IWW, 2007	DE	2005	All federal roads	18,190	342	38%
			Motorways	9,530	781	46%
			Fed. trunk roads	8,660	211	29%
BFS, 2007	CH	2005	All roads	4,970	70	15%
			National roads	1,974	1,124	n.a.
			Canton roads	1,339	74	n.a.
			Urban roads	1,055	21	n.a.
Herry, 2002	AT	2004	ASFINAG network	1,469	745	57%
CE, 2004	NL [1)]	2002	All roads	9,219	73	29%
			Rural roads	4,711	71	n.a.
			Urban roads	4,508	75	n.a.
UNITE D5	DE	2005	All roads	27,293	59	38%
			Motorways	5,100	418	57%
			Fed. trunk roads	4,566	111	35%
			Local streets	17,627	43	33%
	CH	2005	All roads	6,136	86	15%
UNITE D8	AT	2005	All roads	5,273	50	49%
			Motorways	1,222	601	60%
			Trunk roads	1,080	33	45%
			Local streets	2,970	42	46%
	DK	2005	All roads	1,345	19	n.a.
	ES	2005	All roads	9,479	57	n.a.
	FR	1998	All inter-urban roads	25,290	26	40%
			Motorways	6,709	721	40%
			Trunk roads	4,369	164	63%
			Local streets	14,446	16	35%
	NL	1998	All roads	4,895	39	n.a.
	UK	2005	All roads	13,836	37	n.a.
			Inter-urban roads	5,095	329	n.a.
UNITE D12	BE	2005	All roads	1,894	13	n.a.
	FI	2005	All roads	1,109	11	n.a.
	GR	2005	All roads	4,658	41	n.a.
	HU	2005	All roads	10,276	64	n.a.
	IT	1998	All roads	15,199	23	n.a.
			Motorways	3,778	622	n.a.
			Trunk roads	8,967	54	n.a.
			Local streets	2,453	5	n.a.
	LU	1998	All roads	146	8	n.a.
	PT	2005	All roads	0	0	42%
	SE	1998	All roads	2,411	17	n.a.
			Motorways	2,820	1,837	n.a.
			Trunk roads	1,123	11	n.a.

1) Without land take; network lengths from Table 8.

2.4 Accounting framework for European cost estimates

2.4.1 Road network classification

The road networks of the 29 countries are classified into three basic types of infrastructure:

1 Motorways.
2 Other trunk roads.
3 Local and urban roads.

All three types have been further differentiated into tolled and non-tolled networks. Road network lengths for the latest available year per country (2002 to 2005) are taken from EU, 2006. Adjustments to 2005 were made by extrapolation using national growth rates for motorways, while trunk roads and urban roads were assumed to remain constant. Average motorway growth rates reported in EU (2006) are slightly below 2% p.a. for EU-15 countries and roughly 4% for the 12 new Member States. 2004 data was available for most countries. The common denominator is required to compare infrastructure costs to revenues (Chapter 4).

Besides total road lengths, the length of toll roads was determined using statistical data from the ASECAP, 2007. The case of urban toll roads only applies in Norway (Oslo, Trondheim and Bergen), the UK (London) and Switzerland (HGV toll on all roads including local streets). The Stockholm congestion charge was not considered as it officially started only in 2007. For the UK, data from TFL, 2006 was used to compute the length of the toll network in London. For Norway, a share of 9% of tolled urban roads was assumed. The data used is presented in Table 8.

Table 8 Length of road network per country (in km)

Country		Motorways		Other trunk roads		Local/urban roads	
		Total	Tolled	Total	Tolled	Total	Tolled
Austria	AT	2,035	2,035	33,008		71,059	
Belgium	BE	1,747	1	13,880		134,940	
Bulgaria	BG	331		6,981		11,976	
Switzerland	CH	1,341	1,341	18,492	18,492	51,446	51,446
Cyprus	CY	268		5,021		3,577	
Czech Rep.	CZ	546	546	54,946	426	72,300	
Germany	DE	12,174	12,174	219,267		413,000	
Denmark	DK	1,027	38	10,331		60,894	
Estonia	EE	96		16,442		36,441	
Spain	ES	10,747	2,842	85,782		68,623	
Finland	FI	653		78,197		25,000	
France	FR	10,383	8,295	386,269		604,308	
Greece	GR	742	742	37,414	175	75,600	
Hungary	HU	575	575	84,285		75,930	
Ireland	IE	192	83	16,862		78,773	
Italy	IT	6,532	5,638	165,340		496,894	
Lithuania	LT	417		78,914		50,602	
Luxemburg	LU	147		2,747		14,470	
Latvia	LV			52,096		7,338	
Malta	MT			1,439		647	
Netherlands	NL	2,342	18	64,150		59,400	
Norway	NO	194	25	27,058	763	65,259	
Poland	PL	814	197	175,297		201,992	
Portugal	PT	2,100	1,401	15,064		62,528	
Romania	RO	0		44,994		27,817	
Sweden	SE	1,650	4	98,256		40,000	
Slovenia	SI	483	453	19,628		40,222	
Slovakia	SK	316		7,064		10,396	
Un. Kingdom	UK	3,638	42	47,928		364,689	
TOTAL EUR-29		60,864	61,490	36,450	1,867,152	19,856	3,226,121

Source: EC, 2006; UNITE, 2002; ProgTrans/IWW, 2007; BFS, 2003; Herry, 2002.

2.4.2 Vehicle types

Taxes and charges distinguish between vehicle size and in some cases environmental aspects and road infrastructure costs vary considerably by vehicle weight. Nine different vehicles were distinguished, including three types of passenger cars and three types of goods vehicles. The parameters and values for each vehicle class are presented in Table 9. The selection of vehicle characteristics is exemplary rather than providing a statistical average across the entire vehicle fleet in the respective segment; the aim is to illustrate the relation between specific taxes, charges and infrastructure costs.

Table 9 Vehicle types for infrastructure cost and charge estimation

Parameter	Unit	Small car	Big car	Motor cycle	Bus/ Coach	LDV/ Van	HGV 5.5t	HGV 12t	HGV 24t	HGV 40t
Technical description										
Fuel type		Petrol	Petrol	Petrol	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Fuel consumption	l/100km	8	12	5,5	20	12	20	24	28	33
Emission standard	Euro	E4	E2	E3	E2	E2	E2	E2	E3	E3
CO_2 emission	g/km	186	280	128	528	317	528	634	739	871
Weight	t	1	1.7	0.3	18	2	5.5	12	24	40
Axles		2	2	2	2	2	2	3	5	5
Max. axle load	t	0.5	0.5	0.15	11.5	1.2	3	7	11.5	11.5
Length	m	3	4	1.5	12	5	6	8	13	18
CC	l	1.6	1.6	1.6	1.2	2.1	2.0	5.0	9.0	12.0
Engine power	HP	55	100	100	300	1,156,463	150	200	300	400
Engine power	KW	40	74	74	221	85	110	147	221	294
Fiscal HP		5.5	10.0	10.0	30.0	11.56	15.0	20.0	30.0	40.0
Age	a	4	6	4	6	8	7	6	5	4
Sales price	T€	12	25	18	35	20	20	30	40	50
Insurance premium	€/a									
PCE		1	1	0,5	2	1,5	2	2,5	3	3,5
ESAL		0.13	2.14	0.001	19275	2.48	120	2479	17872	27799
Driving parameters										
Performance	Tkm/a	12	16	5	20	20	30	50	80	120
Period of use	a	15	15	10	15	15	15	15	10	8

PCE = passenger car equivalents.
ESAL = equivalent standard axle loadings.

2.4.3 Vehicle kilometres

To properly estimate average and marginal infrastructure costs and revenues, a complete database of vehicle kilometres was established using the following parameters:

1 29 countries.
2 9 vehicle types.
3 + 3 (non-tolled and tolled) network categories.

The database for the year 2005 was established using the following sources:

- Vehicle kilometres and occupancy rates for all networks from Infras/IWW, 2004: Besides passenger cars, for which data on urban and non-urban roads was given, the database delivered vehicle kilometres for the entire networks for the year 2000 only.
- Development of transport demand from 2000 to 2005 for all 29 countries and broad vehicle classes from Mantzos and Capros, 2006. The data allowed to factor up the Infras/IWW vehicle kilometres to 2005 and to estimate vehicle kilometres for all other countries based on average occupancy rates.
- The distribution of vehicle kilometres to road classes was done on the basis of average assumptions about vehicle densities on each road type, based on German statistics and data provided by the UNITE accounts (UNITE, 2003).
- Traffic data on toll motorways and trunk roads was provided by ASECAP, 2006. A specific traffic density was assumed for other tolled and non-tolled roads.

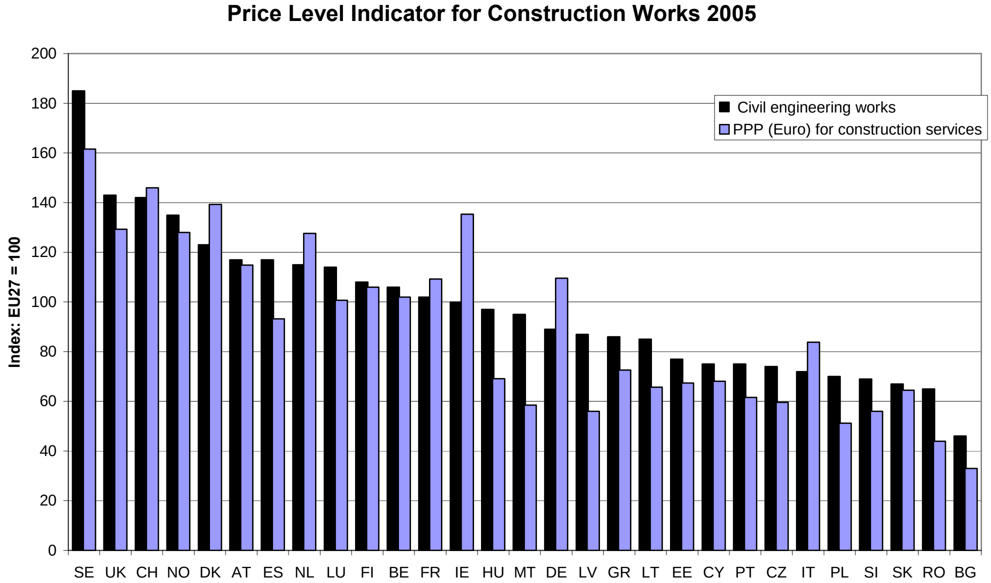
Detailed tables of the cost and revenue database are given in the annex to this report.

2.4.4 Socio-economic data

Data on price indices to factor up infrastructure unit costs to the year 2005 and purchasing power parities (PPP) to transfer costs across countries were taken from Eurostat, 2008. Prognos/IWW (2002) recommends using construction price indices to adjust infrastructure costs across years. But as Eurostat does not provide specific construction price indicators common consumption indicators on price inflation have been applied. In contrast, PPP values in Euro 2005 are available for construction services.

Eurostat (2007) provides price levels for construction works differentiated by private housing, public building and other civil engineering for 33 European countries in 2005. These values correlate rather well with the structure of the Purchasing Power Parities provided by Eurostat (2008) for construction services (Figure 3).

Figure 3 Eurostat values on price levels and PPPs in the construction sector 2005



Data source: Eurostat (2007), Table 2, Eurostat (2008): Purchasing Power Parities in Euro for Construction Services

2.5 Procedure for cost extrapolation

The estimation of infrastructure costs for all network categories and countries is carried out on the macro level. Data on infrastructure costs and cost drivers from existing studies is compiled in a database. Any gaps are then closed by considering similarities between countries and by regression analysis. In its practical application this approach holds a number of caveats and pitfalls:

1 Existing studies are rare and usually outdated.
2 They use different methodologies and scope.
3 They apply different systems of presenting results.

The worst problem was that many countries had no or only incomplete road infrastructure cost estimates. The following multi-stage approach was applied to make the best use of the existing information to arrive at a half-way realistic picture of total and average infrastructure costs across Europe.

1 Selection of data structures and methods for total costs.
2 Application of existing studies to the data structure.
3 Normalisation of basic data.
4 Regression of total infrastructure costs for all countries and road types 2005.
5 Structure of total costs according to cost categories for all countries.
6 Analysis, selection and application of cost allocation approaches.

In this way, figures on total and average costs by vehicle type and road class are obtained. These cost items are then compared to the fixed and variable taxes and charges in order to derive ratios of infrastructure cost coverage.
An alternative approach would be to conduct infrastructure cost calculations for current investment projects. Related information on project costs and construction parameters should be available for many countries in their national

infrastructure investment programmes. However, the level of infrastructure costs across entire networks is, among other factors, determined by the quality and age structure of the assets. Further, the resources of this study do not allow for an intensive search for piecewise construction information across Europe.

2.5.1 Data structures and methods for total cost estimation

Total infrastructure costs can be estimated using a range of methods.

1 Accounting based on expenses.
2 Accounting and capitalising historical investment and current running costs (PIM method).
3 Valuing the existing network using current reinvestment unit cost values plus current running costs (Synthetic Method).

'Expenses' and 'costs' denote two different values of a particular asset: While expenses only express the money paid in a particular period, costs denote the annual depreciation of the investment plus the hypothetical interest which an investor would have to pay if the investment were financed by a loan. In the case of private investors, the interest contains profit margins and a risk premium. Expenses are thus much higher than costs in the year of investment, but costs extend over the entire depreciation period of the asset. Their development over time depends on the depreciation method and the development of interest rates. Costs can also be determined by depreciating the real historical expenses or by depreciating today's hypothetical investment costs of a comparable asset of a contemporary technical standard.

A counter argument to a full economic accounting system often refers to the uselessness of fixed investment costs (sunk costs) for pricing purposes if the policy objective is to maximise the efficient use of infrastructures, e. g. by marginal social cost pricing. The history of existing assets is also irrelevant for decisions on future investments. Another argument frequently made against pricing infrastructure capital costs is that the tax payer has already financed the existing infrastructure .

However, in the long run, virtually all cost elements are variable. Due to long-term reinvestment cycles, capital costs are relevant for the strategic decisions of infrastructure managers and need to be financed either by user charges or by taxpayers' money. An illustrative example for the variability of 'sunk costs' in the current political discussion in Germany is the removal of underutilized railway tracks for cost efficiency purposes by DB-Netz AG. Corresponding examples for roads are the gradually emerging discussions about narrowing or even removing some of the fairly new road links in Eastern Germany as population density there continues to decline and economic growth lags far behind expectations, particularly in the border regions with Poland. Thus, within a sustainable transport policy, decision support systems also need to consider these 'sunk' elements when adapting the quality and capacity to long-term demand developments.

The Governmental Commission on Transport Infrastructure Financing (Paellmann, 2000) in Germany has proposed replacing the tax funding of infrastructure with user payments. The revenues of such a system should provide the money needed by the infrastructure manager to maintain the infrastructure network at a desired quality standard. It is thus not the historical, but the expected future costs of a network which should be covered by user charges. But, as advocated by Paellmann (2000), the introduction of financially motivated pricing systems should be accompanied by a reduction in existing tax burdens in order to avoid double pricing.

Simple accounts of expenses are not considered in this study because the contribution of public bodies and opportunity costs are neglected here. With regard to the PIM and the Synthetic Method, valuation of the existing infrastructure, e. g. the Synthetic Method, is preferable as this reflects the physically existing stock of assets and their true condition. Moreover, we see the Synthetic Method of infrastructure cost accounting as being much more in line with the philosophy of expected future costs than the Perpetual Inventory Method, which is based on historical expenses.

Directive 2006/38/EC, however, tends to prefer the historical accounting approach due to its higher level of juristic liability (Directive 2006/38/EC, Annex II), but the directive does not preclude the ‘Synthetic Method’. This method is applied by the German government and by the Austrian ASFINAG and implicitly it forms the accounting basis for all private road concessionaires.

Germany (UNITE, 2002; Prognos/IWW, 2002 and ProgTrans/IWW, 2007) and Austria (Herry, 2000) are the only cases where both approaches have been applied to the same network. Section 2.2.4 finds no impact of the methodology itself on the level of total capital costs based on the comparisons in Doll (2005) and Herry (2000) . But PIM applications tend to neglect investment backlogs, which need to be considered when estimating future network financing needs. Comparing Prognos/IWW (2002) and UNITE (2002) for Germany shows a respective downwards bias of 10%. This factor is applied to all historical accounting results, although we acknowledge that this might not be correct for countries with newly constructed or privately operated road networks. The difference in specific costs is thus caused by the inventory of assets and by the unit costs per type of asset.

Cost data were split into eight cost categories:

1 Capital costs due to the provision of new capacity.
2 Fixed capital costs due to maintenance.
3 Capital costs of maintenance activities varying with projected traffic volumes.
4 Capital costs of maintenance activities varying with projected axle loads.
5 Running repair and maintenance expenses.
6 Running costs of police and signalling.
7 Running costs of administration.
8 Running costs for charge collection.

2.5.2 Application of existing studies

Estimates of accounting costs were taken from the following sources where available:

1 Prognos/IWW, 2002 and 2007 delivered the synthetic accounts for German motorways and federal trunk roads.
2 UNITE, 2003 has historical accounts for 16 countries, where some data were available for the total network and some for different road classes.
3 Sansom et al., 2001 presents structural capital costs and maintenance data for the UK.
4 CE, 2004 provided network wide data for the Netherlands based on historical accounts.
5 Additional information about expenses and maintenance costs by road class was provided for Hungary.
6 The ASECAP provided total revenues from road charging as a basis for toll road cost estimates.
7 The project partner delivered current road expenditures for CEE countries (Poland and Hungary) to improve the cost model for these countries.

The original data were then normalised to the year 2005 by applying inflation rates for consumption and allocated to countries without available data using purchasing power parities for construction services. The accounting method was corrected by adding 10% to all but the Prognos/IWW data. The total cost figures were then normalised to €/road-km by dividing them by the length of the respective road network.

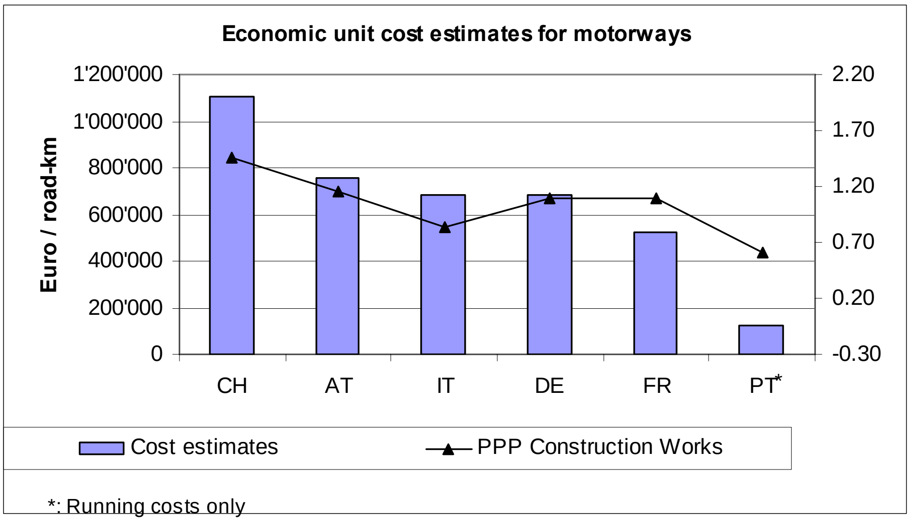
2.5.3 Regression analysis on unit infrastructure costs

The source data on infrastructure costs contains a lot of gaps. For a number of countries, in particular the new Member States besides Hungary, no road cost estimates were available at all and, for most other countries, data on trunk roads or local/urban streets was missing. Thus, a number of assumptions and regressions had to be applied in order to generate the complete database required by the scenario analyses in subsequent work packages of this study. Data situation, regression results and recommended transfer rules are described in turn for each road category.

Motorways: Capital cost estimates for motorways are available for Switzerland (BFS 2007), Germany (ProgTrans/IWW, 2007), Austria (Herry et al., 2002), Italy, France and Portugal (UNITE, 2002b, 2002c). The figures, which were normalised per road kilometre and updated to the year 2005, are more or less the same apart from the results for Portugal. The Portuguese road accounts from UNITE (2002c) only consider capital costs for all the road classes together; the motorway costs in Figure 4 reflect running costs only and are thus not considered further.

The unit figures per road kilometre range between € 0.52 billion for France and.€ 1.1 billion for Switzerland. The differences seem to be motivated by construction price levels and accounting philosophies, but might also be driven by the topography of the countries. However, there is no obvious reason why the Austrian values should diverge so much from the Swiss ones and the small sample does not permit a significant regression analysis on these variables.

Figure 4 Regression of motorway costs at Purchasing Power Parities (PPP) for construction works



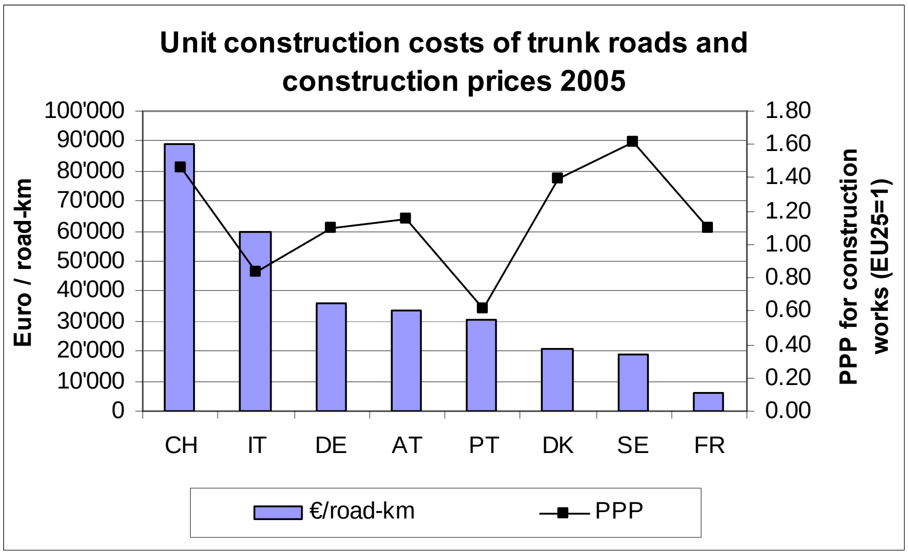
Data source: Own estimates based on UNITE, 2002; ProgTrans/IWW, 2007; BFS, 2007; Herry, 2002.

The comparison of kilometre-specific costs with the slope of PPP-adjusted construction price indicators looks more or less co-linear. Thus, missing values of motorway costs are derived from German unit costs (€ 683 million in 2005) by PPP adjustment.

Trunk and local roads: For other roads, the regression results are less clear; comparing the annual unit costs to purchasing power parity (PPP) for construction works as shown in Figure 5 for trunk roads and in Figure 6 for urban streets even indicates a negative correlation. Looking at the underlying country accounts from UNITE, 2002 this appears to be more a data problem than a real systematic coherence.

To take these findings into account, the sensitivity to changes in PPP values was reduced by 50% for roads other than motorways. This approach was applied to both capital costs and maintenance expenses.

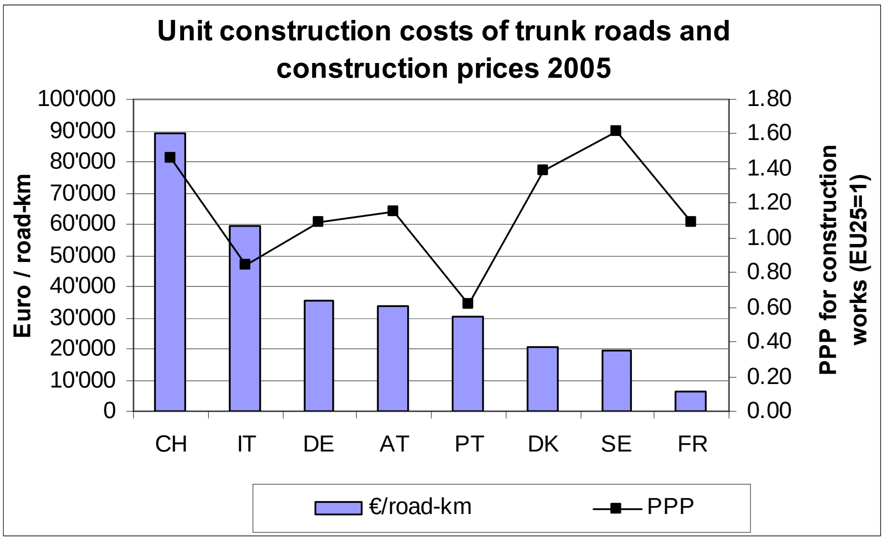
Figure 5 Regression of trunk road costs at Purchasing Power Parities (PPP) for construction works



Data source: Own estimates based on UNITE (2002), ProgTrans/IWW (2007), BFS (2003), Herry (2002).

On communal roads there is no apparent co-linearity between unit costs and the PPP indicator for construction services. Remarkably, the unit costs for Swiss communal roads ranges at the lower end of the scale. This indicates that the Swiss methodology shifts a higher proportion of common costs to higher road levels than other methodologies do (Figure 6).

Figure 6 Regression of local and urban road costs at Purchasing Power Parities (PPP) for construction works



Data source: Own estimates based on UNITE, 2002; ProgTrans/IWW, 2007; BFS, 2003; Herry, 2002.

The extrapolated unit costs were applied to those countries without their own cost accounts. National values were transformed into 2005 prices, but were otherwise left unchanged.

2.5.4 Cost allocation and average costs

The allocation of infrastructure costs to vehicle categories considers the specific characteristics of different cost elements. Two basic categories of total infrastructure costs are capital costs, i.e. depreciation and interest on investments lasting longer than one year, and running costs. Total costs broken down into capital and running costs are available for 14 of the 29 countries. The studies reviewed suggest a 61% share of capital costs in total costs; this figure varies slightly between road classes (Table 10).

Table 10 Share of capital costs by road class according to existing studies

Country		**Share of capital costs**			
Name	**Code**	**All roads**	**Motorways**	**Trunk roads**	**Urban roads**
Denmark	DK	52%	52%	52%	52%
Italy	IT	53%	53%	53%	53%
France	FR	53%	53%	62%	59%
Netherlands	NL	56%			
Portugal	PT	60%	60%	60%	60%
Austria	AT	82%	85%	70%	57%
Switzerland	CH	65%	88%	56%	45%
Germany	DE	75%	75%	77%	71%
Spain	ES	78%			
Greece	GR	85%			
Hungary	HU	94%			
Finland	FI	100%			
Ireland	IE	100%			
Sweden	SE	33%		33%	32%
Selected default		61%	64%	63%	62%

Source: Own estimates based on UNITE, 2002; ProgTrans/IWW, 2007; BFS, 2003; Herry, 2002.

Detailed cost categories for capital and maintenance costs were only available for a few countries. The variability and the causation of capital and running costs are shown in Table 11 and Table 12. Total costs were allocated to fixed and variable costs and to vehicle categories using either simple vehicle kilometres (VKM), passenger car equivalents (PCE), weighted or equivalent standard axle loadings (ESAL) and weighted vehicle kilometres.

– Unweighted vehicle kilometres are used to allocate common costs for which no specific causation or responsibility relationship can be identified.
– PCE denote the road space capacity demanded by different vehicle types in dense traffic relative to a passenger car. They take into account the vehicle's size, its usual and maximum travel speed and ability to accelerate. PCE weighted vehicle kilometres thus represent the road space foreseen for the respective vehicle class.

– The ESAL indicator describes the degree of road damages caused by different vehicle types following the 4th power rule. On the basis of extensive tests by the US AASHTO3, this rule states that road damages are proportional to the 3rd to 4th power of the vehicles' axle load (FHWA, 1997; Doll, 2005). ESAL weighted vehicle kilometres thus describe the share of road damages expected from the respective vehicle class.

The PCE and ESAL equivalency factors used are shown in Table 9 for the nine indicative vehicle classes considered in this study.

Four different types of investment measures were distinguished for allocating capital costs to vehicle classes:

– Investment in new road space: The cost driver for this measure is capacity demand, which is expressed by PCE weighted projected vehicle kilometres.
– Fixed maintenance operations: Replacement of assets because of their age, climate impacts, etc. There is no traffic impact and thus the rules of new investments are applied.
– Traffic load dependent routine maintenance: One example of this type of measure is the reestablishment of road surface quality. This affects all vehicles and thus costs are allocated by simple vehicle kilometres.
– Large repair measures: ESAL weighted vehicle kilometres are applied if the motivation behind replacement or major maintenance measures is to repair damages due to heavy traffic.

Table 10 shows the share of capital costs allocated to these four activity types by various studies and derives default values for studies providing no allocation rules.

Table 11 Structure of capital cost elements

Category		**New capacity**	**Replacement and large-scale renewal**		
Cost variability Causation/responsibility		Fixed PCE	Fixed PCE	Variable VKM	Variable ESAL
Switzerland	All roads	90%		5%	5%
Germany	Motorways	50%	23%	13%	14%
	Trunk roads	50%	26%	10%	14%
Selected default values		50%	40%	5%	5%

[3] AASHTO = American Association of State Highway and Transportation Officials.

Running costs denote all costs which are not capitalised, e. g. which extend no more than two years into the future. These include short term maintenance and repair measures as well as the costs for operating the road network. Four activity types are also identified for running costs:

- Repair and maintenance: Similar to the repair measure of capital costs, short term repair activities are fully allocated by SEAL-weighted vehicle kilometres.
- Traffic police and signalling costs depend on traffic volumes but not necessarily on the type of vehicle. Unweighted VKMs are thus applied to allocate costs to vehicle categories.
- Administration costs are also independent of vehicle types and are thus treated as above.
- Finally, the costs of the charging system are allocated to the affected vehicles. These are HGVs for Germany. As an approximation, ESAL weighted vehicle kilometres are used since these shift virtually all costs to HGVs.

Table 12 shows the differentiation of running costs as reported by several studies. The values suggest that 42% of running costs are due to repair and maintenance measures, 16% to police and traffic signalling and another 42% to public administration. Apart from Germany, the charge collection systems of toll motorways are contained in the administrative costs; for Germany, the system costs of Toll Collect were added separately to the running costs because of their high cost share.

Table 12 Structure of running cost elements

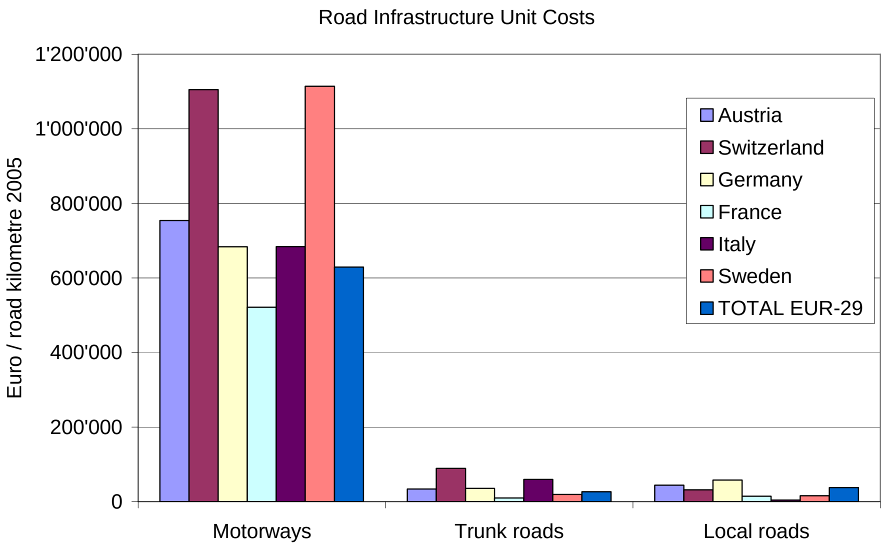
Category		**Repair/ maintenance**	**Police/ signalling**	**Administration**	**Charging system**
Cost variability Causation/responsibility		Variable ESAL	Fixed VKM	Fixed VKM	Fixed ESAL
All roads	Switzerland	42%	58%		
	Hungary	86%	15%		
	Netherlands	51%		49%	
Motorways	Germany	24%	24%	24%	28%
	Portugal	49%	5%	46%	
Trunk roads	Germany	34%	33%	33%	
	Portugal	40%	5%	55%	
Urban roads	Portugal	40%	1%	59%	
Selected default values		42%	16%	42%	0%

The above rules finally allowed total infrastructure costs, e.g. the costs of construction, operation, maintenance and development of the concerned infrastructure network to be allocated into fixed and variable elements. Fixed costs contain the capital costs of capacity-related construction works and all operating costs besides repair and maintenance. Variable costs (in the short- to medium term) comprise some replacement and repair investments and all small-scale repair and maintenance measures.

2.6 Results for unit costs per network kilometre

The resulting unit costs per road category and road kilometre for those countries with road class specific accounts are depicted in Figure 7. It is significant that motorway construction costs are roughly ten times higher than the costs of trunk or urban roads. The unit costs for Switzerland and Sweden are surprisingly high; these are caused by price levels, climate conditions and probably accounting philosophies and road maintenance standards.

Figure 7 Unit road infrastructure costs for 29 countries and three road types



Source: Own estimates based on UNITE, 2002; ProgTrans/IWW, 2007; BFS, 2007; Herry, 2002.

Due to the different methodologies and assumptions in the national studies, the unit costs indicate, but do not prove, the interdependency of infrastructure costs and topological and/or climate conditions. It can be assumed that construction in mountainous areas is more expensive than in flat regions due to the more frequent need for bridges and tunnels. Further, the frost preservation course accounts for a major share of road construction works. Its design, and thus its costs, depend on the number of days with a temperature below 0°C and it is therefore more significant in Scandinavian and mountainous areas than in Southern Europe.

Herry (2000) reports unit running costs for Austria per road kilometre by federal state in a five year average (1995 to 2000). After broadly classifying the ten federal states into ‘mountain’ and ‘flat’ states according to their topography, the ratio between running costs in the two topographical environments can be derived. The results in Table 13 for motorways meet the a priori expectations by showing 20% higher running costs in mountainous areas compared to flat regions. For express roads, the ratio is even roughly 3:1. But lower level roads show the surprising result that running costs in flat regions are higher than in mountainous ones.

Table 13 Running costs by federal state in Austria 2000

	Motorways	Express roads	Federal roads	State & community roads
	Million ATS 2000			
Mountain states				
Oberösterreich	3,348		373	153
Salzburg	2,381		426	156
Steiermark	2,267	1,310	312	138
Kärnten	1,776		336	130
Tirol	2,472	4,870	400	156
Vorarlberg	1,478	3,286	406	203
Average mountain	2,552	2,978	366	152
Flat states				
Wien	3,538		1,164	480
Niederösterreich	1,892	952	358	209
Burgenland	1,379	904	395	196
Average flat	2,128	931	491	253
TOTAL				
Average all states	2,304	1,688	380	177
Mountain/all states	111%	176%	96%	86%
Mountain/flat states	120%	320%	75%	60%

Source: Herry (2000).

A respective evaluation of maintenance cost data for Swiss motorways in 2001 arrives at similar ratios. The figures for mountainous areas are found to be 50% above the Swiss average by GRACE (2006) (Table 14).

Table 14 Maintenance costs per motorway kilometre by Canton in Switzerland, 2001

Canton	Maintenance costs in 1,000 CHF	Length in km	Costs per km in 1,000 CHF/km
Mountain cantons			
Wallis	31,428	101,8	309,00
Glarus	2,203	16,6	133,00
Graubünden	44,745	128,5	348,00
Nidwalden	17,686	23,8	743,00
Obwalden	4,308	32,1	134,00
Uri	81,227	67,5	1,203,00
Total mountain	181,597	370,0	490,80
Relatively flat cantons			
Argau	19,000	99,3	191,00
Basel-Land	18,804	30,2	599,00
Zürich	60,516	121,6	498,00
Thurgau	2,854	38,5	74,00
Total flat	100,454	290,0	347,00
TOTAL			
Swiss average mountain/Swiss average	537,728	1,638,0	3,281,49
Mountain/relatively flat			1,41
Mountain/Swiss average			1,49

Source: GRACE (2006).

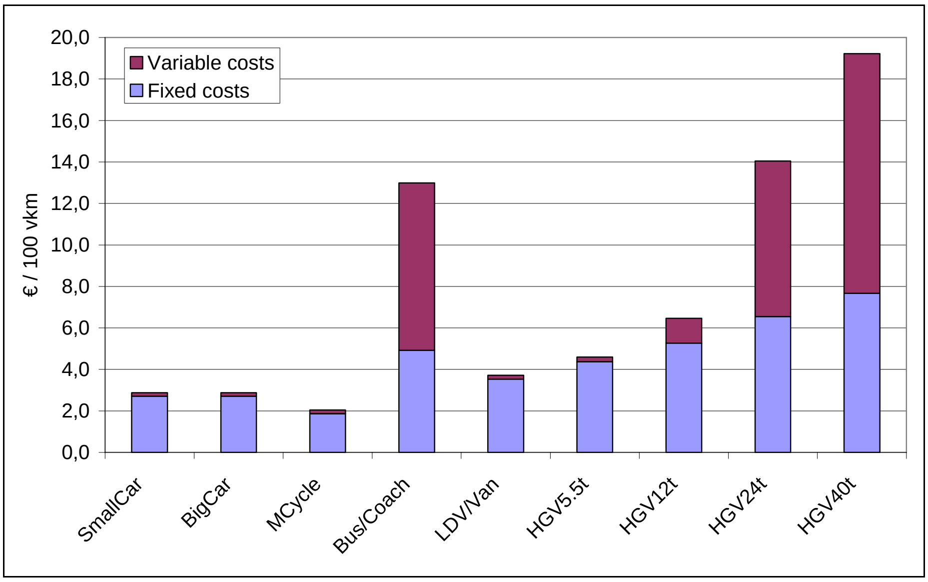
GRACE (2006) points out that the method is too simple to derive a clear statement on the relationship between running costs in different topographical environments. Even in mountainous regions, a considerable share of roads leads through flat environments, e.g. along valley bottoms. Thus, the above comparison tends to underestimate the real cost differences.

Information on investment and capital costs by region is not available. Respective information could be retrieved by surveying past and planned projects. Unfortunately, this was not possible within the time and resource framework of this project.

2.7 Average road Infrastructure cost accounts

Figure 8 shows the resulting average costs on motorways for all countries and Table 15 presents the country overview by road type for 2005 for those countries where information was available either on single road types or the network in total. The underlying data was retrieved from the UNITE country accounts (Nash, 2002), the German federal road accounts (Prognos/IWW, 2002) and Dutch data (CE, 2004). The regression analyses on these data had to bridge a vast amount of missing information (see section 2.5.3). The results presented in Figure 8 and Table 15 are thus to be considered with care as they do not necessarily correctly reflect prevailing national conditions. The figures are intended to provide input to the modelling work of the current project, in no way do they replace national accounts for setting cost related infrastructure charges.

Figure 8 Average fixed and variable costs by vehicle types on motorways, EUR-29 average



Source: Own estimates based on UNITE, 2002; ProgTrans/IWW, 2007; BFS, 2003; Herry, 2002.

Table 15 Average costs for HGVs >3.5 t by variability and road class for selected countries (€-ct/vkm)

COUNTRY		Total by variability			Total by road class		
		Total	Fixed	Variable	Motor-ways	Trunk roads	Local roads
Core countries with road-specific accounting information							
Austria	AT	14.23	3.34	10.90	20.57	7.96	12.62
Switzerland	CH	27.88	6.83	21.05	27.88	12.02	15.86
Germany	DE	11.31	4.46	6.85	18.60	9.59	9.01
France	FR	15.26	8.39	6.86	9.31	5.20	4.11
Italy	IT	13.48	5.93	7.54	11.09	6.92	4.18
Sweden	SE	45.56	30.10	15.47	25.81	18.58	7.23
Countries with accounting information for the entire road network only							
Belgium	BE	12.77	8.38	4.39	33.42	14.63	18.79
Denmark	DK	10.59	6.64	3.96	7.89	4.35	3.54
Spain	ES	10.82	4.60	6.22	10.30	5.03	5.27
Finland	FI	25.70	12.37	13.33	33.63	20.71	12.92
Greece	GR	10.72	4.91	5.81	20.16	10.63	9.54
Hungary	HU	10.98	3.84	7.14	65.22	29.90	35.32
Ireland	IE	24.23	14.72	9.51	65.75	24.61	41.14
Luxemburg	LU	33.54	20.20	13.34	71.82	34.34	37.48
Netherlands	NL	16.17	5.74	10.43	17.93	7.44	10.48
Un. Kingd.	UK	13.55	9.36	4.19	25.19	13.80	11.39
TOTAL EUR-29	0	12.33	5.66	6.67	22.35	12.54	9.81

Source: Own estimates based on UNITE, 2002; ProgTrans/IWW, 2007; BFS, 2003; Herry, 2002. Data extrapolated for BG, CY, CZ, EE, LT, LV, MT, NO, PL, RO, SI, SK.

In the introduction to this report we have stated that possible charging models for the Trans European Networks could consist of marginal infrastructure costs plus congestion costs. Fixed costs could in this case be used to either define a cap for congestion charges or to estimate the level of excess or deficit of total infrastructure costs. Information on the share of fixed costs at total infrastructure costs can thus be valuable for policy decision. Table 16 provides these figures for two classes of HGVs on inter-urban roads in selected countries and for the EUR-27 in total. While on motorways the share of fixed costs for all HGVs above 3.5t is roughly 60% across EUR-27 countries, it is below 50% for HGVs of 40t. For other trunk roads the share of fixed costs is considerably lower.

Table 16 Share of fixed infrastructure costs at average infrastructure costs for HGVs on motorways and trunk roads in selected countries

COUNTRY		Motorways		Other trunk roads	
		HGV >3.5t	HGV 40t	HGV >3.5t	HGV 40t
Austria	AT	79.9%	69.7%	65.4%	51,1%
Switzerland	CH	79.0%	68.4%	50.0%	35,0%
Germany	DE	64.0%	54.6%	47.1%	33,0%
France	FR	50.6%	35.4%	38.0%	24,9%
Italy	IT	61.4%	46.0%	20.2%	11,9%
Sweden	SE	39.5%	25.0%	24.1%	14,0%
Belgium	BE	39.6%	26.2%	20.6%	12,3%
Denmark	DK	42.9%	28.5%	25.9%	15,7%
Spain	ES	62.7%	47.9%	44.0%	29,8%
Finland	FI	57.3%	42.2%	40.0%	26,5%
Greece	GR	59.6%	44.6%	40.0%	26,5%
Hungary	HU	69.7%	55.9%	51.7%	36,7%
Ireland	IE	44.7%	30.4%	25.1%	15,3%
Luxemburg	LU	45.2%	30.9%	26.1%	16,0%
Netherlands	NL	69.3%	55.4%	54.8%	39,7%
Portugal	PT	59.9%	44.9%	47.6%	32,8%
Un. Kingd.	UK	35.9%	23.2%	19.2%	11,3%
TOTAL EUR-29		59,1%	45.3%	40.1%	26.6%

Detailed estimates for all vehicle types and extrapolations for all 29 countries are presented in the annex to this report.

3 Marginal road infrastructure costs for Europe

This chapter provides information on the marginal social costs of infrastructure use by road type and vehicle category. This information goes directly into the IMPACT scenarios to be presented and assessed in Deliverable 3 of this study. The term ‘marginal costs’ in this report refers to the additional costs to the infrastructure manager caused by an additional vehicle kilometre on the network. The term should not be confused with the marginal costs of capacity extension.

Inputs for the elaborations are the detailed estimates of total costs by country, road class and vehicle type presented in Chapter 2 Further, the structure of single cost elements elaborated in the preceding chapter provides valuable inputs for estimating marginal costs.

The scope of marginal social infrastructure costs is the entire life span of the assets in question. Long term marginal costs are considered, which reflect the implications of road use at multiple decision levels from road construction to quality standards, maintenance and repair activities.

3.1 Methodological issues and options

In the following, selected aspects of transport user pricing are presented and discussed in depth. The objective is to look at the various definitions of marginal costs discussed in economic literature. Different approaches are expected to impact the way marginal infrastructure cost based road user charges need to be estimated.

3.1.1 Scope and rationale of marginal infrastructure cost estimation excluding congestion

The general principles of the welfare theory suggest that pricing should be done according to marginal costs. However, when road users are to be charged for the marginal costs of infrastructure use, full cost recovery is not assured: Deficits or surpluses may arise, possibly leading to cross funding between regions. Hence, welfare theory suggests ‘second best’ pricing options, which describe deviations from marginal costs that lead to cost coverage while minimising the negative welfare effects. An example are Ramsey prices. It is clear from the above that such price schemes require information on marginal infrastructure use cost levels as well as on total costs.

According to Lindberg, 2006 and other publications, there is a close link between the marginal costs for constructing, maintaining, repairing, operating, servicing and administrating the infrastructure (briefly: marginal infrastructure costs) on the one hand and the costs of traffic congestion, scarcity and degrading quality (briefly: user costs) on the other hand.

The causality works in two directions:

1 Increasing user costs indicate the need for infrastructure investments or operational activities (e. g. traffic demand management).
2 Construction and maintenance activities may cause congestion around construction sites and omitted maintenance activities may force users to drive more slowly or cause safety problems.

In the following we will focus on construction-related marginal infrastructure use costs and their dependence on traffic demand, construction standards, geographical and environmental conditions. Congestion and scarcity effects are quantified in Deliverable 1 of this study, while Deliverable 3 integrates the two cost categories by elaborating on market-based traffic demand management strategies and policy options.

3.1.2 Short and long term marginal infrastructure construction costs

Increasing traffic levels cause maintenance and repair activities to grow under ceteris paribus conditions. In the long run, traffic levels even affect construction standards and infrastructure dimensions because stronger road layers usually require less frequent maintenance activities. And here the definition of which parts of road infrastructure construction and maintenance costs are 'marginal', i.e. are directly influenced by traffic volumes, starts to get tricky.

Road planning manuals contain well defined functions describing the thickness of layers and other dimension parameters of roads according to projected traffic volumes over the infrastructure lifetime. This implies that it is not only the short to medium term repair measures and replacement and service measures that need to be taken into account, but in principle the entire lifecycle cost of the asset and its variation with traffic demand. Consequently, there is a trade off between higher fixed costs up front which thus do not end up as marginal use costs, and maintenance costs throughout the life-cycle which are determined by the wear-and-tear of traffic and are thus part of marginal use costs. To capture these marginal effects of traffic on long term infrastructure costs, two types of models have been applied in recent studies: econometric models and the duration approach.

3.1.3 Option 1: Econometric models

In the econometric model, time or cross section data on total annual road costs or expenditures are analysed against data on traffic volumes accommodated by these road sections. There are variations in the coverage of activities (renewal, maintenance or operation), the definition of the explanatory variable (AADT, HGV movements or passenger car movements), the size of the network analysed (single links, maintenance delivery units) and the consideration of geographic and environmental variables.

The GRACE case studies for Sweden, Germany and Poland use a double log function to first explain the elasticity of total costs (C) with traffic volumes (Q).

Marginal costs are then computed by the product of the elasticity and average costs.

The practical realisation of the econometric approach causes some problems as explanatory variables, e. g. traffic volumes of different vehicle classes, show a very high co-linearity and can thus not deliver significant detailed results by vehicle type.

3.1.4 Option 2: The duration or engineering approach

An alternative to the econometric approach is to make use of engineering cost functions and maintenance models. To capture total lifecycle costs within a complete maintenance interval, the length of maintenance periods is estimated using data on traffic and infrastructure characteristics. Total cost elasticity or marginal costs then result from the impact of traffic volumes on the length of maintenance intervals and thus on the net present value of future maintenance costs.

3.2 Available studies and results

At a European level, two studies are available on the marginal costs of road infrastructure:

1 The GRACE project (Lindberg, 2006) applies the econometric approach to case studies in Sweden, Germany and Poland. Additionally the duration approach is applied to Swedish roads. The focus of the case studies is to explain the elasticity of total costs with varying traffic volumes, which is the ratio between average and marginal infrastructure costs. The case studies distinguish between renewal, renewal and maintenance, and maintenance/ operation costs.

2 The UNITE project (UNITE, 2002d) focussed on the direct measurement of marginal infrastructure costs in four case studies on Swedish, German, Swiss and Austrian roads. Although the methodology is in line with the econometric approach of the GRACE case studies, the UNITE cases focussed on some specific elements of road infrastructure costs, namely the resurfacing of pavements.

Further work has been carried out by Newberry, 1988a, 1990 and Ozbay et al., 2000 for the UK and Winston, 1988 and Small et al., 1989 for the US.

3.2.1 Results on total cost elasticities

Total cost elasticities describe the share of marginal costs in average infrastructure use costs. According to the GRACE case studies (Lindberg, 2006), they appear remarkably constant with respect to traffic densities. The results are presented in Table 17.

Table 17 Infrastructure cost elasticities according to the GRACE case studies

	β_1	β_{11}* lnQ	β_2* lnX	Mean Q	Elasticity	Output (Q)	Interaction term X
Renewal							
Germany R	0.15	0.38	-0.26	5002	**0.87**	HGV	Pass. cars[C)]
Poland R	0.57			8,592 (1,403)[A)]	**0.57**	AADT	No
Sweden R paved	4.95	-0.38		87,594 (158)[B)]	**0.72**	HGVkm in region	No
Sweden R gravel	0.68			718 (5)[B)]	**0.68**	HGVkm in region	No
Sweden duration model					**0.039**[DE]	HGV	No
Renewal and maintenance							
Sweden R+M	3.3	-0.24		88.313 (125) [B)]	**0.58**	HGVkm in region	No
Poland R+M	0.48			8,592 (1,403)[A)]	**0.48**	AADT	No
Maintenance/operation							
Poland M	0.12			8,592 (1,403)[A)]	**0.12**	AADT	No
Sweden O	0.147	-0.007		869,962 (1,232)[B)]	**(0.05)**	vkm in region	No
Sweden O winter	0.21	-0.0152		869,962 (1,232)[B)]	**(0.007)**	vkm in region	No
Sweden O paved	0.495	-0.034		859,463 (1,554)[B)]	**(0.03)**	vkm in region	No
Sweden O gravel	1.11	-0.136		10,498 (69)[B)]	**(-0.09)**	vkm in region	No

Note: DE = Deterioration elasticity. R = renewal; M = (short term) maintenance; O = Operation; Q = traffic volume; HGV = heavy goods vehicle; AADT = average annual daily traffic; X = statistical error term.

A) Average HGV traffic.

B) Output measure expressed per km road.

C) Mean volume 26632.

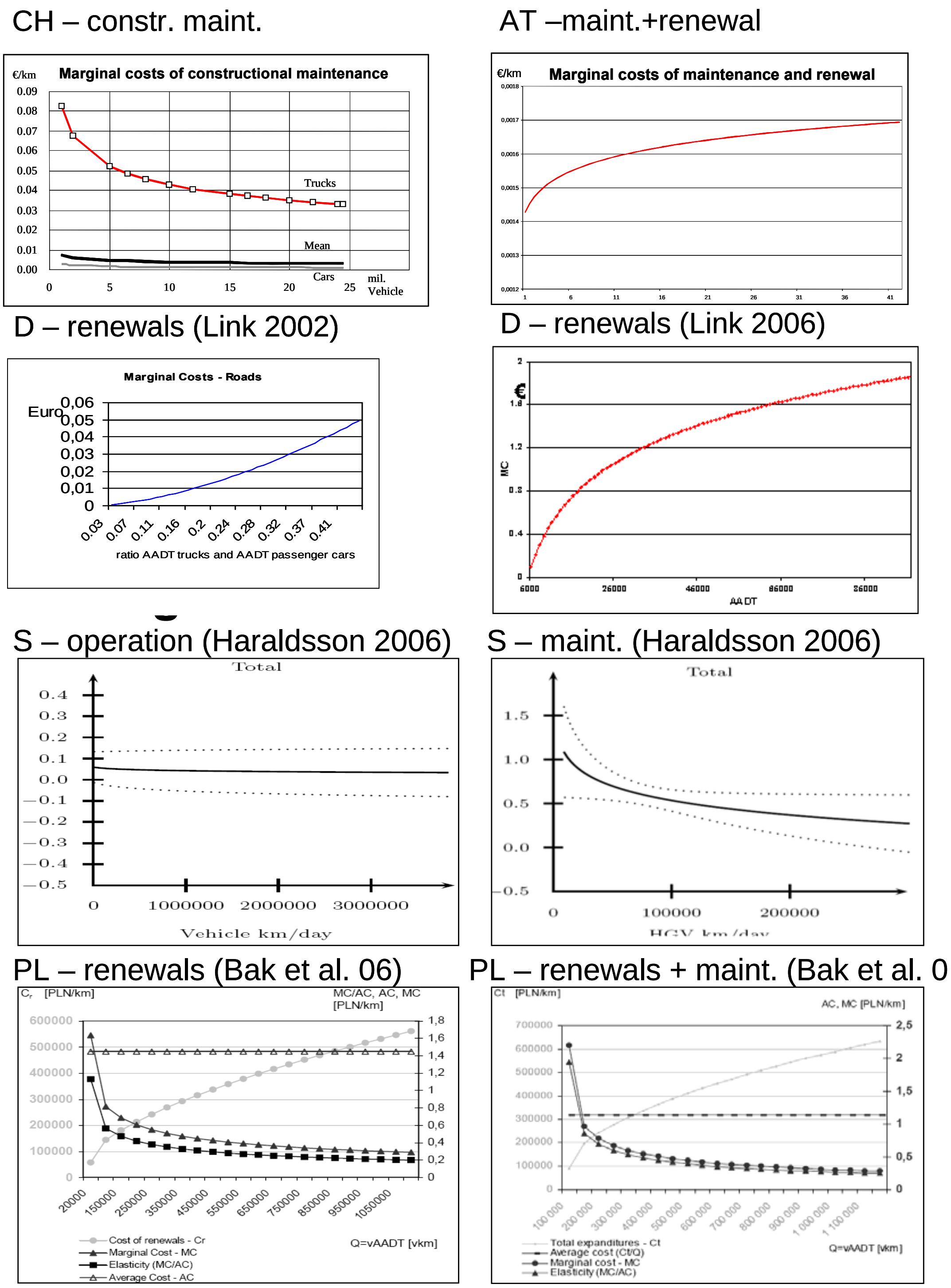
(In parenthesis)= non significant estimates.

Source: Lindberg (2006).

Along with several other model parameters, Table 17 presents the average elasticities of marginal infrastructure use costs related to the respective average costs of the same category (maintenance, renewal (investments) and operation). These elasticities at average traffic volumes were taken from a series of case studies performed in the GRACE project (Lindberg 2006), which aimed to deliver marginal cost and elasticity functions with respect to traffic volumes, the age of infrastructures and external impacts (climate).

Figure 9 presents a number of empirically derived graphs from Lindberg (2006), UNITE (2002d) and other studies based on econometric analyses. Link (2007) also refers to two engineering-based studies for Sweden. While UNITE (2002d) arrives at an increasing marginal cost function, Lindberg (2006) finds the MC function to decrease with traffic volume when the age of the infrastructure and climate impacts are taken into consideration.

Figure 9 Marginal infrastructure use cost functions from various econometric studies



Source: Link (2007).

The results of Lindberg (2006) and Link (2007) lead to the following conclusions:

1 Renewal costs show the highest elasticity values, followed by the combination of renewal and maintenance expenditures.
2 Operation costs in Sweden show no significant relation to traffic volumes; the marginal costs are thus (close to) zero.
3 Given the strong co-linearity of traffic variables there is no significant difference between vehicle classes, but elasticities are more or less constant with regard to differences in traffic loads.
4 Most case studies show a decreasing slope with traffic density. However, the degree of nonlinearity is weak in all case studies which gives rise to the conclusion that marginal use costs (MC) = average variable costs (VC).
5 The marginal infrastructure use cost curves show diverging results: While most case studies find decreasing marginal costs with traffic density, increasing curves have been found for Germany, Austria and Sweden.
6 The German case study suggests that there are significant economies of scale concerning the size of the maintenance delivery unit tendered.

3.2.2 Average and marginal costs

A comparison with studies from North America and Australia confirms the result of the GRACE case studies that the share of marginal costs in average costs is higher for rehabilitation (renewal) activities than for routine maintenance. The studies further show that marginal costs depend strongly on the construction standard (width and layer thickness) of roads. Other international experience confirms the GRACE observation that marginal costs decrease with traffic density.

Table 18 shows the share of road infrastructure expenses which is directly attributable to traffic loads according to different US studies. The values range between 50% and 80%; flexible pavements seem to be much more resistant to the influences of heavy axles than rigid surfaces. According to Lindberg, 2006 these shares can be benchmarked against the elasticities found in the GRACE project.

Table 18 Share of traffic-dependent infrastructure costs in US studies

Study	Year	Flexible	JCP	CRC	Composite
Rehabilitation					
Li et al. (2001)	1995-1997	0.28	0.78		0.38
Indiana HCAS	1984	0.42	0.78		0.38
ARRB Study (AU)		0.88	0.88		0.88
Federal HCAS	1997	0.84-0.89	0.78-0.86		0.84-0.89
Routine maintenance					
Li et al. (2002)	1995-1997	0.257	0.357	0.632	0.28
Indiana HSC	1984	0.21	0.54	1.00	0.29
Ontario study	1990	0.25-0.33			

Note: HCAS = Highway Cost Allocation Study; JCP=joint concrete pavement, CRC=continuously reinforced concrete and Composite; AU = Australia.

Source: Lindberg, 2006.

The results of UNITE, GRACE and selected international studies on marginal and - as far as available - average costs are presented in Table 19.

Table 19 Average and marginal cost estimates of different studies

Study	Area	Vehicle type	Average costs (€/vkm)	Marginal costs (€/vkm) *
GRACE (Lindberg 2006)	Germany R	HGV	1.580	1.390
	Poland R	All vehicles	0.210	0.120
	Sweden R paved	HGV	0.036	0.032
	Sweden R gravel	HGV	0.415	0.236
	Sweden R duration model	HGV	-	0.0013
	Sweden R+M	HGV	0.059	0.040
	Poland R+M	All vehicles	0.270	0.130
	Sweden O	All vehicles	0.024	(0.002)
	Sweden O winter	All vehicles	0.015	(0.001)
	Sweden O paved	All vehicles	0.003	(0.001)
	Sweden O gravel	All vehicles	0.066	(0.010)
UNITE (Link 2002)	Austria M+R	HGV		0.0217
	Sweden resurfacing	All vehicles		0.0077-0.0186
	Germany, R	HGV		0.0005-0.0270
	Switzerland, M+R+U	HGV		0.0362-0.0517
Hajek et al. (1993)	Ontario (R) Urban Freeway Major Arterial Minor Arterial Collector Local	HGV (CA$)		 0.002 0.007 0.012 0.031 0.461
Newbery (1988a)	Tunisia, resurfacing	ESAL (US$)		0.13-2.58
Newbery (1990)	Northern Yersey, resurfacing	ESAL (GBP)		0.00035
Ozbay et al. (2000)	Northern Yersey, resurfacing	All vehicles (US$/mile)		0.062
Small and Winston (1988)	US Highways, Resurfacing	ESAL (US$/mile)		0.022-0.023
Small et al. (1989)	US rural/urban freeways, resurfacing	ESAL (US$/mile)		0.0148-0.0432

Symbols: R = Renewal, M = Maintenance, U = Upgrade, O = Operation.
Source: Data from Lindberg, 2006.
* Unit of GRACE values not clear; a query was sent to the project team.

Due to missing data in the source studies, it was not possible to express the marginal costs in more comparable units, e.g. per ton, ESAL or PCE weighted vehicle kilometres. Related tests with more detailed vehicle classes in Lindberg (2006) showed little significance of the regression results as the vehicle related variables then have a high degree of co-linearity.

3.3 Value transfer procedure

The absolute values of marginal infrastructure costs presented in Table 19 are difficult to compare as the units differ and the type of costs included is unclear in some cases. The ratios between marginal and average costs derived by the GRACE case studies (see Table 20) appear more helpful when transferring marginal infrastructure use costs to different countries. However, given the small sample size, the degree of uncertainty still remains high.

Table 20 Ratio between marginal and average costs: Results of GRACE case studies

Country	Vehicle type	Renewal	Maintenance + renewal	Maintenance	Operation
Germany	HGV	89%			
Sweden	HGV	88%	68%		
	All				<1%
Poland	All	57%	48%	12%	

Table 10 to Table 12 set the structure of total (or average) costs with respect to activities (investment, maintenance, operation) and variability against changing traffic volumes for a default road section. This categorisation allows the marginal infrastructure cost elasticities from Table 20 to be applied in order to gain an impression of the share of marginal costs in total and average costs. It also allows a comparison of the structure and level of marginal costs to variable average costs.

This comparison, however, has a number of shortcomings. First, the elasticities are considered to be constant across varying levels of traffic density. This is in real life most probably not the case, but the GRACE results do not give a clear indication of whether they will increase or fall. Second, the regressions in the GRACE case studies are not always done with all vehicles; a number of case studies consider HGVs only. But as the computation of weighted average costs already consider basic vehicle characteristics and their expected impact on renewal and maintenance costs, the error should be acceptable.

Table 21 presents the structure of average costs and derives several figures for marginal costs of infrastructure use for a default motorway segment. In this case the share of variable average costs in total (= fixed plus variable) average costs is 22%. Applying the range of 57% to 87% to renewal costs and 48% to 58% to renewal plus maintenance costs leads to a range of 18% to 27%. Relating marginal costs to maintenance activities only leads to a cost share of 2%. Finally, due to non-significant values, we have disregarded the variant relating marginal costs to operation activities.

The marginal cost model based on maintenance and renewal costs shows a good match with the cost structure for determining variable average costs. The resulting share of variable average costs is very close to the lower bound (23% of total costs) of the range of cost shares spanned by GRACE case studies for Sweden and Poland (Lindberg 2006, Table 17 and Table 20).

Table 21 Share of average costs for different MC elasticities

Cost component	Average costs		Marginal costs				
	Total	Variable	Renewal		Renewal + maintenance		Maintenance
			87%	57%	58%	48%	12%
Capital costs	63%						
- Capacity	31%						
- Renewal fixed	25%		22%	14%	15%	12%	
- Renewal vkm	3%	3%	3%	2%	2%	2%	
- Renewal ESAL	3%	3%	3%	2%	2%	2%	
Running costs	37%						
- Maintenance fixed	16%	16%			9%	7%	2%
- Pol.+Sign.	6%						
- Admin.+Oper.	16%						
Total costs	100%	22%	27%	18%	27%	23%	2%

Source: Own estimates based on Lindberg (2006) results.

Based on these observations we follow Link (2007) and recommend variable average infrastructure costs as a proxy for the medium-term marginal costs of infrastructure use. These are - across all vehicle categories and for motorways only - 22% of average infrastructure costs. This ratio might be different for individual vehicle types and other roads. Across all 29 countries considered and for all road classes, the share of variable costs to total infrastructure costs is 26%. The progression of average fixed and variable, i.e. marginal, costs with vehicle types is depicted in Figure 8. Table 22 shows a collection of marginal costs values for the six countries providing specific road class data, for motorways and trunk roads and for the four types of heavy goods vehicles. Here very high values appear for Sweden, where high price-level and climate-driven construction costs in combination with low traffic densities lead to extremely high average costs per vehicle kilometre. In contrast, classical transit countries like Germany and Austria with high traffic volumes show rather low average costs, and thus also low marginal costs per lorry kilometre.

Table 22 Indicative marginal cost values for HGVs on motorways in selected countries

Country	HGV on motorways				HGV on other trunk roads			
	5.5t	12t	24t	40t	5.5t	12t	24t	40t
	€/100 vkm				€/100 vkm			
AT	0.28	0.73	3.67	5.57	0.18	0.83	5.06	7.79
CH	0.51	1.44	7.53	11.45	0.30	2.29	15.27	23.64
DE	0.40	1.00	4.91	7.44	0.41	1.86	11.28	17.36
FR	0.20	1.41	9.30	14.40	0.09	0.91	6.26	9.71
IT	0.20	1.05	6.57	10.13	0.41	5.99	42.43	65.92
SE	0.46	4.84	33.38	51.79	0.22	3.14	22.23	34.53
EUR-27	0.24	1.04	6.26	9.63	0.24	2.02	13.62	21.10

Source: Own estimation.

Comparing vehicle classes shows a very sharp progression of average variable (marginal) costs with vehicle weight. The cost level of a 40t HGV is roughly 20 times the marginal infrastructure costs of a 5.5t lorry. Marginal costs on trunk roads are in most cases higher than marginal costs on motorways due to the lower traffic volumes on secondary roads. However, this does not hold for France, where traffic densities on national routes are high compared with motorway traffic.

These medium-term marginal costs consider all costs, including major replacement measures, except for the initial investment in a facility. In the long run, however, these costs are essential to maintain performance of the total system, which comprises the physical network and user quality. The current maintenance related marginal cost values are applied by infrastructure managers who aim to maintain the quality of the physical system but ignore user time costs. In this case, user effects and budget considerations will be addressed by some type of congestion or average cost pricing.

Indicative figures on the marginal costs of road infrastructure use for all 29 countries, three road classes and nine vehicle types are given in the annex to this report. These values have been given to the TRANS-TOOLS and TREMOVE traffic models for computing the IMPACT internalisation scenarios to be presented in Deliverable 3 of this study. For individual countries, the values in the annex may deviate from the figures presented in the main text; the tables were deliberately not updated in order to document data exchange within the study.

To conclude: the GRACE project has taken an important step forward in seeking explanations for the variations in the marginal costs of road infrastructure use. But the transfer of marginal cost estimates between regions still remains difficult and vague for several reasons: the complexity of the matter, the low statistical significance between the causes for infrastructure design and maintenance activities and the different assumptions behind the GRACE case studies. Thus, further research is needed on the generalisation of cost figures.

4 Road revenue accounts

The objective of this section is to give an overview of all taxes and charges which are related to the ownership and the use of road vehicles and the use of road infrastructures. These range from taxes on the purchase of vehicles, through registration and insurance taxes to infrastructure user charges. The values are derived for all 29 countries using appropriate statistics based on unit values. Total tax revenues are generated with the help of vehicle stock and performance statistics. Therefore, total cost figures might diverge from national statistics. However, capturing the structure of the various national tax systems with regard to vehicle characteristics was considered to be more important than total revenue figures.

Purely consumption related taxes, such as value added tax (VAT), were excluded. For fuel tax, different alternatives of earmarking revenue for the transport sector were analysed as, in principle, taxes are defined as making a general contribution to public budgets without receiving a guaranteed service in return. Therefore, a variant of considering only 50% of fuel taxes was contrasted with the main scenario of balancing total infrastructure costs with 100% of fuel taxes.

This holds for the revenue side as well as for infrastructure costs. The following figures reflect the taxation and charging situation of the year 2005. More recent changes, e.g. the introduction of the Czech motorway toll and the Stockholm congestion charge, were not considered.

4.1 Earmarked tax revenues

A specific issue when talking about taxes is to what extent they are earmarked for transport infrastructure. In the first instance, taxes are raised to finance the expenditures of the public sector in general. From the perspective of efficient taxation, specific product taxes may be justified if the price elasticity of such products is relatively low and the distortion of the tax is relatively modest compared to similar levies on more price-sensitive products. These taxes are not necessarily intended to be reinvested in the sector where they have been raised.

Another purpose of non-earmarked taxes is to cover external costs. Some of the IMPACT scenarios assume a level of 7 to 10 cents per litre for the internalisation of climate change costs. This share of fuel tax revenues is not used to finance transport infrastructure and is thus part of the non-earmarked tax share.

Examples of earmarked taxes from Germany are the increases in the fuel tax to help finance German reunification and the first Gulf War and the increases in tobacco taxes used to finance anti-terrorist measures. No doubt there are similar examples from other countries. On the other hand, some countries have legally determined a share of mineral oil taxes to be spent on road transport. In Switzerland this is 50%, while Germany earmarks between 25% and 45%.

The discussion about earmarking transport revenues is important for equity issues. Non-earmarked parts of revenues should not be included when comparing revenues with costs because these should contribute to the overall funding of the state just like other sectors, too. This is particularly valid if transport costs do not consider the associated costs of the public administration. Estimates of administrative costs for Germany range from 15% of total infrastructure costs (ProgTrans/IWW, 2007) to 56% of investment expenditures (Wirtschaftsrat, 2007).

These administrative costs were considered in the database on European road infrastructure costs (Chapter 2) to a moderate extent (15%) according to ProgTrans/IWW (2007). Therefore, only a maximum of 50% of fuel taxes should be used to derive cost coverage figures. The share increases according to the level of administrative costs considered as the empirical evidence for assuming 50% of fuel taxes are spent on general purposes ignores the high share of public administration involved in operating road networks (Wirtschaftsrat 2007). The same holds for insurance and annual registration taxes. All other revenue categories are more directly linked to transport costs and may thus be considered to be 100%. In order to express the uncertainty in the discussion on the cost coverage figures, we present two scenarios: 50% and 100% consideration of fuel, insurance and annual vehicle circulation taxes.

The level of earmarking to the transport sector does not play a role in efficiency considerations related to internalisation which are in the foreground of the IMPACT analysis and the related scenario development. Here, the use of revenues is not considered as only the level of charges influencing user behaviour is important. It is precisely because of the incentives to avoid the external costs that the revenues of these internalising charges should not be earmarked for reimbursing those responsible for the externality nor for compensating those affected. Such compensation may be justified from an equity perspective however. The internalisation purpose does not determine whether revenues should go into the general government budget or be used to finance transport infrastructure.

To conclude: balancing public infrastructure investment taxes on the one hand and taxes and charges on infrastructure on the other can be construed in three equally valid ways:

1. The perspective of the government budget: Is the transport sector a net contributor to the public sector (complication whether VAT should be included or not) in the same way as all the other private sectors?
2. The user pays principle: do transport consumers as a group pay for their use of transport infrastructure?
3. Efficiency: Are changes in the external costs caused by road users reflected in changes in taxes and charges?

Arguably, the first and third balances include all taxes and charges on transport uses, whereas the second only covers those earmarked for transport infrastructure. The problems, of course, are the extent of the overlap between the group of general tax payers and that of infrastructure users, the high share of hidden administrative costs, and the extent that non-earmarked revenues of transport infrastructure taxes and charges are routinely used to finance infrastructure.

4.2 The revenue accounting framework

4.2.1 Revenue categories

Taxes and charges were divided into five categories:

1 Vehicle acquisition taxes. They constitute a certain share of the vehicle sales price and are thus invariant to the number of vehicle kilometres travelled.
2 Vehicle registration, circulation or ownership tax: This is usually a fixed amount to be paid each year by the vehicle holder and is also fixed with respect to the distance travelled.
3 Insurance tax: This is usually a fixed amount on an insurance premium.
4 Fuel tax is a classical, variable tax collected by levying a fixed surcharge on each litre of petrol or diesel.
5 Vignettes are annually paid road user charges and thus are also considered to be fixed. They vary by road class and vehicle type. Where different payment periods are possible, annual vignette charges were selected.
6 Tolls constitute variable fees which depend on road class and vehicle type. In contrast to (vignette) charges, they are levied on the basis of the distance driven.

Information on current taxes and charges is required in order to make sound statements on the degree of internalisation of infrastructure and external costs. By definition, taxes are a means to fund the general state budget (principle: all revenues cover all state expenses). The specific contribution of road users to cover road infrastructure costs thus only equals that part of road user revenues directly devoted (earmarked) to funding road infrastructure costs by law. The degree of earmarking varies considerably by revenue category and country. The budget of the current study did not allow the - partly very complex - legal arrangements in each of the 29 countries considered to be checked. Thus, following Infras/IWW, 2004b, constant shares of earmarking were considered across all 29 countries. The assumptions made are presented in Table 23.

Table 23 Assumptions on variability and earmarking by revenue category

Tax/charge	Unit	Variability	Degree of earmarking
Tax on acquisition	€/veh.	Fixed	50%
Circulation tax	€/veh.,a	Fixed	50%
Insurance tax	€/veh.,a	Fixed	100%
Fuel excise duty	€/l	Variable	50%
Vignettes	€/veh.,a	Fixed	100%
Kilometre tolls	€/km	Variable	100%

The term 'fixed' with respect to pricing revenues refers to short-term changes in traffic volumes. In this sense, only revenues from fuel taxes and distance or trip based road user charges react directly to demand fluctuations. Depending on their structure, these forms of pricing are, in principle, appropriate for internalising marginal social external costs. In contrast, annual charges (vignettes, vehicle taxes, insurance premiums, etc.) can only react in the medium to long term and are thus less suitable for external cost internalisation.

For the compilation of taxes and charges, the same categories of vehicle, road types and countries were applied as for the estimation of infrastructure costs. For reasons of transparency, total revenues do not distinguish between earmarked and non-earmarked shares. Cost coverage ratios, however, are presented for total and earmarked revenues. For calculating internalisation charges, it is recommended to take the earmarked share of user revenues into account.

4.2.2 Data sources

Purchase, acquisition, insurance and fuel tax rates were taken from ACEA, 2006 and crosschecked with information provided by DG TAXUD's Excise Duty Tables (EC, 2007b). Purchase prices, cylinder capacities, horse powers, etc. per vehicle were retrieved from Internet surveys. Road user charges for passenger cars in the EU were also taken from Internet sources (KFZ-Auskunft, 2007). HGV charges were available from BGL, 2007.

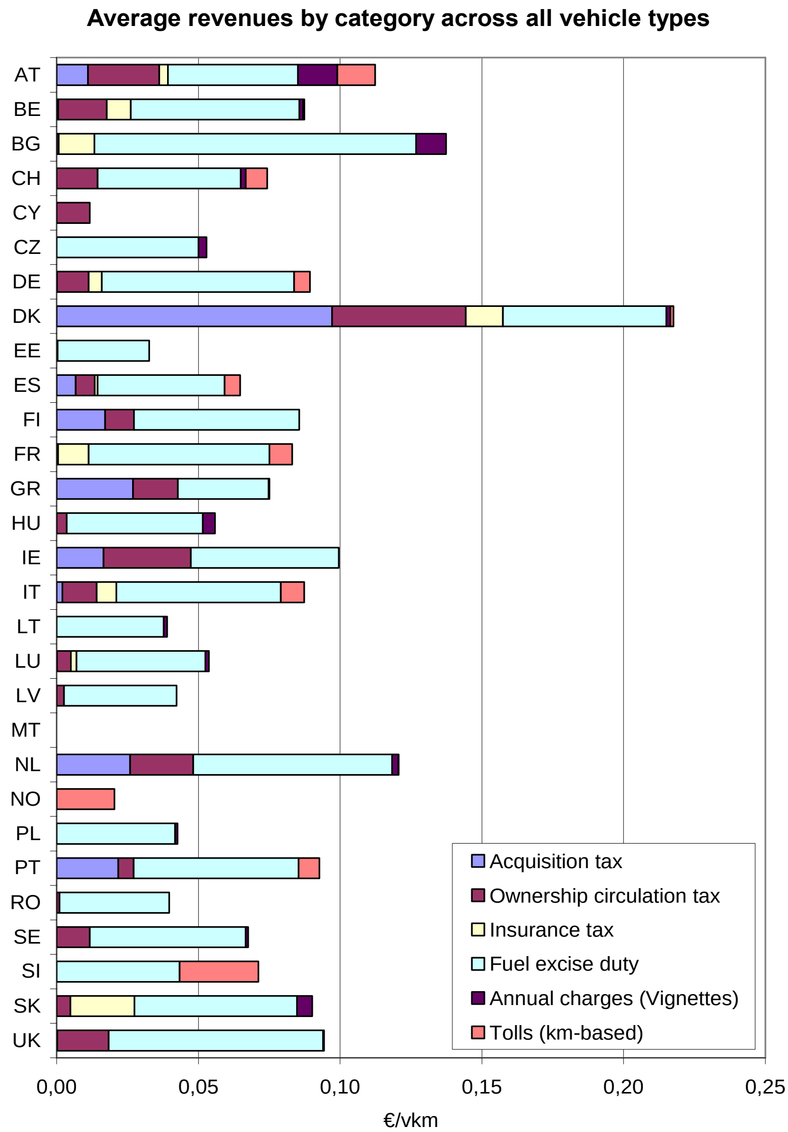
The most recent data were taken wherever possible. This was 2005 for tax information, but historical records were not available for some taxes and charges for specific countries for this year. 2006/2007 data were then derived from the above mentioned sources. Insofar there is a small discrepancy between infrastructure cost estimates and information on the respective charges.

4.3 Average road transport-related revenues for Europe

Answering the question on the extent to which current infrastructure costs are external calls for information on current user payments. Here, the consideration of average costs is sufficient. As the vehicle classes used in this study are indicative and the resulting total cost extrapolation might differ from official national statistical values, the presentation of total tax and charge revenues is omitted here. The annex to this report, however, does provide respective indicative information.

The tax and charge database contains information on average fixed and variable charges as well as on total revenues by country, road class, revenue category and vehicle type. Figure 10 depicts the structure and the level of the average taxes and charges paid by road users per vehicle kilometre by country and revenue category across all vehicle types and road classes in 2005. Fixed taxes and charges were converted into variable ones by dividing the total figures by vehicle kilometres. The high acquisition taxes in Denmark, the road tolls in Norway and the insurance taxes in Slovakia are particularly striking. In most other countries, including Switzerland and Austria with their high road user charges, fuel taxes constitute the biggest share of tax and charge income. Remarkably Denmark, followed by Bulgaria, shows the highest average charges across all vehicles and road categories.

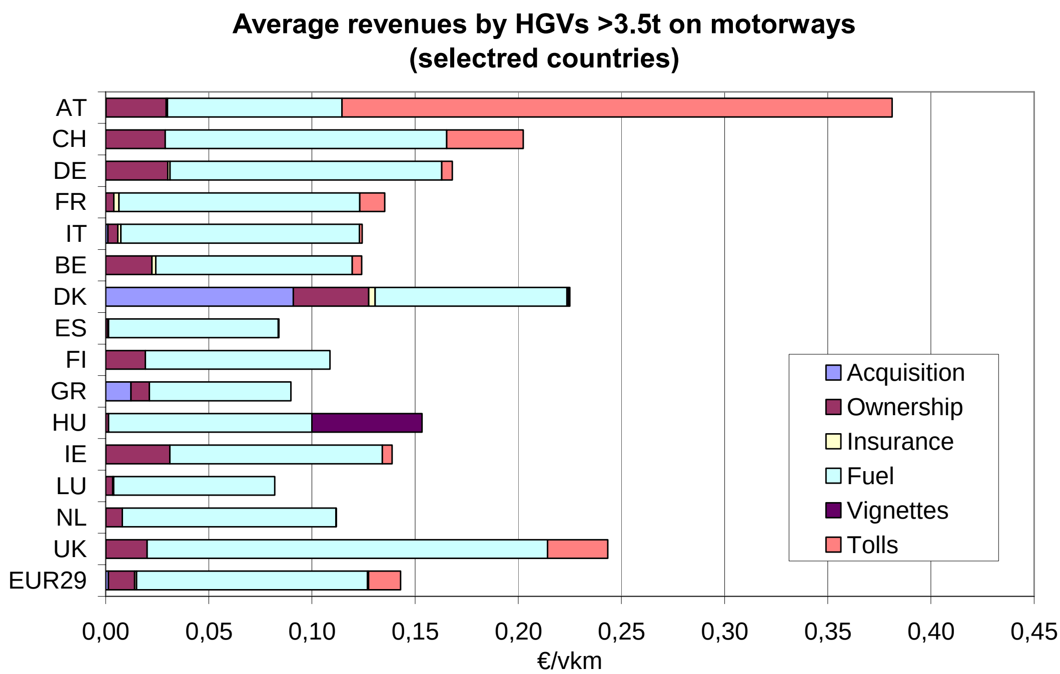
Figure 10 Structure of taxes and charges by country



Remark: Cost data from model output; extrapolated for BG, CY, CZ, EE, LT, LV, MT, NO, PL, RO, SI, SK. Revenue data based on ACEA, 2006 and BGL, 2007.

Figure 11 shows specific average revenues per vehicle kilometre by type of tax and charge for HGVs above 3.5t gross vehicle weights on motorways for those countries where road cost information was available. The values show weighted averages across all HGVs within the range 3.5t to 40t and across tolled and non-tolled motorways (in case both are present in a specific country). The very different results for Austria and Switzerland concerning road tolls is remarkable, but can be explained as the Swiss Heavy Traffic Fee shows a strong progression with vehicle weight while the Austrian motorway charge remains relatively flat in this respect.

Figure 11 Structure of taxes and charges by country



For a direct comparison with average road infrastructure costs (Table 15) or marginal infrastructure use costs (Table 22), the subsequent Table 24 presents average variable revenues for HGVs by weight class for selected countries. The revenue figures are given for motorways and other trunk roads and reflect a weighted national average between tolled and non-tolled roads.

Table 24 Variable taxes and charges of HGVs on motorways in selected countries 2005

Country	Motorways				Other trunk roads			
	5.5t	12t	24t	40t	5.5t	12t	24t	40t
	€-ct/vkm				€-ct/vkm			
	Countries with detailed accounts by road class							
AT	21.26	28.51	40.45	41.96	6.04	7.25	8.46	9.97
CH	16.84	27.17	44.60	67.68	11.24	13.69	14.94	17.38
DE	17.41	23.29	26.17	28.52	9.41	11.29	13.17	15.52
FR	21.49	23.16	29.21	31.30	8.34	10.01	11.67	13.76
IT	12.73	16.56	21.99	24.05	8.26	9.91	11.56	13.63
SE	7.74	9.29	10.83	12.77	7.74	9.29	10.83	12.77
	Countries with single accounts for all road classes only							
BE	7.91	9.27	10.63	12.33	6.80	8.16	9.52	11.22
DK	8.10	10.85	13.84	15.50	6.65	7.98	9.31	10.97
ES	7.30	8.48	9.98	11.45		7.05	8.23	9.70
FI	6.39	7.67	8.94	10.54	6.39	7.67	8.94	10.54
GR	5.40	6.38	7.49	8.72	4.90	5.88	6.86	8.09
HU	7.04	8.44	9.85	11.61	7.04	8.44	9.85	11.61
IE	7.46	8.93	10.43	12.27	7.36	8.83	10.30	12.14
LU	5.58	6.70	7.81	9.21	5.58	6.70	7.81	9.21
NL	7.41	8.93	10.56	12.41	7.40	8.88	10.36	12.21
UK	14.14	16.91	19.69	23.15	13.86	16.63	19.40	22.87
EUR-29	7.91	9.27	10.63	12.33	6.80	8.16	9.52	11.22

Source: Own compilation.

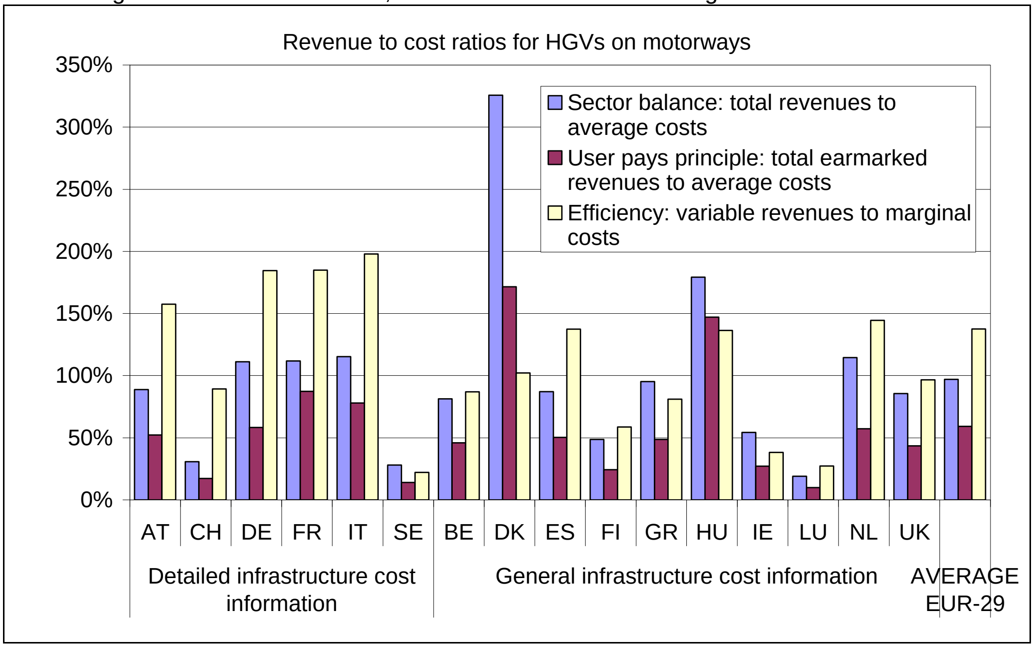
4.4 Revenue to cost ratios

The analysis of revenues to costs adheres to the three perspectives of cost coverage introduced in section 4.1:

1. Net transport sector contribution to the total state budget = total (non-earmarked and earmarked fixed and variable) revenues to total (fixed and variable) costs.
2. User pays principle: Total (variable and fixed) earmarked revenues to total costs.
3. Efficiency: variable (earmarked and non-earmarked) revenues to variable costs.

The revenue to cost ratios presented in this section are limited to those countries with detailed, i.e. comprehensive road-class specific infrastructure cost accounting information (Germany, Austria, Switzerland, France, Italy and Sweden) plus those countries with general accounting information for the road network in total. Figure 12 presents the three indicators for heavy goods vehicles (weighted by size classes) on motorways.

Figure 12 Cost coverage of total and fixed costs, all vehicles and network categories



Remark: Based on cost data from model output (extrapolated for BG, CY, CZ, EE, LT, LV, MT, NO, PL, RO, SI, SK) and revenue data based on ACEA, 2006 and BGL, 2007).

The values in Figure 12 lead to the following conclusions:

1 For those countries with excellent cost accounting data (Austria, Germany, Switzerland, France, Italy and Sweden), the three revenue to cost ratios appear rather high, all are close to or above the level of the EU-29 average apart from Switzerland and Sweden.
2 The high cost coverage ratios involving fixed infrastructure costs for Denmark and Hungary are explained by the high Danish vehicle acquisition tax and the costly vignette system on parts of the Hungarian motorway system.
3 The very low values for the Scandinavian countries (Sweden and Finland) and Switzerland are due to very low traffic volumes compared to the network length. High average infrastructure use costs are combined here with low tax revenues.
4 In contrast, the low cost coverage rates for Luxembourg are due to the extremely low fuel tax and the absence of road user charges.

These observations show that revenue to cost ratios are determined by three equally important factors: (1) the level of road construction and maintenance costs, (2) traffic density on the network and (3) taxation and charging policy. For the three objectives, we can conclude for HGV traffic on motorways:

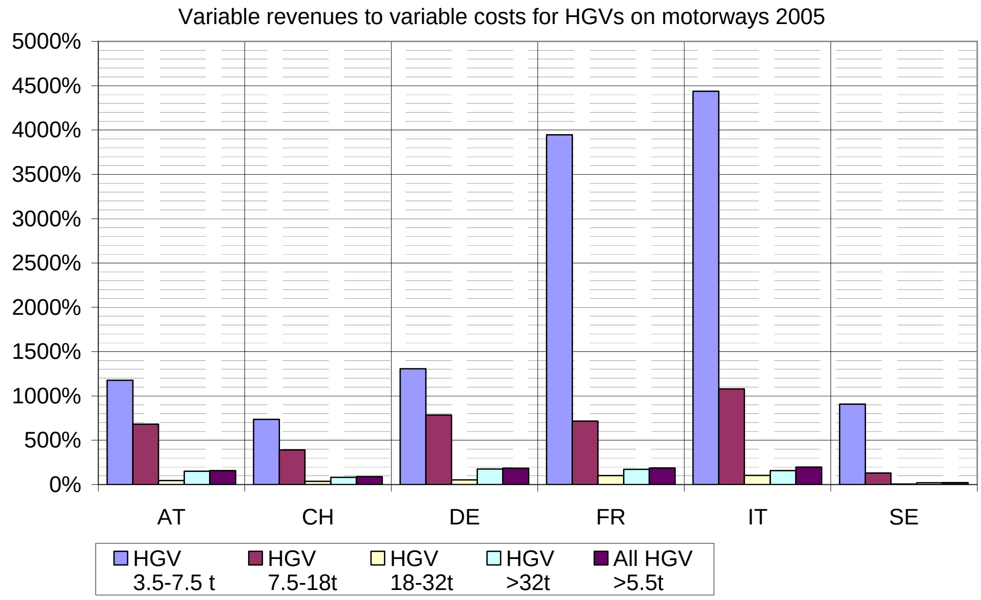
1 Total transport related taxes (excluding VAT) range around 100% of total infrastructure costs (EUR-29 average: 97%). Thus, from the state perspective, motorway infrastructure costs attributed to HGVs are not subsidised. But this also implies that, across Europe, the transport sector does not contribute to public budgets in the same way as is expected of other commercial or industrial sectors. Moreover, the balance does not consider external cost elements, which would lead to a considerable subsidisation of road haulage on motorways in the European average.

2 A different picture emerges when referring to the user pays principle, which takes into account the contribution made to financing public services by the transport user in his function as a common tax payer. When subtracting 50% of fuel and vehicle purchase and circulation taxes, cost coverage rates drop by some 40% (earmarked revenue to total cost rate across EUR-29 countries: 59%). From the user perspective, haulage on motorways is thus heavily subsidised, even when excluding external costs.

3 For pricing purposes, the efficiency perspective, which compares variable taxes and charges with marginal infrastructure use costs, is most interesting. In line with expectations, those countries with distance-based motorway tolls in operation show the highest revenue to cost ratios. One exception is Switzerland, which shows only 89% coverage even though heavy lorries there are subject to the highest charges in Europe.

With regard to efficiency issues, the development of charges to costs is more important than the level of average charges to average costs. Figure 13 presents the variable revenue to variable infrastructure cost ratios for the four HGV types and the six countries with reliable infrastructure cost information. The smaller the differences in revenue to cost ratios between the vehicle classes, the more efficient the structure of charges is with respect to road provision, maintenance and operation costs.

Figure 13 Revenue to infrastructure cost ratios by HGV weight class on motorways for selected countries



The graph gives rise to the following conclusions:

1 In all national schemes, lighter HGVs are overpriced with respect to heavy truck and trailer combinations (40t). This indicates that in none of the charging systems do tariffs rise sufficiently with vehicle weight to reflect the damages and construction requirements caused by high axle weights.
2 Remarkably, lorries or combinations with a gross weight between 18t and 32t show lower revenue to cost ratios than the next smaller class. The explanation for this phenomenon is the slope of the fuel consumption function with respect to vehicle weight.
3 The lowest distortion, and thus the highest degree of efficiency, of road user charges is observed for Switzerland. Here charges vary directly with the weight of the vehicle.
4 The highest distortion of efficiency principles can be observed for those countries with no or flat tolling systems with respect to vehicle weight (Italy, France and Sweden).

In terms of the efficient use of motorway infrastructures by heavy trucks it can thus be concluded that (1) the level of variable revenues is sufficient to internalise infrastructure costs, but that (2) a (further) spread of charges according to vehicle weight classes should be fostered on European motorway (or TEN-T) networks.

Table 25 presents the coverage of total road infrastructure costs across Europe by vehicle types and network categories. Here it becomes very clear that the infrastructure cost coverage of passenger cars is - due to their much lower causation of and responsibility for infrastructure costs - more favourable than that of HGVs. In particular, the coverage of the variable road infrastructure costs of heavy trucks is much lower than that of lighter vehicles. Motorways have the best figures of the different road classes, which is not surprising due to the frequency of charging tolls and vignettes on that road class.

Table 25 Coverage of total infrastructure costs by road and vehicle class

Cost/revenue basis	Total revenues by total infrastructure costs		Earmarked revenues by total infrastructure costs		Variable revenues by variable infrastructure costs	
Road class	Motorways	All roads	Motorways	All roads	Motorways	All roads
Small car	2.68	1.64	1.55	0.92	28.20	22.17
Big car	3.38	2.17	1.88	1.16	39.69	32.50
Motor cycle	5.32	1.91	3.56	1.12	18.84	7.21
Bus/Coach	1.31	0.53	0.80	0.28	1.67	0.59
LDV/Van	2.24	0.94	1.51	0.51	38.98	21.81
HGV5.5t	3.18	1.59	2.20	0.94	55.32	31.38
HGV12t	2.74	1.23	1.95	0.74	15.65	5.63
HGV24t	1.70	0.67	1.20	0.40	3.14	1.01
HGV40t	1.36	0.54	0.94	0.32	2.27	0.75

Remark: Based on cost data from model output; extrapolated for BG, CY, CZ, EE, LT, LV, MT, NO, PL, RO, SI, SK and revenue data based on ACEA, 2006 and BGL, 2007.

The values in the table lead to the conclusions:

1 Passenger cars and light duty vehicles contribute more to covering total as well as variable costs than heavy traffic across all road classes. For motorways this is remarkable since some countries only charge heavy vehicles. Consequently it can be concluded that further promoting HGV charging schemes is favourable for equity reasons.
2 Motorway traffic covers its costs to a higher degree than the network as a whole. This leads to the suggestion to extend charging systems to the entire network. The Swiss toll system could serve as a reference here.

5 Core findings and conclusions

5.1 Full cost accounting methods

Estimating the economic costs of transport infrastructure including depreciation, interest on capital and running costs can either be done using the Perpetual Inventory Method (PIM) or the Synthetic Method. The PIM emerges from the tradition of keeping national accounts by depreciating expenses (by activity or type of asset) over time and adding interest costs to the calculated remaining net capital stock. The Synthetic Method, in contrast, compiles and values an inventory of currently existing assets using their actual replacement values by taking into account age, physical condition and past and projected traffic loads.

Current applications of both methods apply stochastic, i.e. statistically distributed depreciation functions and value assets by their replacement value. Where both methods have been applied to the same networks for Germany, Austria and Sweden, the results show no clear differences at the level of asset value or capital costs. The driving factor seems to be whether maintenance and replacement activities are carried out according to the depreciation assumptions in the model or whether delayed activities cause an investment backlog. In the first case, the PIM should lead to higher results while, in the second case, the Synthetic Method should do so.

Each of the accounting philosophies has strengths and weaknesses. After a thorough check of their pros and cons we recommend the Synthetic Method for infrastructure accounting purposes if there is no tradition of calculating infrastructure costs using the PIM approach for several reasons. (1) The UNITE case studies have shown that the retrieval of detailed historical data from public accounts is difficult or even impossible. (2) The Synthetic Method better reflects the current state and the desired quality standard of a traffic network. (3) A direct application within traffic models and the assessment of investment and maintenance scenarios is easier to do with the Synthetic Method. (4) The relation of costs to real physical objects allows variable infrastructure costs to be differentiated by location and thus approaches the objective of marginal social cost pricing within the accounting framework.

5.2 Cost allocation procedures

There are three main cost allocation principles from which others have been derived: the equivalency factor method, the econometric approach and the game theory approach. The equivalency factor method is the most commonly applied, easy to implement, transparent and can consider specific engineering knowledge. Possible weights for allocating costs among defined vehicle classes may be simple vehicle kilometres, PCE or ESAL weighted vehicle kilometres, or binary variables for each vehicle group.

The econometric method is only applied in the Austrian road accounts. It derives cost responsibilities by regressions of maintenance and investment expenses for a sample of road sections considering the traffic volume and traffic mix for each section. This method suffers from considerable co-linearities between regression variables such that the results appear less reliable. The game theory approach was partly applied in the US Highway Cost Allocation Studies, but has never been fully applied to a real transport network. It allocates costs by total costs occurring with different traffic compositions (Shapley value) based on detailed engineering inputs on road planning and cost progression. It requires considerable computing power and the allocation results cannot be easily verified.

We thus recommend the equivalency factor method using statistically proven results for cost drivers to the greatest extent possible and a sufficiently detailed system of asset types and characteristics.

5.3 Total road infrastructure cost results for Europe

Total costs were derived by analysing the results of recent studies. The most important studies were the UNITE country accounts and the national studies for Germany, Switzerland, Austria and the Netherlands. Unit costs per road kilometre by road class were derived from these sources including depreciation, interest on capital and running costs.

Depending on data availability, the 29 European countries were classified into three groups: Six countries with road cost accounts by road class (Germany, Switzerland, Austria, France, Italy and Sweden), ten countries with total network accounts (Belgium, Denmark, Spain, Finland, Greece, Hungary, Ireland, Luxembourg, Netherlands and the UK) and the remaining thirteen countries with only partial (Portugal) or no accounting information. For setting infrastructure cost related prices, however, road class specific accounts are essential.

The analysis of the country accounts of unit costs per road kilometre revealed similarities in the cost levels and cost structures between the big Western European countries. For these parts of the EU, the cost database created in this study should be reasonable, but of course cannot replace specific country accounts. For these countries, we obtained values between € 600,000 (Austria, Germany, Italy, Spain) and € 800,000 (France) per motorway kilometre. Less reliable are the results presented for other road types and for the new Member States.

The main findings of the country comparison of unit costs per road kilometre were that the unit costs for motorways are roughly ten times higher than those for trunk or urban roads. Only motorways showed some, but very limited, co-linearity with the price index for construction services across countries. For those countries with no accounting information, the German values were adopted using purchasing power parities (PPP) for construction services.

Regional results for Austria and Switzerland reveal that the running costs of the road network are 20% to 50% higher in mountainous areas than in relatively flat regions. Results for capital costs are not available, but it stands to reason that the need for more bridge and tunnel constructions in mountainous areas will push up construction costs considerably.

The data sources are insufficient, in particular for infrastructure costs. To improve the knowledge on the resources consumed in road transport it would be necessary to start a European initiative to develop a unique road cost accounting tool and to fill this with real data. UNITE provides a good starting point but needs to be improved in terms of data availability.

5.4 Average costs by vehicle category

Average costs are derived through dividing total costs by the traffic volume (in vehicle kilometres). The level of average costs is thus not only driven by construction prices, running costs and accounting methodologies, but to a large extent by traffic density. Accordingly, the remote countries (Sweden, Finland, Ireland) show much higher values than the central transit countries.

Average costs were derived separately for each of the nine vehicle types. For HGVs on motorways they were found to vary considerably with vehicle weight from 4 €-ct/vkm for a 5.5t lorry to 19 €-ct/t for a 40t truck and trailer combination.

5.5 Marginal costs of infrastructure use

The GRACE case studies indicate that variable average costs may be a good proxy for the marginal costs of infrastructure use. For motorways in the six countries with detailed accounting data, the share of variable costs across all vehicle categories is 22%. For all other countries and road classes, the share of variable (= marginal) infrastructure use is 26%. Pure marginal infrastructure cost pricing would thus result in a deficit of 74% to 78% of total infrastructure costs if no other cost components are considered. These additional cost categories could be congestion costs.

For the six countries with detailed accounting information, the marginal costs for light lorries (3.5t to 7.5t) range between 0.20 €ct/vkm (France and Italy) and 51 €ct/vkm (Switzerland). For HGVs above 32t, the range is from 5.57 €ct/vkm for Austria to 52 €/100 vkm for Sweden. These extreme ranges make it questionable whether the proxy of average variable costs for marginal infrastructure use remains valid under such different traffic densities.

Marginal costs appear to be much higher on secondary roads than on motorways in countries with dense motorway traffic. The ratio between trunk roads and motorways is found to be above six for Italy and 0.7 for Sweden. In the EUR-29, the average marginal costs on trunk roads are roughly double the costs on motorways for 40t HGVs.

The GRACE project has made an important step forward in quantifying driving factors for marginal cost levels. But the presentation of its results makes it difficult to transfer the elasticities to real costs per kilometre across all countries. Further research is also needed here on the generalisation of cost figures.

5.6 Revenue to cost ratios

The study reviewed several sources on national tax schemes to estimate total and average taxes. For the infrastructure costs, taxes and charges were classified into fixed (vehicle purchase and registration taxes, insurance taxes, vignettes) and variable taxes (fuel tax and road tolls). Taxes were further classified into earmarked taxes, which are allocated for use in the transport sector, and non-earmarked taxes. Three indicators were defined for the comparison of revenues to taxes.

Total transport related taxes (excluding VAT) range around 100% of total infrastructure costs. Thus, from the state perspective, motorway infrastructure costs attributed to HGVs are not subsidised. But this also implies that, across Europe, the transport sector does not contribute to financing public budgets in the same way as is expected of other commercial or industrial sectors.

A different picture emerges when referring to the user pays principle, which takes into account the contribution made to financing public services by the transport user in his function as a common tax payer. Taking earmarked taxes only, cost coverage rates drop by some 40%. From the user perspective, haulage on motorways is thus heavily subsidised, even when excluding external costs.

For pricing purposes, the efficiency perspective, which compares variable taxes and charges with marginal infrastructure use costs, is most interesting. In line with expectations, those countries with distance based motorway tolls in operation show the highest revenue to cost ratios. Even more important in this context is the variable revenue to variable cost comparison by vehicle type. For HGVs on motorways it is found that light trucks are heavily overpriced, distortions are the lowest for those countries with motorway toll systems, and among those, Switzerland shows the highest degree of efficiency as charges here vary directly with vehicle weight.

5.7 The policy perspective

One of the most important observations from the work carried out for this study is that the data needed to roughly estimate average infrastructure costs in compliance with Directive 2006/38/EC is not readily available across the EU. The thorough computation of average cost based charge levels involves either the recording of long time series of investment and running expenditures (PIM approach) or the provision of a full and detailed inventory of assets, quality and age records and reinvestment costs for the entire road network (Synthetic Method). In particular the PIM approach is expensive and can only be done by extensive country studies.

Marginal infrastructure cost pricing excluding congestion results in considerable deficits for the infrastructure manager. The pricing of average costs, systems of mark-ups on marginal costs (Ramsey pricing, multi part tariffs, etc.) or a system of marginal infrastructure costs plus congestion costs would ensure full cost coverage. Of these to some extent complex and costly options, a system of differentiated average costs will probably cause the lowest implementation costs while guaranteeing financial stability.

Due to their very different rationale and objectives, it is not recommended to use revenues for system external costs (accidents, air pollution, noise or climate change) to cover deficits in infrastructure financing. Deliverable 1 of the IMPACT study states that each cost category requires its own specific internalisation measure in order to provide a clear incentive to the transport user. Also for fiscal clarity, transparency and acceptability, transport sector internal and external costs should be strictly separated in terms of internalisation and revenue use.

5.8 Need for further research

There were limited resources for developing the road infrastructure cost and revenue database within the IMPACT study. For this reason, a number of items on the research agenda remained unresolved. These include:

1. Infrastructure cost levels for secondary roads and the new Member States. More country specific studies with local partners should be carried out to provide access to national data. Using the Synthetic Method to do so would help to avoid the considerable data problems faced by the UNITE country accounts.
2. Cost driving factors: Within the framework of this study, the attempt was made to obtain more information on the dependency of infrastructure costs on geographical, geological or meteorological conditions. More information is needed, in particular, practitioners' experience beyond statistical averages. It is proposed to analyse national investment programmes by looking at project design, projected or real costs and the geographical location of the projects.
3. Marginal infrastructure costs: Here more case studies in the style of those carried out within the GRACE project would be needed. But care should be taken concerning a unified design and reporting framework in order to ensure their comparability despite their different environments.
4. Congestion costs: Investigations into the state of European infrastructure and the level of congestion costs and revenues could enhance the discussion on covering SMC driven financing deficits in the infrastructure sector with congestion toll revenues.

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