SIXTH FRAMEWORK PROGRAMME
PRIORITY 1.6.2
Sustainable Surface Transport

CATRIN
Cost Allocation of TRansport INfrastructure cost

D2
Internal Blueprint for Case Studies

Version 1.3
August 2008

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with contribution from partners

Contract no.: 038422
Project Co-ordinator: VTI

Funded by the European Commission
Sixth Framework Programme

CATRIN Partner Organisations
VTI; University of Gdansk, ITS Leeds, DIW, Ecoplan, Manchester Metropolitan University, TUV
Vienna University of Technology, EIT University of Las Palmas; Swedish Maritime Administration,
University of Turku/Centre for Maritime Studies

CATRIN
FP6-038422
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0 Executive Summary
The report highlights four important tasks for CATRIN.

- To provide more evidence on the relationship between marginal cost (MC) and average cost (AC), i.e. the cost elasticity. Ultimately this relationship will define the rate of cost coverage from marginal cost based charges.
- To improve the knowledge on the shape of the cost curve (decreasing versus increasing). The shape of the MC curve will define the MC based price and rate of cost coverage for infrastructure with different levels of traffic demand and thus explain regional differences.
- To increase the knowledge of marginal cost in relation to different vehicle types. For this differentiation the CATRIN case studies include a meta-analysis of engineering experience in the field of infrastructure deterioration.
- To improve the comparability of results between different studies and ensure a clear classification of cost items included.

An important characteristic of research on marginal cost estimation for infrastructure is the lack of sufficiently detailed data on the cost of maintaining, operating and renewing transport infrastructure as well as on the use of infrastructure across all modes of transport. It appears that for applying state-of-the-art estimation methods, researchers have to allocate a considerable bulk of time and resources to collect this type of data. This will also hold true for the CATRIN case studies. While a general improvement of the data situation is a task for the administrations in the sector and cannot be subject of a research project like CATRIN, the CATRIN case studies have to anticipate this problem and should care for a thorough documentation of data collection including a precise definition of the type of data collected.

This report describes definitions of different cost items and clarify that no common classification is available. Nevertheless, to ensure comparability between case studies the classification below is proposed in the report as a blueprint. It is clear that data can not be collected in the ideal way in each case study but the studies will use the classification below as a reference point when describing their studies.
### Table: 0 CATRIN classification

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<td>Bringing the infrastructure back to its original condition. Replacing large sections of more than one layer of the (road) construction but without improving the level of service. Often at the same time replacing drainage, street lighting, signing and safety fence</td>
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<tr>
<td>Maintenance (part of EUROSTAT maintenance)</td>
<td>Preventive measures against deterioration of the infrastructure or corrective measures to repair minor damages</td>
<td>Routine maintenance, Construtional maintenance, Preventive maintenance, annual maintenance</td>
<td>Crack sealing, patching, shoulder maintenance etc Tamping, ballast cleaning etc</td>
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<tr>
<td>Operation (part of EUROSTAT maintenance)</td>
<td>To keep the infrastructure open for traffic</td>
<td>Ongoing maintenance (running expenditures)</td>
<td>Snow removal, cleaning, grass cutting, signals</td>
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1 Introduction

The CATRIN project aims to support policy makers in implementing efficient pricing strategies in all modes of transport, e.g. pricing strategies which are based on the social marginal cost principle. CATRIN focuses solely on infrastructure costs, e.g. on the costs of providing, maintaining, renewing and operating infrastructure, but covers also scarcity and congestion costs due to their close relationship to the costs of infrastructure in a narrow sense. Specifically, it addresses the allocation of infrastructure costs in all modes of transport. It includes three distinctive, though interrelated, sections of work packages which 1) set the approach by providing a state-of-research review well as the theoretical framework, 2) take the approaches to real world cases, 3) exchange findings with infrastructure managers and synthesise results.

The motivation to conduct a research project on this issue is the fact that available studies on marginal infrastructure costs tend to provide some type of “average” marginal cost estimates but often fail to obtain marginal cost estimates by types of vehicles or groups of users. On the other hand, a range of fully allocated cost studies are available which provide average cost estimates by type of vehicle. However, using these studies for pricing purposes bears problems. Average costs are not the appropriate basis for efficient pricing, and the allocation methods used in these studies often tend to allocate arbitrarily fixed, common and joint costs to vehicle types. As a consequence, average costs by vehicle types vary greatly, depending on the methodology used.

This deliverable D2, Internal Blueprint for Case Studies Cost Allocation practices in the European Transport Sector, is the second of two reports from WP1 – State of the art methodology and survey of existing practice. Based on the review of available research and national practices summarised in deliverable D1 (Link et al. 2008) of work package 1, this second deliverable is aimed at providing a common framework for the case studies to be conducted in the further course of CATRIN. Obviously, beside case study specific issues, the scope and the characteristics of case studies as well as estimation methods used will differ, depending on the progress of research already made in the specific mode, and on the quality and disaggregation of data. While these differences between case studies have to be accepted it is felt to be important that all case studies follow a common research framework. First of all, such a common framework refers to a clarification and common understanding of terms and definitions used. Second, all case studies should, apart from their specific area of interest,
cover a set of common research questions and provide a common set of outcomes in terms of estimates and variable types. Third, while estimation methods will differ from study to study, all case studies have to ensure a clear description of methods, and as far as possible sensitivity tests.

This document is organised as follows. Chapter 2 summarises the major findings from the state of the art review of available research and national practice. Chapter 3 defines cost-related terms and definitions. Chapter 4 is the blueprint for the case studies. It contains also a reporting format for the case studies.
2 Starting point for the case studies from available research

A comprehensive review of research and national practice of allocating infrastructure costs has been conducted in D1 of CATRIN (see Link et al. 2008). This review has first of all covered genuine marginal cost studies, either based on observed spending for maintenance, operation and renewal of infrastructure and conducted as econometric cost function studies, or based on physical measurements of infrastructure damages (duration approaches). Second, Link et al. 2008 has also analysed fully allocated cost studies, in particular regarding the underlying assumptions of allocation methods, their coherence within each country and differences across countries, and the type and quality of databases.

The analysis of available research has shown that the body of available research differs considerably between the modes. Marginal cost studies have emerged over the recent years within EU funded projects, in particular for road and rail. Fully allocated cost studies exist traditionally in the road sector where a considerable body of estimation and allocation methods is available, and though to a lesser extent, in the rail sector and in aviation. The situation is rather poor in waterborne transport. In the following we summarise the main findings from this review as a starting point for developing the blueprint for the CATRIN case studies. The focus is on marginal cost studies and the lessons learnt, rather than on lessons and research needs arising from fully allocated cost studies since the CATRIN case studies are aimed at improving knowledge on marginal costs rather than on average costs.

One of the most important policy-relevant findings from marginal cost studies is evidence on the degree of cost variability and on the cost elasticity, e.g. the ratio between MC and AC. For both road and rail, the studies provide evidence that the mean value of the cost elasticity is generally below 1 (road) and 0.5 (rail) respectively. Furthermore, the cost elasticity increases with the time horizon of the measure. Across studies, the variation of estimates for the cost elasticity is larger for studies which deal with maintenance costs than for those dealing with other types of infrastructure measures. Against this background, an important issue for the CATRIN case studies is to provide more evidence on these relationships from analysing new/improved datasets. Since differences across study results might originate from different

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1 For example for road operation: close to zero, for road maintenance: 0.12-0.69, for road renewals: 0.57-0.87, for rail maintenance: 0.07-0.26, for rail maintenance and renewals: 0.18-0.30.
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definitions of maintenance and renewals in the data used, an important point for CATRIN is to clarify and define more precisely which items are included in the data.

A second issue for the CATRIN case studies refers to the shape of the cost curve. At the current frontier of research, marginal cost studies have not yet achieved convergence regarding the shape of the MC curve (decreasing versus increasing). This holds in particular true for the road sector, to some extent also for rail. An important task for the CATRIN case studies is to analyse to what extent the differences might be linked to differences in estimation methods/modeling approaches used.

Third, marginal cost estimates from available studies come currently in form of “average” marginal costs both in relation to the shape (see above) and in relation to different vehicle types. They provide a starting point for marginal cost prices by indicating the level of marginal costs, but need to be disaggregated by vehicle types or user groups. For this differentiation the CATRIN case studies have to include a meta-analysis of engineering experience in the field of infrastructure deterioration.

A fourth research need arising from the current state of research is the comparability of results. One of the most decisive restrictions for comparing studies is the use of different output measures (for example for road: ESAL-km, vkm, HGV-km, for air transport: air transport movements, passenger numbers, work load units) in the studies. It seems therefore desirable that the CATRIN case studies use as far as possible a common set of output measures, apart from case study/data specific output variables.

The review of available research and national practice has shown that the most important factors to allocate road pavement damage costs have still been the ASSH(T)O factors. On the other hand, the rule is still subject to criticism, many countries use adjusted AASH(T)O factors and new developments of vehicle techniques would have to be considered. Against this background, one of the CATRIN case studies will deal with the design of an European road damage experiment.

Finally, an important characteristic of research on marginal cost estimation for infrastructure is the lack of sufficiently detailed data on the cost of maintaining, operating and renewing transport infrastructure as well as on the use of infrastructure across all modes of transport. It

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2 It appears that for rail the most consistent finding from econometric studies is that i) marginal costs fall with traffic levels, and, ii) are initially very high with low usage levels but fall then sharply, a result which is in contrast to the engineering expectation of a proportional increase of wear & tear with usage.
appears that for applying state-of-the-art estimation methods, researchers have to allocate a considerable bulk of time and resources to collect this type of data. This will also hold true for the CATRIN case studies. While a general improvement of the data situation is a task for the administrations in the sector and cannot be subject of a research project like CATRIN, the CATRIN case studies have to anticipate this problem and should care for a thorough documentation of data collection including a precise definition of the type of data collected.
3 Standard definitions of cost related terms

The aim of this chapter is to clarify cost-related terms and definitions which are relevant for the case study work in CATRIN. Two reasons make this clarification particularly important. First, it appears that available studies use a variety of terms for partly the same, partly overlapping issues. Often this has to be accepted due to the fact that the data used have originally been compiled for other purposes with the corresponding definitions and by considering practicability concerns. All the more, a clarification of terms is important for comparing results and explaining differences in research findings. Second, there are different principles and criteria to categorise costs. The outcome of this are sub-categories of costs which may, if properly defined, provide a starting point both for deriving marginal costs and to differentiate average marginal costs further by types of vehicles. This chapter gives explanations in form of a glossary rather than in form of a theoretical chapter. An attempt was made to categorise the different terms regarding the criteria used for defining them.

3.1 The life expectancy of infrastructure measures

Infrastructure expenditures versus infrastructure costs
Infrastructure expenditures are periodical (e.g. annual) monetary flows. In contrast to expenditures, infrastructure costs take into account the service life and opportunity cost (benefits of an alternative use of money) of investments. Infrastructure costs contain thus the capital costs (see below) and the non-capitalised part of annual expenditures for infrastructure.

Investment expenditures and capital costs
All spending on assets which have an expected life of more than one period (one year) should be capitalised. Capital costs comprise the consumption of this fixed capital. In principle, it should be measured by adding two components; the change in value of a piece of equipment at dates t and t+1; and the interest foregone during this period by tying up capital in this piece of asset. For most standard-type assets, secondary markets provides a proxy for the value of an asset over time. Since secondary markets for in particular roads and railways are non-existent, the measurement of capital cost in infrastructure is particularly challenging.
Depreciation based on rule-of-thumb may provide more or less good proxies for the capital costs.³

**Running expenditures (costs)**

Running expenditures are annual monetary flows with a lifetime of less than one year, e.g. production and consumption occur in the same period). Consequently, they are equal to running costs.

### 3.2 The purpose of expenditures

**Investments, maintenance, renewals, operation**

This is an important distinction both for the question which parts of expenditures have a service life of more than one year and are capital costs, and for the comparison of national practice and studies regarding the nature of expenditures considered. In particular the distinction between maintenance and renewal and between maintenance and operation differs across countries and studies, indicating that these categories are sometimes overlapping and fluent. As stated above, investments refer to those expenditures with an expected lifetime of more than one year which have to be capitalised (e.g. calculation of depreciation and interests). These types of expenditures usually comprise new construction and enlargement/upgrading of infrastructure, renewals and replacements. Maintenance which is classified as running expenditure (so-called ongoing maintenance) consists of winter maintenance, snow sweeping, street marking, safety checks and servicing of facilities. Apart from these types of maintenance activities, there are more substantial maintenance measures which have often a life-time of more than one year such as removals of pot-holes, minor repairs, ballast cleaning and compression in the rail sector. In some countries these types of work are called constructional maintenance, in other countries they belong to renewal measures (and as such to investments). Operation expenditures comprise for example expenditures for cleaning, grass cutting signalling and lighting, rail traction, operation of switch towers. In some countries snow sweeping and winter maintenance are defined as operation. Often also the expenditures for administration, traffic control and police are included, if not separately reported as overheads.

In EUROSTAT (2003) a classification is given for investment expenditures and maintenance expenditures on certain types of infrastructure (see table below). In general the two types of expenditures are defined as:

- Investment: Expenditure on new construction and extension of existing infrastructure, including reconstruction, renewal and major repairs of infrastructure
- Maintenance: Expenditure for keeping infrastructure in working order.

### Table 1: EUROSTAT definition of investment and maintenance expenditures for certain types of infrastructure

<table>
<thead>
<tr>
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<th>Investment expenditures</th>
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</tr>
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<tbody>
<tr>
<td>Road Transport</td>
<td>Expenditure on new construction and extension of existing roads, including reconstruction, renewal and major repairs.</td>
<td>Expenditure for keeping roads in working order. This includes surface maintenance, patching and running repairs (work relating to roughness of carriageway’s wearing course, roadsides, etc.).</td>
</tr>
<tr>
<td>Railway Transport</td>
<td>Expenditure on new construction and extension of existing infrastructure, including reconstruction, renewal and major repairs of infrastructure. Infrastructure includes land, permanent way constructions, buildings, bridges and tunnels, as well as immovable fixtures, fittings and installations connected with them (signalling, telecommunications, catenaries, electricity sub-stations, etc.) as opposed to rolling stock.</td>
<td>Expenditure for keeping infrastructure in working order.</td>
</tr>
<tr>
<td>Inland waterways</td>
<td>Expenditure on new construction and extension of existing infrastructure, including reconstruction, renewal and major repairs. Expenditure on locks is included.</td>
<td>Expenditure for keeping infrastructure in working order. Expenditure on locks is included.</td>
</tr>
<tr>
<td>Maritime Transport</td>
<td>Gross investment in buildings, structures and land. Expenditure on land, new construction, purchase of existing buildings (including the land irrelevant), extension of existing infrastructure, including reconstruction, renewal and major repairs. Inland waters, harbours and harbour approaches are included.</td>
<td>na</td>
</tr>
<tr>
<td>Aviation</td>
<td>na</td>
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</tr>
</tbody>
</table>


In European standards (EN 13306:2001) ‘maintenance’ is defined as ‘combination of all technical, administrative and managerial actions during the life cycle of an item intended to
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*retain it in, or restore it to, a state in which it can perform the required function*. Both maintenance and renewal in the table above is thus a part of the general maintenance term. Unfortunately, it is no universal definition of the terms investment expenditures and maintenance expenditure that makes it possible to distinguish between on one hand investment and renewal as well as maintenance and operation. For this reason, cost comparisons should always be accompanied by a clear definition of what is included and excluded in the definition.

Let us nevertheless for the CATRIN studies suggest the following basic classifications as a starting point to which each study should orientate its classifications.

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**Discussion and examples**

The Swedish Rail Administration (Banverket) follows in general the European standard SS-EN 13306 Maintenance Terminology in their definitions of maintenance and associated activities. Infrastructure **operation** consists of activities undertaken without affecting
functional or technical condition of a unit. The two operation categories are winter services (B0707) and other track specific costs for operation and maintenance (B0706), where the former is dominating. Other costs are specifically described as “not being related to a given quality to be performed”. Among these are service of various detection systems and cleaning of station areas. Maintenance is divided into corrective and preventive maintenance, where preventive maintenance can be either condition-based or predetermined. Corrective maintenance is immediate maintenance (B0801) after observed or reported faults, urgent actions after inspection (B0802) or damages (B0803) that occur after sudden and unexpected incidents. Preventive maintenance is condition control, which consists of safety (B0804) and maintenance (B0805) inspections, and other inspections (B0806); condition-based maintenance, which is minor replacements (B0809), tamping (B0810), vegetation control (B0813), rail grinding (B0815), ditching and draining (B0818), painting (B0819), neutralisation (B0822), rail and sleeper adjustments (B0823), overhauls and repairs (B0825) and other condition-based maintenance (B0827). Predetermined maintenance (B0826) is interval based according to specific rules and standards. For renewals the activity codes are common with the codes for upgrades and new constructions, but an internal budget separates renewals from other construction activities. The internal accounts is therefore easily scanned for renewal costs, but it is impossible (without viewing every single invoice) to see the type of renewal undertaken. The activity codes in this case leave no information on the type of activity. Because of this, renewals can be anything from minor replacements (even if this also exists as a maintenance activity) to major rail replacements. The distinction becomes a financial issue rather than a clear cut categorisation of activities. Still, despite the grey zone between maintenance and renewal, the impression from contacts with Banverket is that renewal costs are derived from more large scale activities than minor replacements (Andersson (2008)).

In France the organisation of maintenance for railways is quiet specific as it involves both the infrastructure manager (RFF) and the rail operator (SNCF). The infrastructure manager gives a fixed amount for maintenance of the tracks to SNCF which has to execute the maintenance under the policy decided by RFF. Maintenance operations are usually classified in several categories: inspection and detection; correction maintenance, which aims at curing the damages which the inspection has shown to be both important and local (other ones are included in renewal programs) and prevention maintenance, which aims regularly at correcting small defaults and divergences on a regular and systematic basis. For renewal RFF
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decides and pays on an itemized basis which means that the control of the infrastructure managers is much higher in renewals than in maintenance. A specific category of maintenance is *Operation de Grand Entretien* (OGE) which could be translated in “operation of huge maintenance”. These operations are between maintenance and renewal, and are precisely defined by their origin and end. On the whole, it can be said that there are three broad categories of cost: maintenance (which includes as sub-categories, inspection and detection, correction, and prevention) – which would include small renewals up to 200m; OGE (“huge maintenance”) which includes renewals between 200m and 1000m; Renewals (in excess of 1000m). The present rules of accounting and classification adopted in France classify OGE in maintenance costs and as such they are included in the maintenance. (Quinet (2008)).

In UK the Office of Rail regulation presents Regulatory Accounting Guidelines (ORR (2006) which specifies the definitions. For regulatory accounts purposes **renewals** expenditure consists mainly of capital expenditure projects where the existing infrastructure is replaced with new assets. Costs incurred in replacing an existing asset or components of an existing asset should be recorded as renewals expenditure. Such expenditure does not result in any change or enhancement of the performance of the original asset. However, smaller expenditure should not be categorised as renewals expenditure: for example replacement of rail over a distance of less than 200 metres; replacement of sleepers over a distance of less than 100 metres or replacement of less than 1 in 4 sleepers over a distance of more than 100 metres. **Maintenance** expenditure relates to activities that Network Rail carries out in order to sustain the condition and capability of the existing infrastructure but which do not involve significant replacement of assets. Such expenditure maintains the previously assessed standard of performance. Maintenance expenditure includes: expenditure incurred in repairing (but not replacing) infrastructure assets and routine over-hauls; the cost of preventative work designed to protect assets from future failure; the cost of asset inspection; and the cost of all small-scale replacement work excluded from the definition of renewals. **Operations** expenditure covers costs that are incurred in relation to the operation of the network e.g. signalling.

The definition of **maintenance** in the Swedish Road Administration is services that preserves or restores the desired properties of the road system, and which result in effects and economic values that last for longer than one year. **Operation** services keep the road system functioning.
and have an effect that last for less than one year. These services are in the nature of inspections, rapid rectifications of defects, daily care and the operation of road system equipment (Thomas (2004)). However, lately a new structure has been introduced where the following main classification is used; 1) Catch the customer need, 2) Improve transport condition, 3) Offer travel opportunities and 4) Support during the trip. Based on this we can uncover a more traditional term for maintenance in one of the subgroups (PREST 422) which consists of; maintenance of even and long-term lasting paved road, including maintenance of surface, embankment and pavement and also drainage. The measures include maintenance in the form of sealing, surface dressing, new wearing course and restoration of load-bearing capacity. No distinction is made between new need of maintenance and lagging maintenance. Also maintenance of the drainage system of the road is included (ditch clearing, ditching, repair and replacement of culverts etc).

In Germany, a so-called “Leistungsheft” (service catalogue) for road maintenance and operation has been available since 2004. The background of this catalogue is the decentralised road maintenance and operation for motorways and federal roads. These two types of road network are in the ownership of the Federal Government which has transferred the responsibility for maintenance and operation to the federal states. The service catalogue aims at setting a base for determining services. The classification includes five main categories for maintenance and operation; 1) immediate measures on the road, 2) lawn and garden maintenance, 3) maintenance of road equipment, 4) cleaning and 5) winter services. The first category consists basically of “repair of damages” and is divided into four subgroups; paved roads, non-paved roads, engineering constructions and drainage installations. The first class can thus be seen as maintenance as discussed above.

For aviation and the maritime sector the major question is the limitation of the relevant infrastructure. Following Bickel et.al (2006) we conclude that “practically no useful data on marginal costs in the maritime and port sector are found. Maritime and port undertakings have absolutely no incentive to publish or otherwise make available commercial data”. Bickel et.al. therefore constructs an engineering based model to estimate the costs. The starting point for the calculation of the costs is the subdivision of the trajectory of a vessel in a number of stretches. A vessel on its way to a port can sail on several stretches, depending on the port setting as well as on its own characteristics or on environmental factors: starting with i) maritime transport at sea, ii) a part of a river or canal can be used, iii) further on also a lock,
iv) and finally docks will be reached. Once the ship is v) berthed, other activities can continue: vi) terminal activities such as unloading/loading, storage and unloading/loading of hinterland modes. After this, the goods transformed will be moved to vii) hinterland connections. Following such a trajectory the table below summaries cost components for a port call trajectory.

Table 3: Costs components for a port call trajectory

<table>
<thead>
<tr>
<th>Port call trajectory (arriving vessel)</th>
<th>Infrastructure costs</th>
<th>Transport user costs</th>
<th>Supplier/operator costs</th>
<th>External costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. At sea</td>
<td>None</td>
<td>Vessel operating costs (crew, fuel, stores, lubricants, spare parts, oil)</td>
<td>Pilotage and towage (fuel, oil, spare parts)</td>
<td>Accidents, air and water pollution</td>
</tr>
<tr>
<td>2. Waiting at buoy to enter port area</td>
<td>None</td>
<td>Limited vessel operating costs</td>
<td>None</td>
<td>Air and limited water pollution</td>
</tr>
<tr>
<td>3. From buoy to lock</td>
<td>None</td>
<td>Vessel operating costs (crew, fuel, stores, lubricants, spare parts, oil)</td>
<td>Pilotage and towage (fuel, oil, spare parts)</td>
<td>Noise, air pollution, limited water pollution, accidents (limited)</td>
</tr>
<tr>
<td>4. Lock</td>
<td>Lock replacement costs Maintenance costs</td>
<td>Limited vessel operating costs</td>
<td>None</td>
<td>Limited noise, air and water pollution</td>
</tr>
<tr>
<td>5. From lock to berth</td>
<td>None</td>
<td>Vessel operating costs (crew, diesel oil used instead of heavy fuel, stores, lubricants, spare parts, oil)</td>
<td>Pilotage and towage (fuel, oil, spare parts)</td>
<td>Noise, air pollution, limited water pollution, accidents (limited)</td>
</tr>
<tr>
<td>6. Waiting at berth</td>
<td>None</td>
<td>Limited vessel operating costs</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>7. Loading and/or unloading at berth</td>
<td>None</td>
<td>Limited vessel operating costs</td>
<td>Handling staff, storage staff, use-dependent replacement of superstructure and warehouses</td>
<td>Accidents, noise and air pollution, limited water pollution</td>
</tr>
</tbody>
</table>

Source: Bickel et.al. (2006)

Within each of these categories investment, renewal, maintenance and operation take place. We will not include vi) terminal activities or vii) hinterland transport in our definition of infrastructure cost. However, in CATRIN we will include pilotage as an infrastructure operation service. In addition, we will consider icebreaking services as an infrastructure operation cost.

For airports an important delimitation is the split between aeronautical and commercial airport activities. This has a link to the type of regulation; single-till or dual-till. In the former
commercial revenues are included in the prise-cap formula for the aeronautical charges while the latter only consider aeronautical activities. Aeronautical services are in Link et.al. (2006) classified as i) terminal air traffic control services, ii) manoeuvring area services and iii) apron area services. The former two are pure infrastructure cost while the third element consists mainly of infrastructure cost put includes some non-infrastructure related elements (see further Link et.al. for subgroups). Non-aeronautical services are classified in iv) passenger services, v) commercial services and vi) ground transport services. The first and third group is classified as partly infrastructure cost while the second group is seen as non-infrastructure cost. In addition to these cost elements CATRIN will also examine the cost of vii) Eurocontrol. As for maritime transport, investment, renewal, maintenance and operation take place in each of these categories. However, in research on airport economics it is more common to base the cost estimates on a more traditional economic concept of labour, capital and material. The first two represent approximately 60% of the total airport cost at European airports (Doganis (1992)).

Based on the discussion above the basic CATRIN classifications have been further developed below as an example where different cost items are presented for the four group’s, investments, renewal, maintenance and operation.

Table: 4 Examples of cost categories within the classification

<table>
<thead>
<tr>
<th>Investment or enhancement</th>
<th>Road</th>
<th>Rail</th>
<th>Aviation</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment or</strong></td>
<td>Land purchase, construction of new roads, enlargement of existing roads</td>
<td>Land purchase, construction of new lines, upgrading of existing lines</td>
<td>Construction of new runways, taxiways, apron-area, air-control unit, passenger terminals (transport oriented/commercial side), cargo terminal.</td>
<td>Construction of new fairways, locks, quays. Construction of new ice-breakers.</td>
</tr>
<tr>
<td><strong>Enhancement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Renewal</strong></td>
<td>Replacement of layers in underground engineering, replacement of bridges and other facilities which restores the full utility value</td>
<td>Replacement of bridges, tunnels, switch boxes and platforms, replacement of tracks and other assets which restores the full utility value. Do we need to say something about replacing with modern equivalent</td>
<td>Replacement of facilities above which restores the full utility value</td>
<td>Replacement of water navigation facilities, lighthouses, locks, quays</td>
</tr>
</tbody>
</table>
Abatement costs of noise

Abatement costs of noise are merely the costs of reducing noise emissions. The costs of noise abatement consist of investment costs and operating costs, and may also result in other costs, such as changes in time costs (e.g. if reduced speed is used as a noise measure) and visual intrusion (e.g. when introducing noise barriers) and changes in air pollution costs and safety costs.

### 3.3 The relevant time period to be considered

#### Fixed and variable costs

Fixed costs are those which remain the same (in total) over a wide range of output levels while variable costs as those which vary with changes in output. Accounting texts use a more
precise definition according to which variable costs change in direct proportion to changes in output (Dominiak and Louderback III, 1985, p.18). The distinction between variable and fixed costs is highly dependent on the time horizon considered: In the long run all costs are variable, meaning that even the largest investment may be modified to change fixed costs, given a long enough time horizon (Pappas and Hirschey 1990, pp. 346-347). Note, that the terms fixed cost and capital cost and the terms variable cost and running cost cannot be used synonymously since parts of capital cost and running cost might be either fixed or variable. The distinction between fixed and variable costs is important for pricing purposes: Fixed costs are irrelevant for efficient pricing while variable costs are a starting point for deriving marginal costs. Often variable costs are taken as proxies to marginal costs, however, the underlying assumption of a linear cost curve has to be proven on a case-to-case basis. At the current frontier of research the majority of studies on marginal infrastructure costs suggests non-linearities, even though they appear to be rather weak.

**Capacity costs**

Capacity costs are those costs which occur due to the provision of infrastructure capacity independently of the level of traffic. They comprise shares of capital and running costs and are equal to the fixed costs. The term “capacity costs” is often synonymously used with the term fixed costs (see “fixed costs”, Link et al. 2002) p. 74).

### 3.3 Specific costs and charging principles

**Average and marginal costs**

Average and marginal costs are both specific costs per unit of output. Average costs are equal to the total costs of providing a good or a service, divided by a measure of output, such as vehicle-kilometres. They include both fixed and variable costs and therefore show the costs of infrastructure provision, renewal, maintenance and operation per unit of traffic. Average cost information – in combination with revenues – is important if a budget constraint is imposed and cost recovery has to be achieved (Link et al. 2002, pp. 73-74). The average cost principle does not ensure an efficient pricing, nevertheless average costs can provide important information for pricing, for example to avoid overcharging if mark-ups on marginal costs are raised to meet a budget constraint.
Marginal costs are the costs incurred by increasing output by “a small amount”, more precisely by an infinitesimally small amount. Marginal costs are (mathematically) equal to the first derivative of total costs with respect to output. In practice, the relevant concept is the additional unit of output. However, for a transport company or for transport infrastructure which produces relatively few units of output with large per-unit costs, the cost of producing an additional unit of output is a poor approximation of marginal cost. For this reason, analysis involving the transport industry often uses the concept of incremental costs (see “incremental costs”) instead (see Dominiak and Louderback III 1985, p.369).

**Short-run and long-run marginal costs**

Since the variability of costs depends on the time horizon considered, short-run and long-run marginal costs have to be distinguished:

- **Short-run marginal costs** are related to the use of already existing infrastructure. Capacity is given and cannot be adjusted to changes of demand in the short-run.

- **Long-run marginal cost** is the change in variable cost caused by producing an additional unit of output, plus the estimated additional capacity costs per unit, based on the additional capacity that will have to be constructed if sales at that price are expected to continue or to grow over time. Since theoretically all costs are variable in the long run, no fixed costs do exist and the total costs as the basis for the mathematical derivation of (long-run) marginal costs include these future increases of capacity.

**3.4 Empirical approaching to marginal costs**

**Incremental and avoidable costs**

Incremental costs are the present value of costs incurred due to discrete changes in output. While marginal costs are a theoretical measure of changes for an instantaneous (continuous and infinitesimal) change in output, which generally cannot be measured in reality, incremental costs measure changes over finite or discrete changes in output, which can be measured (Price and Berardino 1977, p. 147-149). Incremental costs can therefore also considered as an empirical measure of marginal costs.

Avoidable costs are those cost that will not be incurred if an activity is suspended; also called escapable cost. For example, it is the cost that can be saved by dropping a particular product.
line or department (e.g., salaries paid to employees working in a particular product line or department). All costs are avoidable, except (1) Sunk Costs (see “sunk costs”) and (2) costs that will continue regardless of the decision. The method of calculating avoidable costs is the same as that for calculating incremental costs (see “incremental costs”). As an example, suppose that a railroad is considering discontinuing a service which obligates it to spend $100 next year and $200 two years from now. If the service is discontinued, the railroad will need to spend only $25 per year. The avoidable cost would then be the discounted present value of $75 plus $175. Note that this avoidable cost is not necessarily the same as the incremental cost of starting an equal amount of new service elsewhere (Price and Berardino 1977, p. 154).

3.5 Cost responsibility

Specific, joint and common cost

While some type of costs can easily be allocated to specific products and services, there is a whole range of costs which are difficult to trace directly to any specific product or service. These costs may either be “joint” or “common” to a number of users. Joint costs exist when the provision of a good or service necessarily entails the output of some other service. Jointness is a technical feature costs and exists at all points of time (Button 1993). Joint costs cannot be eliminated by removing one of the product lines or services but only if all product lines or services involved are withdrawn together (for example: return trips where the provision of a transport service in one direction automatically involves the provision of a return service). Kahn 1988, p. 151 states that those costs are joint costs when the same inputs are used to make products A and B, and when producing A takes up capacity which could otherwise be used to supply B. Under this definition, products do bear a causal responsibility for a share of joint costs.

The term common costs is often used synonymously with joint costs. The difference, however, lies in the fact that the use of resources to provide one service does not unavoidably result in the production of a different one (for example: the provision of roads where the removal of trucks leaves costs still to be borne by private motorists, see Button 1993). This means that the difference in the underlying concepts of defining joint costs and common costs is the variability of proportions of multiple products. While joint products are produced in fixed proportions, products produced in common are subject to variable proportions (see also Williams and Kennedy 1983).
3.6 Cost reversibility

Sunk costs
Sunk costs are those costs which have been irrevocably committed and cannot be recovered, for example expenditures for advertising or researching a product idea, or infrastructure facilities such as rail tracks, air control towers etc. Sunk costs can substitute a barrier to market entry. If potential entrants would have to incur costs, which would not be recoverable if the entry failed, they may be scared off.

3.7 (Over)utilisation of infrastructure

The use of a piece of transport infrastructure, such as a road or a railway, consumes the capacity of that asset. Where that capacity is fixed in the short run, greater utilisation of the capacity leads to congestion, which usually manifests itself as the reduction of traffic speeds to below free-flow speed and/or the occurrence of queuing at junctions. Depending on characteristics of access to infrastructure, over-utilisation of infrastructure leads to congestion costs (non-scheduled transport) or scarcity costs (scheduled transport).

Congestion costs
Congestion costs occur when the presence of one vehicle increases the journey time of another one. This phenomenon may happen for two distinct reasons as traffic builds up. Firstly, increased traffic density obliges drivers to drive more slowly because the gap between vehicles is reduced. Secondly, queuing may occur at junctions or other bottlenecks. Congestion costs consist of incremental delay costs, incremental vehicle costs, crash risk and pollution resulting from the interference between vehicles if infrastructure approaches its capacity. Each vehicle on a congested piece of infrastructure both imposes and bears congestion costs.

Scarcity costs
Where infrastructure managers control access to the network on a planned basis (e.g. rail, airports), shortages in capacity on the network manifest themselves in a different form – scarcity. For example, on the rail network scarcity represents the inability of a train operator to obtain the path they want, in terms of departure time, stopping pattern or speed. In the
extreme, the operator may decide not to, or be unable to introduce the service at all. The inability of the train operator to provide the service it estimates will best meet its’ customers’ demands represents a cost to society equal to the social value of that train service, where social value comprises profit to the train operating company, consumer surplus declines and net benefits to third parties (e.g. changes in pollution).4

4 A common methodological framework for the case studies

4.1 Overview on the CATRIN case studies

The CATRIN project contains a number of real world case studies for all modes of transport to improve existing knowledge on marginal infrastructure costs and to provide more differentiated estimates. Table 1 gives an overview on the planned case studies and their characteristics.

Table 5: The CATRIN case studies

<table>
<thead>
<tr>
<th>Mode/case study</th>
<th>Approach</th>
<th>Type of costs analysed</th>
<th>Data</th>
</tr>
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<tbody>
<tr>
<td><strong>Road</strong></td>
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<tr>
<td>S</td>
<td>Econometric cost function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Econometric cost function</td>
<td>Ongoing maintenance</td>
<td>Pooled cross-sectional expenditures per maintenance unit, own data collection within case study</td>
</tr>
<tr>
<td>PL</td>
<td>Econometric cost function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allocation factors</td>
<td>Meta-analysis of engineering knowledge</td>
<td>damage costs</td>
<td></td>
</tr>
<tr>
<td>European Road Experiment</td>
<td>Development of a design for an European Road Experiment</td>
<td>damage costs</td>
<td></td>
</tr>
<tr>
<td><strong>Rail</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>Econometric cost function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH</td>
<td>Econometric cost function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AT</td>
<td>Econometric cost function</td>
<td>Maintenance</td>
<td>Pooled cross-sectional maintenance expenditures</td>
</tr>
<tr>
<td>France</td>
<td>Econometric cost function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>Engineering methods</td>
<td>Rail track damage costs</td>
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<tr>
<td>UK</td>
<td>Estimation of avoidable costs</td>
<td>Capacity costs</td>
<td></td>
</tr>
<tr>
<td>IT</td>
<td>Estimation of speed differences</td>
<td>Capacity costs</td>
<td></td>
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compared to optimal speed

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<thead>
<tr>
<th>S</th>
<th>Econometric cost function</th>
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**Airports**

<table>
<thead>
<tr>
<th>Landing fees congested hub</th>
<th>congestion costs</th>
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</thead>
<tbody>
<tr>
<td>Landing fees uncongested secondary airport</td>
<td></td>
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</tbody>
</table>

**Maritime**

<table>
<thead>
<tr>
<th>Baltic countries</th>
<th>Costs of icebreaking, comprising capital costs, running costs (labour, bunker, maintenance), external costs (air pollution)</th>
</tr>
</thead>
</table>

4.2 **A common set of research issues**

As stated in chapter 2, it is desirable that apart from mode and case specific issues, all CATRIN case studies cover a common set of research issues. This common set is listed below:

1. **Evidence on marginal cost curves**

   At the current state of research, studies have come up with different shapes for the marginal cost curve. The case studies should explore to what extent different modelling approaches can be blamed for these differences. Ideally, it were desirable that within each specific case study different functional forms are tested, however, this will often be restricted by the data availability. Nevertheless, some of the case studies with good databases should explore this issue.

2. **Disaggregated estimates for types of vehicles/infrastructure users**

   While probably econometric cost function studies will not be capable to provide disaggregated MC estimates by types of vehicles, CATRIN involves a number of case studies with engineering-based methods (for example the case studies for road and rail).
The findings from both directions of research need to be brought together in order to conclude on MC estimates by types of vehicles.

3. Treatment of renewals
Renewal measures are infrastructure measures with a cyclical character, e.g. they cannot be observed annually. This poses serious problems to such models which use annual cross-sectional observations for infrastructure expenditures. Attempts to solve these problems are to cumulate or to average both renewals and traffic data over time. If very long time periods of measurements for infrastructure condition are available, the duration approach might be the best choice to overcome this problem. The case studies should explore this issue further. As a minimum requirement, estimation with renewal expenditures and with expenditure data which exclude renewals should be conducted.

4. Other issues
Apart from these common issues there are open questions which probably cannot be analysed across case studies but rather in single studies which have the respective access to data. These relate for example to the question whether and to what extent marginal costs differ between highly and low utilised infrastructures. An indicator on the level of capacity utilisation should be included.
Furthermore, whether maintenance policies and the organisation of maintenance work affects the level of marginal costs and how.

4.3 Methodological guidelines
While it has to be anticipated that case studies will follow different estimation approaches which suit best to the data available, there are some common requirements which should be taken into account for each case study. This refers first of all to a precise explanation which cost categories are reflected in the data used for model estimation, based on the definitions give in chapter 3 of this deliverable. Second, as far as possible common output measures should be used or a transfer into other output measures should be given. For road this relates to vkm and axle-load-km, for air transport to the use of ATM and WLU. Third, the underlying assumptions of the models should be discussed as for example the question whether in cross-sectional models input prices can be consider not to vary across sections/regions etc.
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Fourth, all case studies should aim at providing the following types of outcomes: i) Cost elasticity (ratio between MC and AC), ii) Marginal cost estimates with minimum and maximum and average MC estimate, iii) MC curve.

### 4.4 Reporting format for the case study reports

In the following we present a blueprint for the case study reporting format.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>Background</td>
</tr>
<tr>
<td>2</td>
<td>State of the art summary</td>
</tr>
<tr>
<td>3</td>
<td>Research questions</td>
</tr>
<tr>
<td>4</td>
<td>Methodology</td>
</tr>
<tr>
<td>5</td>
<td>Description of data</td>
</tr>
<tr>
<td></td>
<td>Sources</td>
</tr>
<tr>
<td></td>
<td>Delimitation/definition of data (for each variable), in particular:</td>
</tr>
<tr>
<td></td>
<td>Items classified as maintenance expenditures versus renewals?</td>
</tr>
<tr>
<td></td>
<td>Treatment of outsourcing (if applicable)</td>
</tr>
<tr>
<td></td>
<td>Level of disaggregation, type of reporting unit (e.g.: maintenance district, region, network section)</td>
</tr>
<tr>
<td>6</td>
<td>Estimation results</td>
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<tr>
<td></td>
<td>cost elasticity (MC/AC)</td>
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<tr>
<td></td>
<td>cost curve</td>
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<td></td>
<td>Range of MC estimates and average MC</td>
</tr>
<tr>
<td>7</td>
<td>Conclusions</td>
</tr>
</tbody>
</table>
References


Link, H.,W. Götze and V.Himanen (200&), Estimating the marginal costs of airport operation by using multivariate time series models with correlated error terms, Diskussionspapier Nr. 11, Institut fur Verkehrswissenschaft, Berlin.


