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Executive summary

As requested by the High Level Group on infrastructure charging, Working Group 1 carried out the task of developing a harmonised approach / methodological framework for the estimation of marginal infrastructure costs of road and rail transport.

The Working Group agreed that this harmonised approach had to meet the following requirements:

- a similar structure and methodology to estimate marginal infrastructure costs should be used in all modes;
- the proposed methodology should be transparent in order to facilitate non-discriminatory charging structures;
- the proposed methodology should be practical and applicable on the basis of existing (accounting) data in Member States.

The basic assumption and starting point of the whole exercise was to consider the marginal costs of the use of existing infrastructure. The group analysed the nature and causation of the different types of infrastructure costs as defined currently by Member States and agreed on the following distinction:

Fixed costs are those that, for a given capacity, do not vary with traffic volume. Variable costs are those that (over a certain, short time horizon e.g. one year) vary with traffic volume, and to a lesser extent, with weather or other cyclical conditions. Within the variable costs category some variable costs are only vaguely related to traffic volume - for instance they may increase stepwise (eg. lighting, snow clearance) with certain thresholds. Others vary directly with the level of traffic and can be attributed to vehicles (eg. filling potholes). These costs which vary directly with use are relevant for estimating the short run marginal costs of infrastructure use. They can be classified under certain broad categories, such as maintenance and repairs, operations and some services.

The group accepted that Member States’ practices of road and rail track maintenance are not always ideal and can lead to sub-optimal use of (public and/or private) resources. However, in practical terms expenditure data kept by Member States should be used as a satisfactory reflection of damage costs to the road or rail track.

As most infrastructure data are held at an aggregated level, a "top down" approach to estimating
cost functions is appropriate, using econometric approaches to determine specific functional forms on the basis of cost causes ("drivers") such as traffic volumes; vehicle weight; axle weights configurations; vehicle speed; and (train) operating requirements. However, countries generally keep records of infrastructure expenditure (or costs in categories) that are relevant for budgeting, taxation and other administrative and allocative purposes. Consequently the group proposes, where (in most cases) sufficient information does not exist, to take a more pragmatic approach, whereby a marginal cost figure rather than a cost function is estimated.

The expenditure/cost figures thus identified should related to road or track type (motorway, national, state, regional roads, urban streets; track speed and formation, existing categories: main/minor lines/ electrified, single/double for rail).

The next methodological step involves attributing these costs to vehicles. Ideally, this should be related to the way different vehicle types cause costs (e.g. vehicle axle weight for road; weight and speed for rail), but currently used vehicle and train classifications could also be applied as proxies since data are not available to the required detail. In this respect the group is proposing a practical vehicle classification assumed to be satisfactory and realistic. To allocate the costs to the different vehicle/train types engineering based approaches are appropriate e.g. the 4th power rule in road relating axle weight to road pavement damage.

The proposed methodology uses existing cost data and categories of infrastructure and vehicles. Relationships can then be forged that link specific marginal costs to specific situations and vehicle types. Such a method can be applied generally to pass on the marginal costs of infrastructure to users.

1 Introduction

1.1 The mandate of Working Group 1

The White Paper on ‘Fair Payment for Infrastructure Use’1 proposes to apply the principle of Social Marginal Cost Pricing in order to increase efficiency in the transport sector and to

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internalise external cost in a proper way. According to this White Paper, transport infrastructure charges should strictly be based on marginal cost of infrastructure, congestion, accidents and environmental damage.

Working Group 1 is aimed at supporting the High Level Group on infrastructure charging with methodological issues in the field of infrastructure cost accounting and estimation. It is aimed at developing a methodological framework for the estimation of marginal infrastructure cost, considering the Member State’s practice and focusing on road and rail transport.²

This report summarises the current practice of infrastructure cost accounting (Chapter 2) and draws basic recommendations for a methodological framework (Chapter 3) in order to estimate marginal cost. The most important issue of this report is the definition of marginal cost and the discussion of different estimation methods.

1.2 Delimitation of transport infrastructure

In a narrow sense, transport infrastructure can be defined as the physical and organisational network, which allows movements between different locations. These are the roads (road transport) and tracks (rail transport) and the organisation of the traffic (e.g. police, systems managing etc.). In this definition the railway stations and freight terminals are excluded. The proposed methodological framework as well as the recommendations in this report will be based on this definition. If also the use of rail stations³ and freight terminals is to be charged, similar methodological frameworks have to be developed. However, these types of infrastructure are certainly characterised by other types of cost behaviour/cost functions than those for the "transport ways" (roads, tracks). This holds also true for waterborne and air transport where the transport way in the narrow sense has to be treated separately from the terminal (e.g. the inland/seaport, airport).

Furthermore, one has to discuss the treatment of various additional services which enable an efficient use of provided infrastructure. These service packages might differ between the transport modes and will depend also on the different institutional backgrounds and

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² Due to its minor importance and different institutional structures, infrastructure cost of air and waterborne transport is not treated in detail in this report. However, the working group will refer in its recommendations also to these transport modes.

³ The DB AG has two separate charging systems for the use of tracks and stations which are based on different methodological principles and different charging factors.
organisation of the transport chain. A typical example is the provision of electric energy for rail transport, which is an additional service of the rail infrastructure provider. In contrast to that, the provision of fuel for road transport or of diesel for rail is a private responsibility or a transport service duty without direct interrelation to the provision of infrastructure. The same is true for parking facilities or marshalling yards.

Given this definition of infrastructure costs, it is essential to address specific service items in a transparent way. If different transport modes (e.g. road and rail) are to be compared, one has to address a basic service package, which includes the physical and organisational aspects only. This includes the traffic network (incl. rail platforms) and the traffic organisation and control units.

1.3 The scope of marginal infrastructure cost

According to the concept of Social Marginal Cost Pricing\(^4\), only the cost caused by an additional traffic unit have to be considered for pricing issues. In the short run, fixed costs (costs of existing infrastructure which are independent of traffic volumes) are regarded as sunk costs. From an efficiency point of view, these costs are not relevant for pricing. In regard to the estimation of infrastructure costs, this principle is essential, since marginal costs and average costs differ considerably. Thus, a key issue is to elaborate a transparent distinction between fixed and variable costs.

From the viewpoint of the European Commission, a basic harmonised methodology for the estimation of **marginal cost of infrastructure** use is most important in order to draw conclusions for appropriate levels of pricing instruments (i.e. road pricing, rail access charging). This harmonised framework has to meet the following requirements:

- Road and Rail infrastructure operators should use the same methodological principles to estimate prices based on marginal infrastructure cost.
- The allocation of costs to different type of vehicles and trains should follow the same principles, in order to avoid discrimination.

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\(^4\) Note that within this report social marginal costs do not include non-transport related types of opportunity costs such as marginal costs of labour, which can be different in the countries. Social marginal opportunity costs of public funds are not considered either.
It should guarantee transparency to ensure charging structures have a rational basis and are not causing discrimination.

As total costs and cost coverage are important issues (relating to issues of fairness, financing and compensation of eventually occurring deficits in case of charging marginal costs) certain aspects of capital costs will be touched on. However, in this report we will concentrate our recommendations on the issues of marginal cost calculation. Given this, cost causation and its reflection in appropriate allocation methods is a very important issue to be dealt with in this report. This implies that transparent classifications for different type of vehicles and trains are essential. For the allocation of total costs to different type of vehicles or trains, specific assumptions have to be made, too. Possible indicators might be vehicle (or train) kilometres or weighted factors considering the speed or the size of the vehicles/trains.

Infrastructure capacity is considered to be given. Costs of scarce capacity or of capacity enlargement in case of congestion are not treated as an ex-ante cost. If capacity is indeed enlarged these costs would be included in the ex-post capital costs of these investments which are, however, not relevant for the short term marginal costs. Nevertheless, it is important to hint at the problem of double counting which might occur in this field between WG 1 and WG 2.

Finally, it should be noted that the working group 1 on infrastructure costs deals - in contrast to the other working groups - with cost types reflected in real financial flows. Although only parts of these flows do reflect optimality concepts of charging, the whole of infrastructure costs is important with regard to financing issues.

1.4 Marginal infrastructure costs and pricing

Social Marginal Cost Pricing implies charging systems, which are based on marginal costs. With respect to infrastructure costs, road or track pricing schemes with different prices for different types of infrastructure and different types of vehicles are supposed to be most appropriate. Since other social costs of transport (like congestion costs or environmental costs) might be charged in a similar manner, the charge to cover marginal infrastructure costs can be considered as a base price for the use of infrastructure.

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Working Group 2 on congestion and environmental cost: This group will draw recommendations how to measure marginal external congestion costs, which are a basis for pricing scarce infrastructure within the approach of Social Marginal Cost Pricing.
In order to derive optimal charges, one has to consider the revenue side, too. The difference between costs and user contributions (revenues from the users) are seen as the external part. However, today’s taxation and charging systems are not linked to the social marginal cost principle. Moreover there are indirect charges (fuel tax, vehicle tax) which are aimed at covering total infrastructure costs. This causes difficulties when comparing marginal infrastructure costs with respective revenues. It is therefore not useful to include the revenue side at this stage. Thus, we will deal with the cost side only. In a next stage however it will be necessary to define transparent implementation paths which shift from indirect taxation towards infrastructure oriented road and track pricing.

2 Current Practice

2.1 Road sector

2.1.1 Classifications

a) Cost terms and categories
Reviewing the current practice of cost categorisation in the EU, we can state that it is heterogeneous and in most countries not very detailed. However, there are some countries which distinguish between variable and fixed costs and differentiate between different cost categories especially for cost allocation (see examples in the annex). The UK and Sweden have according to our knowledge probably the most detailed cost categorisation. However, the examples in the annex show that functional categorisations (such as maintenance, operation, renewal, reconstruction) are partly mixed up with rather asset-oriented categorisations (such as bridges, drainage).

b) Vehicle categories
Most common is the differentiation of the following categories:
- Motorcycles
- Passenger Cars
- Buses

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Moreover, there is (for example in Germany) no consensus which revenues are considered to be infrastructure revenues, independent on the question whether marginal or total infrastructure costs are of interest.
• Light Goods Vehicles (< 3.5 t max. Gross vehicle weight)\(^7\)
• Heavy Goods Vehicles (> 3.5 t max. Gross vehicle weight)\(^7\)
  - Rigid goods vehicles (lorries without trailer)
  - Lorries with trailer
  - Articulated vehicles (tractors with semi-trailer)

However, it should be noted that the classification practice per country differs (for example, treatment of trailers, weight classes). Furthermore, the treatment of buses is an open question. Some countries report separate data concerning buses (mileage’s) but in many countries buses are simply mixed up with passenger cars which is - from a cost-causation point of view - somewhat problematic.

c) Road classifications

Usually cost statements are differentiated according to state levels (Federal, Provincial, communal). Based on the requirements of EC infrastructure regulation from 1970, a common classification is:
- National Motorways
- State roads (trunk roads)
- Regional roads (Provincial roads)
- Urban roads

It has to be noted, that data availability and cost accurateness is most developed for national motorways. Many Member States have no detailed information of other road categories.

2.1.2 Current methodological practice\(^8\)

a) General practice

Table 2 gives an overview on today’s practice in the Member States and Switzerland.

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\(^7\) EUROSTAT has revised the classifications, related to the 3.5 t MiVW for distinguishing light goods vehicles and heavy goods vehicles.

\(^8\) Based on DIW et al. (1998).
Table 1: Practice of road infrastructure cost accounting in Europe

b) Estimation of variable and marginal costs
While some countries (as shown above) distinguish between fixed and variable costs, there is no country applying a sophisticated approach to estimate marginal costs. Older regression analyses from Germany (1969) indicate, that about 15% of total costs are marginal. Several countries distinguish between fixed and variable costs, as mentioned above. A common approach is the allocation of percentages to different costs categories by road category (Top-down), based on empirical and engineering judgement.

c) Capitalisation of investments
The derivation of capital costs out of investment expenditures is not primary relevant, if we want to estimate marginal costs, since large parts of these costs are fixed. In order to have an appropriate information of the capital value and the economically correct opportunity cost, capitalisation of yearly investment expenditures however would be necessary. Only six Member States are using a specific procedure for the estimation of capital cost. Most sensitive in this procedure is the definition of
- The lifetime expectancies of different road elements (i.e. bridges, tunnels etc.). The figures used in EU-countries differ considerably.

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9 However, this share of fixed parts in total capital costs depends on whether the capital costs are related to new investments/enlargements or to replacement of assets which has to be capitalised too. This share can change over time. Furthermore, it has to be considered to what extent maintenance expenditures are capitalised (as for example done in Germany and Switzerland).
The type of depreciation (linear or declining balance). There exists different practice within the Member States but most common is linear depreciation or depreciation derived from a direct evaluation of the existing road network (road inventory).\textsuperscript{10}

The choice of the interest rate (most common is the opportunity cost of public loans).

d) Cost allocation

The cost allocation to different types of vehicles is a very sensitive issue, usually with a political dimension (e.g. HGV-taxation). Most common is a top-down approach which allocates total costs (e.g. the sum of variable and fixed costs) by applying specific indicators to different vehicle categories. DIW et al. (1998) has shown, that the practice within the Member States (and thus the share of HGV) differs considerably. Table 3 gives an overview. It indicates that it is common to apply indicators like vkm, PCU’s and axle-load vkm based on different AASHO-factors. Most countries allocate the costs by using percentages which stem either from econometric studies or from engineering knowledge. The most sophisticated approaches are illustrated in the annex.

\textsuperscript{10} For example the UK is currently evaluating the condition and the value of infrastructure.
<table>
<thead>
<tr>
<th>Country</th>
<th>Method used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Regression analysis&lt;br&gt;Adaptation of the German method</td>
</tr>
<tr>
<td>Denmark</td>
<td>Differentiation of capital and running costs into:&lt;br&gt;- Fixed costs,&lt;br&gt;- Vehicle-km dependent costs&lt;br&gt;- Space dependent costs&lt;br&gt;- Weight dependent costs&lt;br&gt;Use of specific weight and space factors by type of vehicle</td>
</tr>
<tr>
<td>France</td>
<td>Differentiation between fixed and variable expenditures&lt;br&gt;Use of different allocation factors such as:&lt;br&gt;- vkm&lt;br&gt;- weight-vkm&lt;br&gt;- standard axle-vkm</td>
</tr>
<tr>
<td>Germany</td>
<td>Differentiation between marginal costs and capacity costs&lt;br&gt;Allocation of:&lt;br&gt;1. Marginal costs by AASHO-Road factors<em>vehicle -km&lt;br&gt;2. Capacity costs by (speed-dependent) equivalent factors</em>vehicle -km</td>
</tr>
<tr>
<td>Italy</td>
<td>Differentiation between marginal and capacity expenditures, allocated by:&lt;br&gt;- vkm&lt;br&gt;- axle-weight-km&lt;br&gt;- standard-axle-km</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Differentiation of investment expenditures and running expenditures into different sub-categories allocated by:&lt;br&gt;- vkm&lt;br&gt;- PCU-km&lt;br&gt;- axle load-km</td>
</tr>
<tr>
<td>Finland</td>
<td>Differentiation between fixed and variable expenditures allocated by:&lt;br&gt;- vkm&lt;br&gt;- weight-factors</td>
</tr>
<tr>
<td>Sweden</td>
<td>Differentiation of fixed and variable expenditures into&lt;br&gt;- vkm-dependent expenditures&lt;br&gt;- space- and speed-dependent expenditures (allocated by PCU-km)&lt;br&gt;- weight-dependent expenditures (allocated by AASHO-factor-km)</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Allocation of:&lt;br&gt;1. Weight dependent costs of new investment (estimated by percentages per road type) by weight-factors&lt;br&gt;2. Weight dependent costs for pavement and investive maintenance by axle-load-vkm&lt;br&gt;3. Capacity costs: 80% by vehicle-length *vehicle-km 20% by vehicle-km&lt;br&gt;4. Current costs by vehicle-km</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Allocation of:&lt;br&gt;1. Capital expenditure: 15% by max. GVW-km, 85% by PCU-km.&lt;br&gt;2. Maintenance expenditure further differentiated by types of expenditures and different allocation factors applied&lt;br&gt;3. Policing and traffic wardens by vehicle-km.</td>
</tr>
</tbody>
</table>

Source: Review of studies carried out by DIW, INFRAS, HERRY, NERA.

| Table 2: Current practice of cost allocation methods in Europe |

Simulations within DIW et al. (1998) indicate, that the application of the different methods lead to a quite significant range of results. Figure 1 shows this sensitivity of different allocation methods applied to data sets from Austria, Germany and Switzerland. As can be seen from there the cost share of HGV yielded by the different allocation methods\(^\text{11}\) vary
- within Austria from 13.5 % to 42.8 %,

\(^{11}\) The methods from D, DK, NL, S, CH, UK and A were used. The German method leads to the highest share, whereas the Swiss method is an HGV "friendly" one.
within Germany from 18.3 % to 47.9 %,
within Switzerland from 13% to 36.1%.

In particular the estimation of the share of weight dependent costs is a sensitive methodological issue with considerable quantitative impacts on the overall results. These costs are usually allocated by applying weight dependent factors such as the widely used AASHO-factors\textsuperscript{12}. The more costs are assumed to be allocated by these factors, the higher is the share of HGV.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{chart.png}
\caption{Application of different cost allocation methods for Austria, Germany and Switzerland}
\end{figure}

2.2 Rail sector

In contrast to the road sector we cannot draw from any extensive empirical study on rail infrastructure costs which could provide methodologies and empirical estimates of variable and fixed costs and of cost allocation methods including the respective sensitivity analyses in European countries. To our current knowledge, only in Austria and Germany rail infrastructure cost accounts based on the same principles as for the road sector were elaborated. Nevertheless, there exist some review studies as well as theoretical knowledge on rail infrastructure charging.

\textsuperscript{12} It should be mentioned that some countries apply also other than the AASHO-factors or reduced AASHO-factors.
defining differentiated service packages. The experience from the empirical studies from Austria and Germany together with the findings of NERA (1998), Cooper & Lybrand (1998), the PETS project and the EU draft directive on railway infrastructure charging formed the basis for this chapter.

2.2.1 Classifications

a) Rail infrastructure costs
The available infrastructure cost accounts for the rail sector distinguish usually between the cost of operation and maintenance, administration and overheads and the capital costs. A more detailed cost categorisation is certainly available inside the rail companies. Furthermore, in the profit/loss statements costs are categorised. However, due to our current knowledge there is no categorisation officially available concerning the distinction between variable and fixed costs.

It should also be noted that infrastructure cost accounts for the rail sector have to tackle with the problem of how to distinguish between the costs of tracks in the narrow sense and those related with other facilities such as stations and freight terminals (see section 1.2). The German rail infrastructure cost account, for example, draws here a delimitation line in the following way: All costs required to operate transport from A to B are counted as track costs. This means for the railway stations that the platforms belong to the tracks but not the station in the broader sense.

b) Train classifications
Classifications used in European railway statistics are: 13

- Freight trains (wagon load, combined transport, rolling road)
- Passenger trains (High-speed trains, Euro-/Intercity and other long-distance trains, regional trains, Urban rail)

c) Network classifications
A classification of the rail network similar to road network classification is complicated. Rail networks are for the most part characterised by the use of both passenger trains (often long-distance as well as short-distance traffic) and freight trains. Even the HGV network is often

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13 Germany differentiates the track pricing scheme according to speed classes, which are very important for the classifications of the network, too. However, a published statistic on traffic performance according to these classes is not available.
also used by other trains (so for example by freight trains in Germany). In rail statistics usually two types of network classifications can be found:

1. **Regarding the importance of lines**
   - Main lines
     - out of these: electrified lines
     - out of these: double track or more
   - Minor lines

2. **Regarding the type of traffic**
   - Passenger transport only
   - Freight transport only
   - Mixed traffic

Germany’s DB AG has additionally differentiated the rail network into speed-dependent network classes, these are, however, not required to be published. Generally, it should be mentioned that the classifications mentioned above are not directly reflecting the cost drivers.\(^\text{14}\)

We will come back to this point later.

### 2.2.2 Current methodological practice

a) **General practice**

In general, characterising the current practice in Europe requires to distinguish between cost accounting and charging. Available studies reviewing the situation in the EU (NERA (1998), Cooper & Lybrand (1998)) focus on the charging side with some statements on which cost categories to be considered for different charging regimes (as for example in the NERA-study: with and without cost recovery target and for the uncongested and congested rail network). Table 3 gives an overview on the current practice of rail infrastructure charging in Europe. As can be seen from there, charging principles as well as the structure and level of charges in Europe are extremely heterogeneous. In the annex, the elements of an access service package are shown, based on the propositions of the EU draft directive on railway infrastructure charging. The Cooper & Lybrand study (commissioned by UIC) has proposed to consider similar items.

\(^{14}\) These are infrastructure features such as mix of traffic, geographical area and track formation.
However, it is cost accounting and here in particular the estimation of marginal infrastructure costs which is of importance for this working group. In that context the estimation of fixed costs, variable costs and marginal costs and methods to allocate these costs to train types according to causation factors is in the focus of interest. Studies supporting this with methodologies and empirical estimates seem to be rare in Europe. To our current knowledge only Germany carried out frequently such cost accounts. In Austria a rail infrastructure cost study for 1990 is available. Furthermore, there exists an econometric study in Sweden for estimating marginal maintenance costs (Johansson and Nilsson 1998). Concerning the remaining countries we can only state that they are obliged to report annually to the EU-commission the expenditures for railways and the utilisation of the rail network (in terms of train-km and gross tonne-km). However, it seems to be obvious that inside the national rail companies very detailed cost accounts should exist. In the following we will concentrate on the studies in Germany, Austria and Sweden which are in their main features summarised in table 4.

### Table 3: Overview on the charging situation in European countries

<table>
<thead>
<tr>
<th>Criteria/country</th>
<th>Germany</th>
<th>Austria</th>
<th>Sweden</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership of rail infrastructure</td>
<td>Public</td>
<td>Public</td>
<td>Public</td>
<td>Public</td>
</tr>
<tr>
<td>Charging principle</td>
<td>Adjusted average costs</td>
<td>Adjusted average costs (except interests) aimed at cost coverage</td>
<td>Adjusted average costs</td>
<td>No charges until 2000, from 2000 onwards marginal operating costs</td>
</tr>
<tr>
<td>Features of the charging system</td>
<td>• Two part tariff • charging factors: – type of routes – gross-tonne km</td>
<td>• Two part tariff • charging factors: – type of routes – speed classes – requirements regarding reliability</td>
<td>• Two part tariff • charging factors: – type of routes (suburban, high-speed lines, ordinary trunk lines, others) – peak/off-peak for suburban and high-speed lines</td>
<td>—</td>
</tr>
</tbody>
</table>

### Source: DIW.
Table 4: 
Features of rail cost estimations in Germany, Austria, Sweden and the UK

b) Estimation of marginal costs

Similar to the road sector the methodological and empirical situation is weak if fixed and variable costs are to be distinguished and if marginal rail infrastructure costs shall be derived. 

As can be seen from table 4, studies for estimating marginal infrastructure costs were only carried out in Germany and Sweden. The basic calculations for Germany were elaborated at the end of the sixties and yielded an extremely low share of marginal costs in total costs (only 2%). Until the beginning of the 90ies these calculation schemes were internally updated by DB. The Swedish analysis of marginal maintenance costs\(^{15}\) proved empirically that 10% of the average costs for maintenance are marginal costs which implies that the share of marginal costs in all average costs is even lower.

Railtrack (1999) has undertaken specific research for the structure of rail access charges. Within this study asset usage costs (marginal costs of maintaining and renewing assets) were estimated with a specific model. The initial results of the usage cost research which are variable costs, indicate that the proportion of Railtrack’s costs that vary with asset usage is around 10-15%, rather than the 3% reflected in the existing passenger charging regime. Vehicle type, line-

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\(^{15}\) Unfortunately, it is not clear whether this comprises also renewal costs. It is also open how maintenance is defined in terms of assets (tracks, equipment etc.).
speed and electrification are identified to be the key drivers of costs and Railtrack propose that these parameters should be part of an efficient charging regime. This model simulations will be carried on in order to provide more detailed information as well on geographical variations.

NERA (1998), although not an empirical study, gives some guidelines which cost elements are relevant for deriving short-run marginal costs. These costs relate to an existing rail network which is not congested, and contain\(^{16}\):

- additional track wear and tear
- traction current
- signal operation costs
- train planning costs
- management and administration costs
- costs of disruption caused to other train services.

The NERA study mentions that these costs are likely amount for only 10% to 20% of total rail infrastructure costs but it is not clear from which empirical sources these figures stem. This range, however, lies in line with information from DB for Germany. DB estimates that 15% to 20% of costs are variable costs.

The Annex provides some numerical results for the UK from the Railtrack study and results of the Swedish rail administration for Sweden. It should be noted that there is a variety of ongoing activities in this field, since the European railways are in the process of developing or revising their track access prices. These are often based on average variable costs. However, since these cost schemes are developed in institutional structures which are increasingly independent on governmental influence or which are even private (Railtrack in the UK), the respective information is not publicly available.

c) Capitalisation of investments

Capitalisation of investments is not necessary if short-run marginal costs are in the focus of interest. However, investments have to be capitalised if total costs and cost coverage calculations are required and if some quantitative knowledge on the necessary deficit compensation has to be provided.

Capital values of railways are usually published in the balance-sheets of the rail companies. These are, however, not comparable with capital values for the road sector since rail companies

\(^{16}\) Additionally to the categories listed here NERA also mentions additional noise, pollution and other external effects which, however, we will not treat them here in this infrastructure cost paper.
derive their capital values (and hence also the capital costs) from entrepreneurial principles.\textsuperscript{17} The differences which DIW et al. (1998) identified for road capital values of private motorway companies hold also true for rail companies. They are:

- other evaluation principles for the gross fixed capital formation (profit expectations)
- other methods for calculating capital values (for companies usually by inventories, for national assets mostly with the perpetual inventory method).
- other depreciation methods
- other depreciation periods

Capitalisation of rail investments based on the same principles as for the road sector are annually carried out in Germany. The values differ considerably from the capital values in the balance sheet of DB AG due to the above mentioned reasons. For other countries at least some basic information on rail capital values should come from the Systems of National Accounts (sector: transport and communications).

d) Cost allocation

To our knowledge no sophisticated cost allocation methods have been published except the German basic study from 1969. The German costs allocation method for rail follows the concept applied in the road sector: In a first step marginal costs and capacity costs are estimated and in a second step these cost categories are allocated to traffic/train types by using different allocation factors.

The UK cost allocation method uses another concept. For the allocation of costs to trains running on the same line a hierarchy of users was established. The prime user was allocated the basic costs of the route and all other users were only charged to the costs which could be avoided if these traffic types would not run on the route.

Information on the relevant parameters in the cost allocation procedures as provided for the road sector in DIW et al. (1998) does not exist for the rail sector.

2.3 Summary

- The current practice of infrastructure cost accounting the Member States is heterogenous

\textsuperscript{17} Often there is a mixture of entrepreneurial principles and accounting principles for publicly owned companies.
and depends on the institutional background (level of privatisation in the infrastructure sector, financing principles, general transport policy) and on taxation issues.

- Some countries distinguish between variable and fixed infrastructure costs. Marginal infrastructure costs, however, are not estimated. Although there are scientific studies available, they are not transferable to other countries and do cover only parts of the costs.

- The data situation on infrastructure expenditures is in general sufficient for the motorways and the national rail network. Genuine cost accounts, however, have only been elaborated by a few countries. Yearly values are available for different expenditure categories (esp. maintenance and traffic control). For the remaining network (feeder rail, provincial and municipal network), data situation is in general poor.

### 3 Proposition for a harmonised methodological framework for road and rail

#### 3.1 Aims and general principles

A harmonised framework should form the basis for a European unified approach to estimate marginal infrastructure costs for different vehicle categories and different type of infrastructure in order to provide basic information for the definition of infrastructure charges. Since national conditions and existing practice have to be considered, it is important to state that the level of harmonisation should focus on

- the definition and delimitation of marginal costs,
- the methodologies to estimate marginal costs,
- the classifications (cost categories and differentiation).

#### 3.2 Definition and estimation of marginal infrastructure costs

##### 3.2.1 Which costs are marginal?

a) **Definition of short run marginal costs**

The working group defines the "short run" as where infrastructure capacity is fixed. **All costs which occur to keep the system running (but not depending on traffic volumes) are**
Marginal costs are those caused by one additional vehicle or train when entering the system or using the infrastructure. Mathematically, marginal costs are the first derivative of a total cost function to this additional traffic unit. They are not equal to variable average costs. Moreover, they can follow even a different functional form than the variable costs. Depending on the shape of the function for the variable costs there are cases possible where the marginal cost function first lies below the variable cost curve and from a certain point onwards above.

The working group suggests in chapter 3.3 cost categories which are considered to be variable in the short-run and which are therefore a starting point for the estimation of short-run \textit{marginal} costs. In this cost categorisation also cyclically occurring costs such as surface dressing are defined as short-run \textit{variable} costs.

\textbf{b) The influence of the quality and level of service}

The level of variable and fixed costs also depends on the quality and level of service on a certain road type or rail line. For example, if the quality standard of a road is defined in such a way that it is always lit, cleaned and free from snow the related costs are considered to be fixed. If the service quality is set lower (for example there is no street lighting due to a low traffic level) the share of such fixed costs might change. So some level of these initial operating costs can be seen as fixed, because they are necessary for a basic quality and level of service of specific traffic volumes. If quality and levels of service change with the level of traffic, then the extra costs are variable. The working group suggests that basic costs for a minimum quality and level of service are fixed costs.

Another influence factor might result from different climate and topographic conditions. Possible additional costs in order to increase the stability of a road (e.g. in mountainous areas) are definitely fixed. The same is true for maintenance which might occur due to landslides (e.g. after heavy rainfalls). However, there might be some interrelations between the amount of traffic and such events. Since these mechanisms are rather complex and coincidental, we do not consider these costs as (potential) marginal costs. Thus, maintenance costs due to specific exogenous events should be separated from ordinary maintenance.

\footnote{This definition of the term short-run is essential for the level of fixed costs and, thus, the remaining variable costs. In economics, the term long-run is defined as the time sufficient to allow firms to adjust their inputs optimally to changes in their outputs. In this consideration all costs are variable. However, if outputs are constantly changing it is never possible to reach such a long-run equilibrium. It is the resulting presence of fixed or quasi-fixed inputs that makes short-run costs deviating from long-run costs. Furthermore, it has to be considered that some costs occur annually (e.g. regular maintenance) and other costs follow specific cycles (e.g. reconstruction, surface dressing).}
3.2.2 Basic methodological considerations

a) Optimal or actual costs?

According to pricing theory, optimal prices should be set equal to optimal marginal infrastructure costs. Optimal means: The marginal infrastructure costs are based on optimal traffic levels and optimal allocation of variable costs. In order to estimate marginal infrastructure costs in its optimum, one has to rely on theoretical recommendations (e.g. engineering simulations) for optimal maintenance and reconstruction cycles and their respective costs, considering optimal traffic flows and anticipating possible adaptation processes. This information is usually not available and deviates from existing maintenance practice (due to limited available financial resources, practical implementation, different engineering standards etc.)

Thus, it is not realistic to base the estimation of short-run marginal costs on (optimal) costs which would represent the first-best practice of maintaining infrastructure. Thus, they should be derived from actual occurring costs. In most cases these can be taken from published official governmental cost statements. In case of privatised infrastructure or of infrastructure which moves towards independence from governmental control (such as the rail sector), an auditor's certificate or a proof by the regulatory body is necessary.

When the estimation is based on existing costs, it is necessary to consider whether there are good reasons for modifying the published estimates. Such adjustments to costs might be required because existing expenditure levels do not reflect the equilibrium level of expenditure required or because of external effects. For example, existing expenditure on maintenance may be below the level required to minimise the costs of maintenance over the full life of the asset. Initially if an infrastructure operator neglects maintenance due to budget constraints, marginal infrastructure costs based on actual maintenance costs (and thus infrastructure charges) will be too low whereas user costs will rise (due to bad surface conditions). If there is no monopoly situation, users can react by changing to other roads or other modes. However, this substitution competition is often limited in regard to the use of infrastructure. In the long run however, in order to repair occurring damages, maintenance costs will rise rapidly, which lead to higher prices and respective reaction of infrastructure users.
Another type of adaptation process should be realised within the social marginal cost approach for infrastructure charging. It seems to be sensible to review in periodic intervals the cost figures in order to adapt the prices to changes of (all) cost categories.

b) The basis for estimating marginal costs: Expenditures versus cost accounts
It should be borne in mind that also for estimating marginal costs a cost account with capitalised investment expenditures has to be chosen. The necessary distinction for estimating marginal costs is those between fixed and variable costs. Also capitalised expenditures such as renewals can contain variable parts. Vice versa one can sort out fixed costs from non-capitalised expenditures (an example is winter maintenance).

c) Interlinkages with other cost categories
Should costs for (existing/implemented) environmental protection measures (such as noise walls, repair or compensation costs for nature and landscape) or traffic control measures (to reduce congestion) be considered, too? Since these costs are internalised (e.g. existing), they should be considered as infrastructure costs. Within a marginal cost approach however, only these costs have to be considered which vary with the traffic level. In fact environmental protection measures already implemented do cause marginal infrastructure costs to a very limited extent. Possible examples are ventilation systems to reduce air pollution within tunnels. All remaining costs are usually fixed.

Thus, additional costs of additional traffic units should be considered within the estimation of congestion and environmental costs, which are treated in the other working groups.

d) Non traffic related parts of infrastructure
This issue is related to road transport. Within the current practice, some countries consider a share of costs which are not necessarily allocated to road transport. The argument is that the road can be used as well by other user groups and other functions (pedestrians, special transport purposes market function). For estimating marginal costs, this aspect is of minor importance, as long as a detailed classification of vehicles (and the allocation method) is used. With regard to

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19 A typical example are maintenance or renewal cycles, which might take place within specific predefined time periods.

20 There is, for example in Germany, also a discussion on costs of rail infrastructure which occur due to politically motivated electrification of lines. Since the respective marginal costs are rather low we neglect this discussion here.
pedestrians, only communal roads have to serve for additional purposes. However, since pedestrians do not cause relevant marginal infrastructure costs, this aspect can be neglected.\textsuperscript{21}

e) Treatment of VAT
Should VAT be included in cost estimations? From an economic point of view, taxes are transfers and should not be considered in a resource oriented cost estimation. At the other side, taxes will increase the financial costs of the operators.

Based on the welfare theoretical baselines of the approach of Social Marginal Cost Pricing, we recommend an exclusion of VAT, since only marginal changes of resources should be considered. This is especially important for practical top-down approach.

3.2.3 Two approaches to estimate marginal infrastructure costs

Based on the recommendation to estimate costs by using empirical cost information, we can distinguish two possible approaches:

1. Estimating cost functions: Based on national data for different influence factors, a cost function can be estimated. Marginal costs will be obtained by the mathematical derivation of this function. The most important baseline is a comprehensive estimation approach and sufficient data.

2. Estimating a marginal cost figure: This approach assumes linearity of the cost function and yields constant marginal costs. This assumption allows a breakdown of existing cost accounts into cost categories as a basis for estimating variable and marginal costs.

a) Estimating cost functions

This approach is both from the theoretical and empirical point of view satisfying and follows the theoretical principle of Social Marginal Cost Pricing correctly. The idea is to estimate a total cost function depending on different influence factors such as

- amount of traffic volumes,
- vehicle weight,
- axle weights configurations,
- vehicle speed,

\textsuperscript{21} However, one has to consider maintenance policy in practice. If a specific road will be paved including the bicycle lanes (due to practical reasons), these additional costs should not be considered for the estimation of marginal infrastructure costs of motorised transport.
– add. for trains: operating requirements (number of stops for trains); number and type of wagons, type of traction.
<table>
<thead>
<tr>
<th>Classification criteria</th>
<th>Approach</th>
<th>Characteristics of approach</th>
<th>Scope</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Functional form</td>
<td>Cost function</td>
<td>Estimation of a total cost function and deriving the marginal cost function, either by econometric methods or engineering background</td>
<td>Whole network, network parts, single sections/lines</td>
<td>Theoretically and empirically adequate approach (first best approach)</td>
<td>High data requirements</td>
<td>BMV (1969) Johansson and Nilsson (1998)</td>
</tr>
<tr>
<td></td>
<td>Single cost figure</td>
<td>Linearity assumption for total cost function, pragmatic breakdown approach of variable cost categories to marginal costs</td>
<td>Whole network, network parts, single sections/lines</td>
<td>Less information necessary, easier (second best approach)</td>
<td>Linearity assumption not confirmed</td>
<td>DIW et. al (1998)</td>
</tr>
<tr>
<td>2. Direction of approach for estimating cost functions</td>
<td>Bottom-up</td>
<td>Starting point are costs of basic package, additional costs of successor vehicle categories are stepwise added (discrete approaching of a continuous cost function)</td>
<td>Single lines/sections</td>
<td>can be done experimentally, real world characteristics, use of engineering knowledge</td>
<td>Generalisation from single sections/lines to whole network complicated, only rough approach to marginal concept</td>
<td>TRL et al. (1996) AASHO-Road test</td>
</tr>
<tr>
<td></td>
<td>Top-down</td>
<td>Starting point are real occurred total costs, functional relationship elaborated by econometric analysis of costs and cost drivers (influence factors)</td>
<td>Whole network, network parts, single sections/lines</td>
<td>Easier to elaborate, generalisation better</td>
<td>BMV (1969) Johansson and Nilsson (1998)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experiment-based or simulated engineering information</td>
<td>Observed or theoretical/simulated engineering relationships</td>
<td>Single lines/sections</td>
<td>Proper reflection of engineering knowledge</td>
<td>Generalisation often difficult, experiments often heavily disputed</td>
<td>TRL et al. (1996) AASHO-Road test</td>
</tr>
</tbody>
</table>

Source: DIW.

Table 5: Approaches for estimating marginal infrastructure costs
There are different approaches for estimating a cost function. They are summarised in table 5. From the direction of the approach one can distinguish between bottom-up and top-down approaches. Concerning the type of information/data used there are estimation procedures based on observed cost behaviour on the one hand and the use of theoretical and experimental relations (engineering knowledge) between infrastructure damage and traffic volume on the other hand.

**Bottom-up approaches** consider first the cost of basic packages (for example construction costs of infrastructure for the lowest vehicle category). In a stepwise approach the additional costs caused by the successor category (or the secondary user) are added. If the successor categories are defined detailed enough one could characterise the bottom-up approach as a discrete (or incremental) approaching to the first deviate of a cost function, e.g. to the marginal cost function. Examples for bottom-up approaches are the Swiss approach of the "minimal road", the prime-user concept of British Rail and a more recent British study which investigates the cost effects of eliminating stepwise certain vehicle categories from the road (TRL et al. 1996).

In contrast to the bottom-up concept which typically investigates single infrastructure sections or lines and generalises the results, **top-down approaches** take the real occurring total costs or total cost components as given and try then to find a functional form for the total costs and the marginal costs. The German infrastructure cost study (BMV 1969) and also the Swedish rail maintenance cost study (Johansson and Nilsson 1998) are examples for this concept.

A typical example for an experiment-based estimation of cost function is the AASHO road test\(^{22}\) which derived within engineering experiments a relation between road damage and axle weight factors: The so-called ‘fourth power rule’ indicates that doubling the axle weights increases road damages by a factor of 16 (\(=2^4\)). This damage function can be translated into cost functions. If road infrastructure costs are proportional to road damages, marginal road infrastructure costs are depending on the axle weight configuration by the same relation. The AASHO experiment would also classified as a bottom-up approach.

Cost functions based on such engineering principles do partly exist both in the road and the rail sector. Since they are used especially for the design of infrastructure, the weight component is most important. Engineering based damage relations are thus an important background.

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As already mentioned, cost functions can also be derived within top-down approaches by using empirical information on cost behaviour, either by cross section analysis or by regression analysis based on time series. In the first case, different sections of infrastructure will be compared and road infrastructure cost will be analysed according to traffic volumes, weights etc. In the second case the change of traffic volumes and weights and the related development of costs in time will be analysed. For both approaches the following steps are necessary:

1. Definition of those cost elements which are relevant for short-run marginal costs
2. Separation of cost elements into classes reflecting the use by different weight classes or different operating requirements
3. Collection of cost and usage data for the classes derived under 2.
4. Regression analysis in order to detect functional relationships between costs, infrastructure characteristics and use of infrastructure

Such regression analysis does as well exist partly. The mentioned German study 1969 has elaborated time series on road costs differentiated for cost components and some network classes with the related traffic volumes. The regression analysis carried out in this study yielded the result that 15% of total costs are marginal costs. A Swedish study of rail maintenance costs derived that 10% of maintenance costs are marginal.

However, there is at present not enough information to derive a representative cost function for the road and rail sector. Therefore, an empirical study analysing these relations would be necessary. In order to improve the empirical basis, a regression analysis (scientific study) providing values for marginal costs might be an interesting addition in order to provide maximum and minimum values for the distinction between variable and fixed costs. This could be done on a European scale (cross section) or on a country scale (cross section, analysis of time series). For the rail sector basic investigations of both approaches are urgently required since there is much less empirical material than for the road sector.

b) A pragmatic approach: Estimating a marginal cost figure rather than a cost function

A more pragmatic approach relates to the existing financial information based on the cost schemes applied in several countries. It is not aimed at estimating cost functions but assumes the total cost function is linear, which means that marginal costs are constant (and not, for instance, increasing with traffic volume). Such an assumption is not generally supported by the
empirical evidence (such as AASHO Road Test, the Swedish study on rail maintenance costs), but it is one of the simplifications often made on pragmatic grounds. The pragmatic approach would contain the following steps:

1. In a first step, according to the cost classification, total expenditures are to be translated into annualised costs (for consistency)
2. Distinction between variable and fixed costs
3. Distinction of the marginal part of variable costs
4. Allocation of marginal costs to different type of vehicles, using different allocation factors.

At least in the road sector such a pragmatic approach is used in some of the EU-countries. However, a harmonisation of these approaches is quite difficult, since road standards, road conditions and maintenance practice will differ between the Member States.23

### 3.3 Classifications

Independent on whether a cost function shall be estimated (econometric study) or a pragmatic approach assuming linearity shall be applied one has to reach a judgement about the relevance of each category of cost for deriving marginal costs. For the moment, the working group has elaborated a proposal dividing different cost elements according to table 6 into fixed and variable costs and indicating how far they are relevant for short-run marginal costs. Within this approach, marginal costs might be (at maximum) equal to average variable costs. In DIW et al. (1998), a study on infrastructure costs of HGV, a similar approach was chosen to estimate marginal costs. The results are given in the annex of this interim report. Similar pragmatic approaches can be applied in rail.

The classification of infrastructure costs is an essential step in order to provide the necessary preconditions both for applying the cost function approach and the more pragmatic approach. Based on current practice, we propose the following structure.

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23 It is very important to state, that private and non private motorways have to be treated the same way as state owned motorways. Thus financial costs (e.g. of a private operator) are not relevant.
a) Cost categories

In table 6 we present a proposal how cost categories could be defined and distinguished from each other. For each of the cost categories it has to be clarified whether and to what extent they are fixed and short-run variable costs and how far they are relevant for marginal costs. The table proposes as a first step some examples of cost categories which are relevant for the estimation of short-run marginal costs.

In that context, it is still open how to define some of the terms used in the table. Some (reconstruction, renewal, replacement) are based on German systems of road accounting (agreed in the 80es) and on international national accounting standards. Created for different reasons, these categories are not ideal. However the table does serve to illustrate the process of categorisation necessary, and to consider costs and cost categories from this perspective. Equivalent Danish categories for instance focus on "new", "renewal", "preventative maintenance", and "routine or running maintenance".

For completeness, table 6 deals with the whole range of total infrastructure costs, including also construction costs. In particular the categories 1.-3. are not relevant if capacity is considered to be given. Energy provision is a specific aspect of the railways. If energy is provided by the infrastructure operator, the costs should be included as short run marginal costs.

Where the cost is identified as "partly" fixed, variable or marginal, a clear basis for splitting the cost should be provided, i.e. after assessing the cost item in detail, determining that X% is fixed and X% marginal. Such a calculation must be transparent, reasonable and defensible.

As short run marginal costs are by definition a subset of short run variable costs, a classifying a cost as a short run marginal cost implies a "yes" in the variable cost column as well.
<table>
<thead>
<tr>
<th>Road</th>
<th>Rail</th>
<th>Fixed costs (only long-run variable)</th>
<th>Short-run variable costs (depending on use of infrastructure)</th>
<th>short-run marginal costs (depending on amount of trains/vehicles)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Land purchase</td>
<td>1. Land purchase</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>2. Construction of new roads</td>
<td>2. Construction of new lines</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>3. Enlargement of existing roads/adjustment to higher axle loads</td>
<td>3. Upgrading/enlargement of existing lines</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>4. Replacement investments</td>
<td>4. Replacement investments</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>4.1 Major repairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Dressing of thin layers and surfacing</td>
<td>– Periodical treatments of route structure (“Gleiskörper”)</td>
<td>partly</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Repairs of bridges, supporting walls and other facilities</td>
<td>– Major repairs of bridges, tunnels, switch boxes and platform which are only performed in larger time intervals</td>
<td>partly</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>4.2 Renewal</td>
<td>4.2 Renewal</td>
<td>partly</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Replacement of layers in underground engineering</td>
<td></td>
<td>partly</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Replacement of bridges and other facilities which restores the full utility value</td>
<td>– Replacement of bridges, tunnels, switch boxes and platforms (or parts of these) as well as replacement of tracks and other facilities which restores the full utility value</td>
<td>partly</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>5. Construction maintenance</td>
<td>5. Construction maintenance</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>– Removal of pot-holes, spilling of joints</td>
<td></td>
<td>no</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Minor repairs (e.g. bridge railings, noise protection walls, protection planks)</td>
<td>– Minor repairs of bridges, noise protection walls, technical facilities</td>
<td>partly</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Pavement renewal (treatment of road surface)</td>
<td>– Ballast cleaning, compression</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Ongoing maintenance and operation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Operation, Servicing and ongoing maintenance</td>
<td>6. Operation, Servicing and ongoing maintenance</td>
<td>yes</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Winter maintenance (snow sweeping)</td>
<td>– Winter maintenance (thawing of switches, snow sweeping)</td>
<td>yes</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Street marking</td>
<td>– Street marking</td>
<td>yes</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Cleaning, cutting</td>
<td>– Cleaning, cutting</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>– Check of facility condition</td>
<td>– Check of facility condition (route servicing, switches)</td>
<td>yes</td>
<td>partly</td>
<td>partly</td>
</tr>
<tr>
<td>– Servicing of bridge beddings, traffic lights for general safety reasons</td>
<td>– Servicing of bridge beddings, signalling, telecommunication facilities for general safety reasons</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>– operation of signalling/telecommunication facilities, switch towers (staff, electric power)</td>
<td>mainly not</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>– traction current</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Administration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Overhead</td>
<td>7. Overhead</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>8. Police/Traffic control</td>
<td>8. Police</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>9. Time tabling, train planning</td>
<td>9. Time tabling, train planning</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 6: Proposition for a classification of cost categories
b) **Vehicle categories**

Since the most important cost category to derive marginal costs is road damage, a vehicle classification which allows to reflect the most important factors for road damage is necessary. The most significant cause of damage is vehicle axle weight. Categories should therefore relate directly to axle weight where possible. Where such information is unavailable, a slightly weaker version would be to use max. gross vehicle weight, number of axles, type of suspension and tyre pressure. A third option is to use standard existing classifications, and to distinguish categories on the above grounds where possible. For the road sector we suggest the minimum standard classification given in section 2.1.1 b, e.g.:

- Motorcycles,
- Passenger Cars,
- Buses,
- Light Goods Vehicles (< 3.5 t max. Gross vehicle weight),\(^{24}\)
- Heavy Goods Vehicles (> 3.5 t max. Gross vehicle weight),
  - Rigid goods vehicles (lorries without trailer),
  - Lorries with trailer,
  - Articulated vehicles (tractors with semi-trailer),
  - agricultural or military vehicles, if important.

As far as rail is concerned trains should be classified according to wagon weight and speed, as these are the cost drivers. Again, using pragmatic existing categories, we propose:

- freight trains (wagon load, combined transport, rolling road)
- Passenger trains (High-speed trains, Euro-/Intercity and other long-distance trains, regional trains, Urban rail)

and ideally further sub-divisions according to the following criteria:

- operating requirements (number of stops, required distance to other trains)
- construction standards (speed)
- weight (axle weight)
- number and type of wagons

\(^{24}\) Resp. acc. to actual classifications of EUROSTAT.
• Type of traction for the energy provision (Electric, Diesel)
• Quality of maintenance of trains

e) Network categories
As with vehicle categories, network categories separate infrastructure of widely differing costs. Since marginal cost differ between road categories (motorways, main roads, communal roads), the following classification should form the basis:

- National Motorways
- State roads (trunk roads)
- Regional roads (Provincial roads)
- Urban streets

It should be borne in mind that in particular for introducing urban road pricing a separate treatment of urban roads is necessary. However, the data situation in most EU-countries is extremely weak for this road category.

Additional elements for the differentiation of importance for cost considerations are different road elements such as number of lanes, bridges, tunnels, specific road sections. A further classification according to these items should be used, if there are significant differences to the average.25

For the rail sector a division of the network into main lines and minor lines with a separate treatment of electrified lines seems to be realistic. A typology of traffic types into short-distance passenger transport, long-distance passenger transport and freight should form the minimum standard.

3.4 Cost allocation
Cost allocation procedures depend on the estimation method applied. Within a theoretical or empirical cost analysis, cost allocation is usually indirectly provided, since coefficients for different influence factors will be the implicit result. These influence factors can be combined in order to derive marginal costs for different type of vehicles or trains.

25 It has to be noted, that this further differentiation is necessary, if price differentiation of road will have a similar scope.
In a more practical approach\textsuperscript{26} the allocation procedure has to be more transparent. The following proposition is aimed at meeting this requirement.

\textbf{a) Road sector}

Based on the current practice in the EU-countries we recommend a top-down approach, since this guarantees the required transparency. As soon as the short-run marginal cost components (or at least the variable costs) are separated, the allocation goes along specific indicators as mentioned in chapter 2.

\begin{table}[h!]
\centering
\begin{tabular}{|l|l|}
\hline
Variable cost categories & Possible allocation               \\
\hline
Major repairs & Axle weights, Gross vehicle weights (maximum or average) \\
\hline
Renewal & Axle weights, Gross vehicle weights, Passenger Car Units \\
\hline
Construction maintenance & Axle weights \\
\hline
Operation, servicing and ongoing maintenance & vehicle kilometres, Passenger Car Units \\
\hline
Police & Vehicle kilometres \\
\hline
\end{tabular}
\caption{Possible allocation factors for the allocation of variable cost to different type of vehicle in the road sector.}
\end{table}

Basically the allocation should use standard axle factors (AASHO factors, if reasonable also reduced factors) to allocate weight dependent marginal costs and PCU’s and/or vkm to allocate non weight dependent marginal costs. These factors might vary from country to country.

In order to improve the empirical basis for Europe, an extension of the above mentioned cross section analysis (considering as well different traffic mixes, different HGV shares) might be useful.

\textsuperscript{26} As discussed this approach assumes linearity of cost functions. A more advanced practice could be to use results of empirical studies on the shape of cost functions.
b) Rail sector
If charging systems shall be linked to cost figures, first of all some quantitative knowledge on the proportion between variable and fixed costs is necessary. This must be followed by a definition of allocation factors. These could be for the variable part weight dependent factors and factors reflecting the number of stops required.

4 Recommendations
4.1 Proposition for the estimation of marginal costs
In chapter 3 we have stated that the estimation of marginal infrastructure costs should be based on actual costs, taking into account the requirement to adjust these figures in certain circumstances. Given this we recommend to use the possible approaches in parallel:

- In the short run, the pragmatic top down approach should be used in order to estimate a cost figure. The recommended table 6 serves as a basis for the classification of different cost elements. Besides, a transparent cost allocation procedure should be applied.

- The expected optimum equilibrium, however, would require that the short-run marginal costs are estimated in a theoretically and empirically adequate approach, e.g. with increased knowledge on cost functions. We suggest therefore, in parallel to the pragmatic approach, that more work on the empirical basis of cost functions and on the variables that influence them is carried out in order to provide more detailed information. Thus, we recommend further investigation, based on a pilot study using available data of some Member States. We also suggest that in the case of short-run marginal infrastructure costs this would be feasible since methodologies exist and data are available (or can be elaborated).

- The output of both approaches should be reviewed and the plausibility of the results assessed by comparing the country results and the results of the pilot study on cost

---

27 It is important to state, that capacity pricing in the rail sector (cost oriented according to opportunity cost or demand oriented according to willingness to pay) should be treated in WG2.

28 It is important to mention, that such a study must consider possible sub-optimal maintenance procedures in different countries in order to provide robust results. Thus it is necessary to include certain adjustment factors to make countrywise data comparable.
functions.

- At the end of this process a unit cost scheme based on the empirical output should be elaborated. This should serve as national standard cost tables.

- Separate investigations both on the methodological and empirical side for air transport and waterborne transport have to be carried out.

### 4.2 Data requirements

Starting with data requirements for the pragmatic top-down approach, one first has to state that there exists an EC-regulation from 1970 which obliges all member states to report infrastructure expenditures and infrastructure usage data. These data, if they were indeed reported by all countries, would be sufficient as an empirical basis for the pragmatic top-down approach. However, experience shows that most data are not or only partly reported which might amongst other reasons also be due to the excessive level of detail required. Given this, we suggest that the essential data which should be collected on an annual basis should comprise:

- expenditures for road and rail infrastructure, divided into investment, maintenance and operation, administration,

- mileage’s broken-down to vehicle categories, in particular to weight classes for HGV and with a separate treatment of buses,

- train-km and axle weight-km, broken-down to traffic types.

These data should be provided for the network categories proposed in chapter 3. Additionally, information on cost allocation procedures in the rail sector is necessary, at least information on the split between variable and fixed costs for the most important cost categories.

The following requirements are necessary for the estimation of cost functions:

- Clustering: Apart from traffic and vehicle characteristics, the cost drivers are certain features of infrastructure such as construction standards for certain usage classes and traffic mix, geographical area (for example mountainous areas or ecologically sensitive regions) and track formation (number of sleepers etc.). Therefore, for the mentioned econometric study, the road and rail network has to be differentiated into such cost-relevant classes, if possible broken down to line sections. A minimum requirement, however, if such a detailed differentiation is not possible, is the differentiation into
road/rail types as pointed out in 3.3,

- Cost information according to the classifications in table 6 for the network classes mentioned above
- Traffic performance (tonne-km) and mileage’s/train-km
- Traffic split according to vehicle characteristics (esp. weight, axle loads)

For a cross-section analysis this information has to be provided for one reference year, however, for very detailed network sections. For a time series based regression analysis these data have to be delivered for a longer time period.
Annex 1: Extended list of rail service packages

(Source: EU Draft directive of railways infrastructure charging)

The "minimum access package" shall comprise:

a) Handling of requests for capacity.

b) The right to utilise track capacity which is granted.

c) Use of running track points and junctions.

d) Train control including signalling, regulation, dispatching and the communication and provision of information on train movement.

e) All other information required to implement or operate the service for which capacity has been granted.

Access Services shall comprise:

a) Access to refuelling facilities

b) Access to passenger stations, their buildings and other facilities

c) Access to freight terminals

d) Access to marshalling yards

e) Access to train formation facilities

f) Access to storage sidings

g) Access to maintenance and other technical facilities

Mandatory services shall comprise:

a) Assistance in the case of serious incidents or serious disturbance to normal train movements.

b) Police intervention where necessitated

c) Monitoring the compliance with safety and regulatory standards by undertakings.

Additional services shall comprise:

a) Use of electrical supply equipment for traction current

b) Traction current

c) Pre-heating of passenger trains

d) Supply of fuel

e) Shunting

f) Tailor made contracts for: control of transport of dangerous goods

Ancillary Services shall comprise:

a) Access to telecommunication network

b) Provision of supplementary information

c) Technical inspection of rolling stock
Annex 2: Road sector: Classifications and cost allocation methods in selected Member States

The following tables presents the existing practice on classifications, separation of fixed and variable costs and cost allocation to different vehicle categories. For this annex the member states with the most sophisticated practice (source DIW et al. 1998) were chosen. The tables serve as an illustration for applying the recommended top-down approach.

a) Denmark

<table>
<thead>
<tr>
<th></th>
<th>Fixed costs</th>
<th>Variable costs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in % Vehicle-km in % Vehicle-length-km</td>
<td>in % Standard-axle weight-km in %</td>
<td>in %</td>
</tr>
<tr>
<td>Administration</td>
<td>Motorways and trunk roads</td>
<td>70 30 0 0 0 0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Principal and communal roads</td>
<td>80 20 0 0 0 0</td>
<td>100</td>
</tr>
<tr>
<td>Winter maintenance</td>
<td>Motorways and trunk roads</td>
<td>50 30 20 0 0 0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Principal and communal roads</td>
<td>50 30 20 0 0 0</td>
<td>100</td>
</tr>
<tr>
<td>Other maintenance</td>
<td>Motorways and trunk roads</td>
<td>70 20 10 0 0 0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Principal and communal roads</td>
<td>70 20 10 0 0 0</td>
<td>100</td>
</tr>
<tr>
<td>Reconstruction</td>
<td>Motorways and trunk roads</td>
<td>30 0 25 45 0 0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Principal and communal roads</td>
<td>50 0 10 40 0 0</td>
<td>100</td>
</tr>
<tr>
<td>Investment</td>
<td>Motorways and trunk roads</td>
<td>0 45 40 15 0 0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Principal and communal roads</td>
<td>0 80 15 5 0 0</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: COWI.
### b) UK

<table>
<thead>
<tr>
<th>Expenditure item</th>
<th>Percentage of costs of item allocated to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vehicle-km</td>
</tr>
<tr>
<td>Capital expenditure</td>
<td>-</td>
</tr>
<tr>
<td><strong>Maintenance expenditure</strong></td>
<td></td>
</tr>
<tr>
<td>1 Reconstruction and resurfacing</td>
<td>-</td>
</tr>
<tr>
<td>2 Haunching</td>
<td>-</td>
</tr>
<tr>
<td>3 Surface dressing and skid treatments</td>
<td>20</td>
</tr>
<tr>
<td>4 Patching and minor repairs</td>
<td>-</td>
</tr>
<tr>
<td>5 Drainage</td>
<td>100</td>
</tr>
<tr>
<td>6 Bridges and remedial earthwork</td>
<td>-</td>
</tr>
<tr>
<td>7 Grass and hedge cutting</td>
<td>100</td>
</tr>
<tr>
<td>8 Sweeping and cleaning</td>
<td>50</td>
</tr>
<tr>
<td>9 Traffic signs and pedestrian crossings</td>
<td>100</td>
</tr>
<tr>
<td>10 Road marking</td>
<td>10</td>
</tr>
<tr>
<td>11 Footways, cycle tracks and kerbs</td>
<td>-</td>
</tr>
<tr>
<td>12 Fences and barriers</td>
<td>33</td>
</tr>
<tr>
<td>13 Winter maintenance a. miscellaneous</td>
<td>100</td>
</tr>
<tr>
<td>14 Street lighting</td>
<td>50</td>
</tr>
<tr>
<td>Police and traffic warden</td>
<td>100</td>
</tr>
</tbody>
</table>

<sup>1)</sup> Except on motorways, where no allocation is made to pedestrians and all expenditure is allocated to vehicles.

*Source: DETR.*
c) **Finland**

<table>
<thead>
<tr>
<th>Service</th>
<th>Fixed costs in %</th>
<th>Variable costs allocated per km in %</th>
<th>Variable costs allocated per weight in %</th>
<th>Total in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter maintenance</td>
<td>95</td>
<td>5</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Maintenance of paved roads</td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Maintenance of light-paved roads</td>
<td>25</td>
<td>25</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Maintenance of gravel roads</td>
<td>40</td>
<td>25</td>
<td>35</td>
<td>100</td>
</tr>
<tr>
<td>Traffic guidance and information</td>
<td>70</td>
<td>30</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Landscaping and sanitation</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Bridges</td>
<td>50</td>
<td>25</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Ferries etc.</td>
<td>75</td>
<td>20</td>
<td>5</td>
<td>100</td>
</tr>
</tbody>
</table>
**d) The Netherlands**

<table>
<thead>
<tr>
<th></th>
<th>Investment expenditures</th>
<th>Maintenance/Operation/Overhead expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>capacity costs</td>
<td>fixed costs</td>
</tr>
<tr>
<td></td>
<td>weight dependent costs</td>
<td>variable costs</td>
</tr>
<tr>
<td></td>
<td>others</td>
<td></td>
</tr>
<tr>
<td></td>
<td>85 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 %</td>
<td></td>
</tr>
<tr>
<td>allocated by Vkm *</td>
<td>allocated by Vkm *</td>
<td>allocated by Vkm *</td>
</tr>
<tr>
<td>PCU¹</td>
<td>axle-load</td>
<td>PCU¹</td>
</tr>
<tr>
<td></td>
<td>4th power</td>
<td></td>
</tr>
<tr>
<td>treated as</td>
<td>allocated by Vkm *</td>
<td>allocated by Vkm *</td>
</tr>
<tr>
<td></td>
<td>maintenance/overhead</td>
<td>PCU¹</td>
</tr>
<tr>
<td></td>
<td>expenditures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>allocated by Vkm *</td>
<td>PCU¹</td>
</tr>
<tr>
<td></td>
<td>axle-load</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1st power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4th power</td>
<td></td>
</tr>
<tr>
<td>category I</td>
<td>42 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>maintenance of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bridges, tunnels,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>retaining walls</td>
<td></td>
</tr>
<tr>
<td></td>
<td>maintenance of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>earthwalls</td>
<td></td>
</tr>
<tr>
<td></td>
<td>grass and hedge cutting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>traffic signs,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>traffic surveillance,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>telephones</td>
<td></td>
</tr>
<tr>
<td></td>
<td>street lighting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>drainage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>maintenance of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bicycle lanes and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sidewalks</td>
<td></td>
</tr>
<tr>
<td>category II</td>
<td>29.6 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>winter maintenance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(snow sweeping, sand)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>street marking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>safety measures</td>
<td></td>
</tr>
<tr>
<td>category III</td>
<td>11.5 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>treatment of road</td>
<td></td>
</tr>
<tr>
<td></td>
<td>surface</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(thin tar/asphalt layers)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>partial maintenance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>measures for pavements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>repair of road holes,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>etc.</td>
<td></td>
</tr>
<tr>
<td>category IV</td>
<td>16.9 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pavement renewal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>other reconstruction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>measures</td>
<td></td>
</tr>
</tbody>
</table>

¹ As PCU’s are used: passenger car = 1, rigid goods vehicles = 2, goods vehicles combinations = 3. Source: Dienstwegen Waterbowkunde en TU Delft.

*Source: DHV/Tebodin 1992.*
e) Sweden

<table>
<thead>
<tr>
<th>Cost items</th>
<th>Vkm</th>
<th>Vkm * PCU</th>
<th>Vkm * AASHO-factors</th>
<th>Vkm</th>
<th>Vkm * AASHO-factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed costs % allocated by</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Variable costs % allocated by</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Investments**
- Federal roads 79 21
- Municipal roads 74 26
- Private roads 92 8

Increase in bearing capacity 100

**Maintenance/Operation expenditures**

**Federal roads**
- Winter road maintenance 95 5
- Paving maintenance 25 75
- Bridges 67 13 20
- Ferries & bridge oper. 75 20 5
- Gravel road maintenance 40 25 35
- Driving supervision, etc. 90 10
- Traffic security 90 10
- Improvement measures 75 25

**Municipal roads**
- Paving maintenance 20 40 40
- Winter road maintenance 95 5
- Bridges, etc. 60 20 20
- Other 100 10

**Private roads**
- 74 6 10

1) As PCU’s are used: passenger car = 1.

Annex 3: Overview on figures of marginal costs within the road and rail sectors

Within the HGV study launched by DG VII (DIW/INFRAS 1998), average and marginal costs of HGV in different countries were estimated, applying the proposed practical top down approach by allocating different cost categories, as far available data allowed this. As can be seen from there the variety of results is quite high and it should be noted in advance that the estimation of marginal infrastructure costs is complicated. The results presented should be treated with some caution since they are based on different methodologies and stem from different sources.

It is not the idea here to interpret this data in detail. Moreover it should become clear, that a cost allocation based on available financial data seeks for a detailed analysis of the cost categories themselves (What is meant in different countries?) and the variability of these categories (Which part of the costs are variable, which marginal?). The analysis within the study has shown, that both elements could currently not be answered in the necessary detailed manner. Thus a cross country analysis would be very helpful in order to verify the different cost levels obtained.
Within this study the French results of the Brossier-study (1996) are included. For Austria, there is more recent information available for the infrastructure costs of HGV (ISTU 1998). Within a comparative analysis of total costs, they get ATS 0.52 resp. EURO 0.03/Km for motorways and ATS 1.28 resp. EURO 0.08/Km for other roads. These values are significantly lower than the values estimated in the DIW-report.
Figure 2  Average and marginal costs of HGV for roads in Europe 1994  
- Motorways -

The following table provides some model results (unit costs) for different items of marginal railway infrastructure cost:

<table>
<thead>
<tr>
<th>UK</th>
<th>Cost (£000s)</th>
<th>Sweden</th>
<th>Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail renewal (£/mile)</td>
<td>254</td>
<td>Track wear and tear (per gross tkm)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Sleeper renewal (£/mile)</td>
<td>486</td>
<td>Use of marshalling yards (per wagon, occasion)</td>
<td>0.4457</td>
</tr>
<tr>
<td>Ballast renewal (£/mile)</td>
<td>501</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Points renewal (£/unit)</td>
<td>181</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tamping (£/mile)</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail repair (£/failure)</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Points repair (£/failure)</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5:  Comparison of Unit Activity Cost Inputs  (current prices) (Source: Railtrack (1999) and Swedish National Rail Administration data (1998))\(^{30}\)

\(^{30}\) France recommends a value of 11 Franc resp. 1.7 EURO per train kilometer as a basis for marginal costs, based on a paper by Laurent Menard, ministry of finance.)
## Glossary

**Total cost**  
Sum of fixed and variable costs occurring in a specific time period (of a vehicle category/infrastructure category).

**Average costs**  
are the total costs divided by a measure of output such as vkm of train-km.

**Variable cost**  
refer to those costs depending on the amount of vehicles/trains passing a specific road/track. One of the most important examples are maintenance costs due to road/track deterioration. These costs depend usually on the amount of vehicle/trains, the size and weight of vehicles/trains.

**Fixed costs**  
are independent on the km driven by vehicles/trains. Most important are (main parts of) capital costs and fixed costs for administration.

**Marginal costs (short-run)**  
are specific variable costs, referring to the vehicle-km/train-km driven on existing infrastructure (without considering a capacity increase). They reflect the additional cost of an additional vehicle/train imposes. As long cost functions can be assumed to be linear, marginal costs are equal to variable costs.

**Marginal costs (long-term)**  
Additionally to short term marginal infrastructure costs, long term costs do consider possible new investments or capacity increases. The calculation of these cost is rather difficult since it has to be known which future infrastructure are necessary and appropriate. To find an optimal path for capacity increases, an infrastructure operator has to compare marginal congestion costs and marginal investment costs for future capacity increases.
References

BMV, Arbeitsgruppe Wegekosten im Bundesverkehrsministerium: Bericht über die Kosten der Wege des Eisenbahn-, Straßen- und Binnenschiffsverkehrs in der Bundesrepublik Deutschland, Schriftenreihe des Bundesministeriums für Verkehr, Heft 34, Bad Godesberg 1969.


Coopers&Lybrand Le péage study. UIC Phase 1 and 2

DIW/INFRAS/HERRY/NERA: Infrastructure capital, maintenance and road damage costs for different heavy goods vehicles in the EU. Berlin 1998

ECMT Efficient Transport in Europe, Paris 1998


EU 1998b Proposals for directives concerning railway infrastructure, Brussels 1998

ISTU Institut für Strassenbau und Strassenerhaltung, TU Wien: Einfluss des Schwerverkehrs auf die Bau- und Erhaltungskosten des Strassenoberbaus, Vienna 1998

LIBERAIL Methodology for determination of the costs of using the infrastructure (Work package 3)


Railtrack Structure of rail access charges; summary of asset usage cost research, Feb. 1999
<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PETS</td>
<td>Pricing European Transport Systems, D2, Summary of Transport Pricing Principles</td>
</tr>
</tbody>
</table>