COMPETITIVE AND SUSTAINABLE GROWTH (GROWTH) PROGRAMME

UNITE

UNIfication of accounts and

marginal costs for Transport Efficiency

Deliverable 3:
Marginal Cost Methodology

Version 2.1
9 March 2001

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Executive Summary

The UNITE project is designed to support policy-makers in the development of pricing and taxation policies for the transport sector, and refers to three aspects: transport accounts, marginal costs and integration of approaches. The purpose of this report is to advance methodologies for the estimation of marginal costs for the cost categories – infrastructure costs, supplier operating costs, transport user costs, accident costs and environmental costs. Furthermore, it will propose case studies that will implement the specified methodologies for all significant transport modes – road, rail, aviation, inland waterway and short-sea shipping.

In UNITE, marginal social cost is defined as the cost of an additional transport unit - vehicle kilometre for road, train km for rail, aircraft km for air, ship km for waterborne modes. Infrastructure capacity is assumed to be fixed, while the rolling stock may vary.

The report begins with providing a summary of existing methodologies considered to be state-of-the-art. In doing so, benchmarks are established, against which the methodologies for the marginal cost case studies in UNITE may be assessed. Such benchmarks allow the contribution of the individual case studies to be assessed in terms of whether they provide additional evidence that either makes use of or goes beyond state-of-the-art techniques.

In order to specify the disaggregations (e.g. of area type – urban, rural etc.) for the case studies, cost categories and their cost drivers to be considered in the case studies are then identified. A set of classification criteria was determined to identify the range of cost categories relevant to the marginal costs case studies. The relevant cost categories are compiled in a list which is characterised by:

- High level of disaggregation (as high as the time-frame and practical circumstances allow within UNITE);
- Full information of the MC structure and clear distinction of overlaps between different cost categories;
- Distinction between marginal external costs and marginal private costs.

The report summarises the methodologies developed for the estimation of marginal costs of all of the main cost categories associated with all principal transport modes. The report seeks to summarise the technical issues related to marginal cost estimation and provide direction for the implementation of the case studies. It tries to detect the possible level of generalisation of the respective methodologies and estimates.

The main approaches proposed for the estimation of transport producer costs, which consist of infrastructure provider and supplier operating costs, are the econometric approach and engineering approach. Previous applications of these approaches, although rare, exist for road and rail modes. In the past, aviation and waterborne transport were not studied in great depth, since it was assumed that marginal cost

categories represent a limited proportion of overall costs. In this respect there is considerable potential for further methodological and empirical exploration within UNITE.

Transport user costs consist of congestion, scarcity and the Mohring effect. For road congestion, speed-flow and speed-operating cost functions will be applied. To quantify congestion costs for rail transport a network wide approach as well as the investigation of demand-delay characteristics at single stations will be used. For air transport a sample of major European airports will be considered. The Mohring effect, for scheduled public transport and scheduled freight transport, results from a benefit to existing transport users when service frequencies increase. This benefit will be estimated in terms of combination of the existing passenger/freight base with the frequency change and the value of waiting time.

Accident costs place themselves on the border between user costs and transport system externality costs. Other sector-external costs include the environmental costs of local and regional air pollution, noise and global warming. Accident costs will be estimated on the basis of the risk elasticity approach. For air pollution and noise costs the "impact pathway approach" will be applied. This involves modelling emissions, dispersion, estimation of their impacts, and consequently monetary valuation of these impacts. Global warming cost estimation will be based on damage cost factors.

Finally, a range of case studies were proposed and elaborated. Table E.1 summarises the distribution of case studies across modes and main cost categories.

Table E.1: Distribution of the Marginal Cost Case Studies

Category	**Road**	**Rail**	**Air**	**Inland Waterways**	**Maritime**	**Total – by cost category**
Infrastructure costs	2	2	1	1	2	8
Supplier operating costs	0	2	1	0	0	3
Congestion costs	6	5	1	0	0	12
Mohring effect	0	1	1	1	1	4
Accident costs	3	2	0	1	1	7
Environmental costs	6	4	1	1	1	13
Total – by mode	17	16	5	4	5	47

The case studies will provide valuable empirical output, in that they:

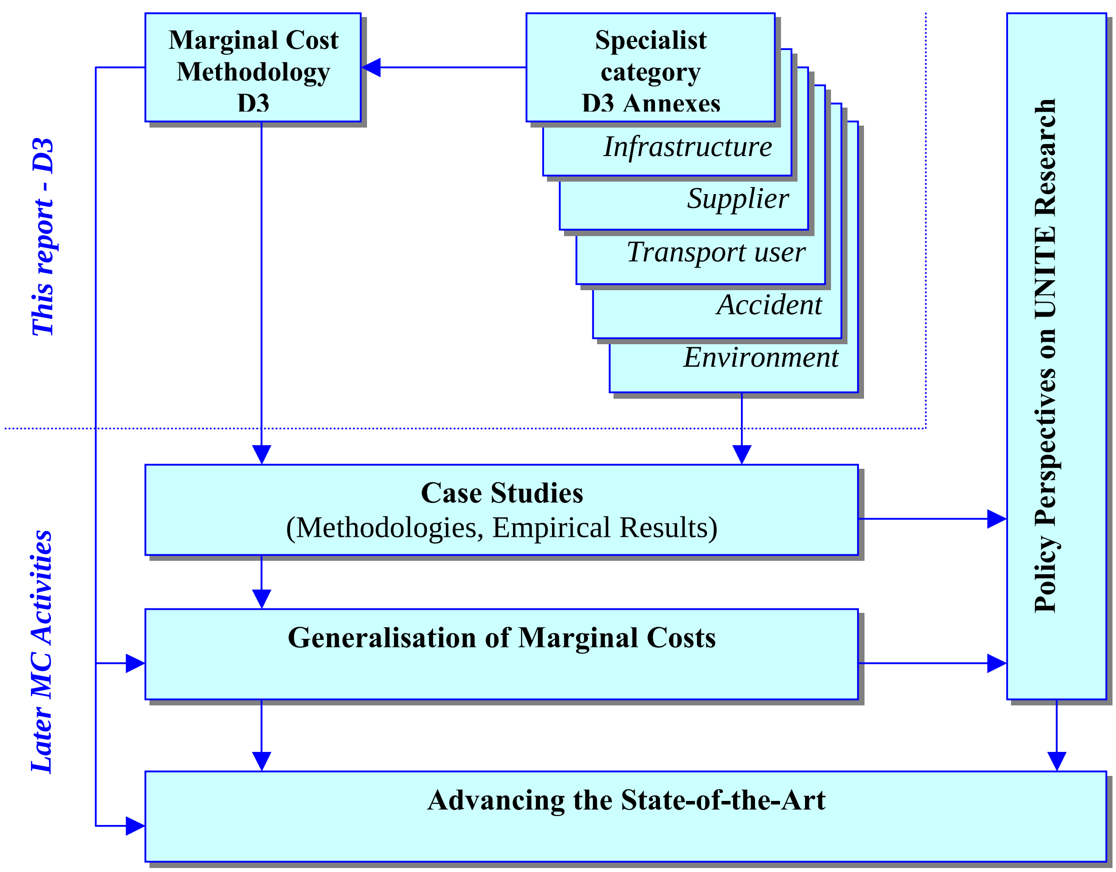
- represent significant added value, building on existing empirical evidence; and,
- are capable of generalisation from the case study context to other contexts.

1 The UNITE Marginal Cost Work – Context and Objectives

1.1 MC Component of UNITE

The UNITE project is designed to support policy-makers in the setting of charges for the transport sector by providing appropriate methodologies and empirical evidence. For achieving this aim the work in UNITE is built on three core aspects, namely transport accounts, marginal cost estimation and the integration of both. This deliverable deals with the methodological approach for the marginal costs. Figure 1.1 represent the interrelationships between MC components of UNITE, in particular how this report relates to the later MC activities in the project.

Figure 1.1: Interrelationship of this report with other MC Components



As it can be seen in the figure above, the MC work in UNITE is intended to provide a strong theoretical and empirical basis for advancing the state-of-the-art. The aim of this report is to build on the methodological framework with the help of the theoretical inputs from specialist cost categories. Case studies will be performed on the basis of the framework developed in this report.

At the empirical level the later individual work will provide valuable evidence for the overall policy perspectives. In order to understand and apply it, this report will endow the reader with a strong and clear understanding of overall framework of estimating marginal costs for different modes and categories – the required methodological input.

Generalisation of the empirical output will show how the methodological and empirical output can be fully exploited both for generalisation and policy matters. Although this report will try to identify the possibility of generalisation of the results – both input and output - to different contexts, since this is dealt with on completion of the MC case studies, this is not its main objective. However, identifying generalisation possibilities already at this stage will allow maximising the value-added by the case studies. The main progress on generalisation can take place in the stage following the completion of the case studies.

1.2 What MC Methodology in UNITE Seeks to Achieve

The purpose of this report is to provide an overall methodological framework for determining the marginal costs in the transport sector. In particular, the report aims at:

- summarising the systematic, comprehensive and transparent methodologies for the estimation of marginal costs for the transport sector - state-of-the-art review;
- providing summary of adequate and coherent methodological guidelines for the setting-up and implementation of all the marginal costs case studies – overview of the proposed methods for case studies;
- proposing case studies that explore the important empirical and methodological gaps by building up on the existing state-of-the-art.

Summarising, the report will come up with detailed methods, information on the desirable level of disaggregation of data, and preliminary recommendations on generalisation.

One of the UNITE MC work’s objectives is to expand existing evidence on the marginal cost estimates and to build up new evidence. That is, the proposed case studies are to bring more evidence – for modes and cost categories where studies exist; and to either i) apply the state-of-the-art techniques to modes/cost categories where very little or no evidence exists, or ii) advance the state-of-the-art technique and consequently apply it.

1.3 What MC Methodology in UNITE Does not Seek to Achieve

This report does not seek to elaborate and discuss marginal cost pricing principles. Moreover, it does not intend to demonstrate the full calculation process for overall optimal short-run marginal cost– this process is well illustrated in Proost et al. (1999) as part of the TRENEN II STRAN project; and Nash et al. (2000) within the PETS project.

This project's aim is to maximise the quality of the marginal cost 'building blocks' for subsequent use in policy analysis.

As a marginal cost component of UNITE, this report does not intend to provide every answer to generalisation of the MC estimates and policy-related questions. Besides, it does not represent any modelling of all costs in one case study. It will not give an answer to optimal prices and will not discuss any principles behind that.

1.4 Structure of this Report

This report provides mainly a summary of the work done in the specialist cost categories components of the UNITE project. The detailed outcome is presented in the annexes to this report.

The report starts with an overview of the state-of-the-art marginal cost methodologies (Chapter 2). In particular it discusses the benchmarks of different methodological approaches. Based on this review, case studies are proposed and elaborated.

Building up on the state-of-the-art, Chapter 3 elucidates the scope of the marginal cost analysis. Chapter 4 clarifies some general and technical issues important for the case studies in particular related to cost drivers and level of disaggregation that is desirable for the case studies.

Having set the scope of the marginal cost detailed summary of the proposed methodologies for estimation of individual cost category follows. A common methodological approach along with the respective steps for its application is developed (Chapter 5). Further, alternative methodologies are proposed and issues of sources of uncertainties considered.

This is followed by the discussion of the possible transferability of estimates between different contexts in Chapter 6. The report ends up with an overview of the proposed case studies.

Many past empirical studies have often been self-contained, with the study findings seen as an end in their own right – rather than an input into subsequent analysis. In contrast, the purpose of UNITE MC component is to create building blocks that can be applied in different contexts either directly or by means of adaptation. Therefore, presenting results and methodologies so that they may be generalised is an additional challenge for the MC work. The basic principles which are taken into account are consistency of approach, coverage of all main modes and marginal cost and benefit categories, and relevance to a range of traffic situations, geographic contexts, transport characteristics and other sources of variation.

2 Review of Existing Marginal Cost Methodologies

2.1 The Purpose of this Review

The purpose of this chapter is to provide a summary of existing methodologies considered to be state-of-the-art. In doing so, benchmarks are established against which the methodologies for the marginal cost case studies in UNITE may be assessed. Such benchmarks allow the contribution of the individual case studies to be assessed in terms of additional evidence using state-of-the-art techniques, or methodologies that further develop the state-of-the-art.

Since the High Level Group on Infrastructure Charging commissioned a range of state-of-the-art review papers recently (in 1999[1]), this review is brief and merely seeks to identify the overall framework for analysis and the main methodologies by cost category.

2.2 The Overall Analysis Framework

In UNITE, marginal social cost is defined as the cost of an additional transport unit - vehicle kilometre for road, train km for rail, aircraft km for air, ship km for waterborne modes. Infrastructure capacity is assumed to be fixed, while the rolling stock may vary, so that the approach is not a strictly short-run one.

Building the basic framework for the analysis the starting point is to observe that total social costs (TSC) in UNITE comprise five specialist categories: infrastructure costs, supplier operating costs, transport user costs and benefits, accident costs and environmental costs:

$$\mathbf{TSC = TSC_{infra} + TSC_{operator} + TSC_{user} + TSC_{accident} + TSC_{env}}$$

The next step is to define the marginal social transport costs (MSC) of an extra vehicle kilometre that is to differentiate this with respect to output (Q). Consequently, by subtracting the marginal private cost (MPC) of the extra vehicle kilometre from the marginal social transport cost one gets the marginal external cost (MEC). This yields the price-relevant marginal cost:

$$\mathbf{MC = MC_{infra} + MC_{operator} + MEC_{user} + MEC_{accident} + MC_{env}}$$

where for the respective specialist cost category:

$$\mathbf{MEC = \partial TSC/\partial Q - MPC.}$$

[1] Namely: Link and Maibach (1999) on infrastructure costs; Nash and Sansom (1999) on congestion and scarcity costs; Lindberg (1999) on accident costs; and, Friedrich and Ricci (1999) on environmental costs.

This provides the framework for the analysis. However, in order to determine changes to prices[2], the next steps would be to: a) compare these costs with existing taxes, charges and subsidies to identify any disparities; and, b) simulate demand/ supply interactions in order to yield the equilibrium charge.

UNITE seeks to develop methodologies and undertake empirical analysis relating to the components of the marginal cost equation. Chapter 5 will present a summary of the developed methodologies for estimating marginal costs components. The analysis will cover five modes: road, rail, air, inland-waterways and short-sea shipping.

2.3 Approaches for Infrastructure and Supplier Operating Costs Estimation

For both categories, infrastructure provider costs and supplier operating costs, two main approaches exist:

- the **econometrics approach** – where costs are the dependent variable, and transport outputs (e.g. train kms) are among the independent variables. Cross sectional and/or time series analysis produces parameters that may be directly interpreted as marginal costs, or used to construct the total cost function; and,
- the **engineering approach** – where total costs are disaggregated into sub-categories, and for each of these categories, separate analysis provides the technical relationship between inputs and output measures.

For **infrastructure costs**, both approaches are valid, but the econometric approach has rarely been applied other than for rail – where interest has generally focused on combined infrastructure and operating costs, rather than purely infrastructure costs. Notable exceptions include: Johansson and Nilsson (1998) for Swedish railways; and, Herry et al. (1993) for Austrian roads.

Of the engineering approaches to infrastructure cost estimation, the most renowned study is Highways Research Board (1961), which sought to establish the relationship between road damage and axle weights, establishing the 'fourth power rule'.

Summarising, econometric and engineering approaches have been rarely applied for the estimation of the marginal infrastructure costs for road and rail. For airports and waterborne transport, relevant studies are non-existent – in part due to the limited ratio of marginal cost categories in overall costs. Thus, substantial scope for methodological and empirical development of marginal infrastructure costs exists for UNITE.

For **supplier operating costs**, application of the econometrics approach has been undertaken extensively, but the results are not usually directly applicable to pricing decisions. This is due to three major constraints: firstly, output measures are too aggregate (with heterogeneity due to journey length, origin-destination patterns, and

[2] In this instance, purely based on marginal costs, although further conditions such as budget constraints generally need to be considered.

peak/ off-peak travel typically being ignored); secondly, the difficulty of separating the relevant parts of total accounting cost data that relate to output, and the fact that such costs do not necessarily relate to real costs; and, thirdly, the way in which quality of service systematically varies at different levels of output. These constraints imply that the econometrics approach will seldom yield viable marginal cost estimates, although it may be helpful in giving an idea of the degree of economies of scale and how this varies with circumstances.

Application of the engineering approach has been demonstrated for a range of modes, including urban bus transport (OECD, 1985), rail passenger transport (ECMT, 1998) and scheduled public transport in general (Jansson, 1984, 1997). A key issue is the interaction with the benefits of increased frequency (the Mohring effect) if capacity is increased by this means. If capacity is expanded by means of increased occupancy, or greater vehicle size/length, this issue does not arise.

As with infrastructure costs, for supplier operating costs there is considerable potential for further methodological and empirical exploration within UNITE.

2.4 Estimation of Transport User Costs and Benefits

This category is made up of congestion, scarcity and the Mohring effect. Accidents straddle the boundary between user costs and transport system-external costs. However, these are considered under the next sub-section in this chapter.

For **congestion**, different approaches apply for road and for rail, air and waterborne transport – since the latter modes involve central allocation of a fixed capacity to a limited number of known operators. For road congestion, a common approach is adopted in Nash et al. (2000) and Proost and van Dender (1999). This involves the use of speed-flow relationships – for individual road links/ junctions, aggregated areas within a city or a city as a whole – combined with an iterative transport modelling approach to determine equilibrium prices.

For rail, air and waterborne transport, methods for estimating congestion have rarely been implemented. Although a method involving the relationship between train flow and track capacity has been illustrated in Christensen et al. (1998) for rail, arguments that congestion for non-road modes is internal (particularly if only one service operator exists) or is overcome through realistic timetabling, have often dominated.

For **scarcity**, i.e. the valuation of the opportunity costs associated with service provision limits for collective transport, no relevant empirical studies have been identified as part of this review.

The **Mohring effect**, for scheduled public transport, results from a benefit to existing transport users when service frequencies increase. It applies to passenger transport and to freight transport where a given service is used by multiple customers.

The Mohring effect arises when the operator chooses to provide additional carrying capacity by increasing service frequency. However, it is important to note that system capacity can be adapted to the increased demand through the following actions: increasing vehicle size, increasing service frequency, addition new lines or routes, changing existing routes. Depending on the effect, the outcome can imply lower marginal operating costs or/and lower transport user costs.

The optimal approach to increasing carrying capacity would result from social cost-benefit analysis of the options. However, past studies have either ignored the Mohring effect, or (as in Nash et al., 2000), adopted a pragmatic approach to the way in which increased service capacity is catered for. Where service frequencies change, combination of the existing passenger base with the frequency change and the value of waiting time provides a simple methodology for the estimation of this benefit.

In summary, for transport user costs and benefits, scope exists for further elaboration of the methodologies for estimating road congestion and the Mohring effect. Furthermore, piloting of approaches for estimating congestion for non-road modes and scarcity also has potential.

2.5 Approaches to the Estimation of External Accident Costs

By entering the traffic flow, the user exposes himself to the average **accident** risk in that specific transport mode. In his decision he internalises the risk he exposes himself to. At the same time, however, he can affect the accident risk for all other users of the same mode or other modes. The economic values assigned to these consequences express the marginal accident cost. The external marginal accident costs represents the remaining cost after internalisation.

The perception of risk is different across different users. In general, risk and its perception in particular depends on the type on the vehicle, type of infrastructure/mode, driver characteristics (e.g. personality, behaviour and age), environment (e.g. weather and time). By not considering all factors, the users might end up with underestimating the real accident risk. Consequently, the level of risk will affect the external marginal costs of the accident.

The issue of valuation of accidents is complicated. The risk elasticity approach set out in Jansson and Lindberg (1998a) is applicable to all modes of transport. This considers the risks that a user imposes on himself, on others using the same mode, and on users of other modes (including pedestrians). In addition, the way in which such risks vary with an additional unit of traffic, i.e. the risk elasticity, is also incorporated. Valuation of the external element is specific to each risk type, reflecting the wider costs to society. Application of the risk-elasticity approach is shown in Nash et al. (2000) for rail, aviation and road transport as well as in Proost and van Dender et al. (1999).

2.6 Approaches to the Estimation of Environmental Costs

For both **air pollution and noise**, the 'impact pathway approach' set out in, for example, Bickel et al. (2000), is suitably generic that it may be applied to all modes of transport. This involves modelling emissions, dispersion of emissions, estimation of impacts (e.g. on health), and finally applying monetary values to these impacts. This method has been tried and tested for local and regional air pollution (e.g. European Commission, 1998; AEA, 1997). Although substantial uncertainties remain at each stage of simulation of the impact pathway for air pollution, no robust alternative approach exists. For noise, application has yet to be attempted, and a particular challenge lies in modelling noise dispersion to take account of factors such as topography and noise barriers, to a degree of accuracy that yields plausible results.

For **global warming**, since emission estimation is relatively straightforward, the main area of continuing debate is the monetary estimation of damages. Studies inevitably include high and low ranges of values.

The preceding text has set out the main methodologies for marginal cost estimation. At a theoretical level, these methodologies are reasonably well established. However, there is a clear need for a major expansion of case study evidence – for modes that have been examined in the past (road and rail) as well as for less well studies modes (air, inland waterways and short-sea shipping). The remainder of this document elaborates the proposed methodological approaches for the UNITE marginal cost case studies.

3 Summary of the Scope of the Marginal Costs

3.1 System Delimitation and Definitions

The scope of marginal cost valuation is to provide information that contributes to optimal price setting and efficient use of transport infrastructure. There are many forms of pricing policy that seek to increase the relationship between charges and social costs from the present day situation. These include short-run marginal cost, long-run marginal cost, and forms of marginal cost pricing subject to constraints such as budget limitations (e.g. two-part tariffs, Ramsey pricing). All of these cost-related pricing policies necessarily require information on the cost structure, and an essential component of this is marginal cost information.

It is not the role of the marginal cost analysis in UNITE to determine or discuss which form of pricing principle should be implemented by decision-makers. These issues have been examined in the past in a range of European Commission and national research projects, and extensively explored in the academic literature.

The UNITE MC analysis does seek to provide extensive new information that supports decision makers in their policy decisions.

If external costs (environment, external congestion, and external accidents) form no part of the prices, transport users will perceive them as costless, which leads to sub-optimal equilibrium. Following the allocational efficiency principle, those external costs should therefore be part of the total price.

Since for marginal cost efficiency and social purposes only the costs arising from the addition of a transport unit (e.g. road vehicle) matter, it is essential to distinguish between fixed and variable costs. Only variable costs are relevant because they depend on the use of infrastructure[3].

Marginal *infrastructure* costs are understood as the increased costs of operating, maintenance and reparation of infrastructure, noise walls and technical facilities as a result of an additional transport unit entering the flow.

Marginal supplier *operating* costs are understood as the increased costs of services or other infrastructure operations of the transport provider as a result of an additional transport unit entering the flow.

The marginal external *transport user* costs relate to the increased operating costs/ benefits and the costs of increase/decrease in journey time caused by increased traffic flow, Additional user costs due to traffic accidents are within the scope of the marginal user cost in cases where marginal accident rates are considered. Additional costs due to

[3] In order to develop a consistent and transparent methodology it is important to define certain notions and system delimitation in a proper way. For that reason a glossary of terms is included at the end of the report.

road maintenance and bad weather conditions, however, are not subject to marginal cost considerations.

The marginal *accident* cost is the economic value of the change in accident risk when a user enters the traffic flow (this risk relates to the user himself as well for other users). Marginal external accident costs is understood as the difference between the marginal accident cost and the private marginal cost (a part of the marginal accident cost which is internalised by the user). These costs include repair costs, medical costs, suffering and delays imposed on others as a result of an accident. UNITE will deal with external accident costs.

Marginal external *environmental* costs include the additional damage resulting from emissions of airborne pollutants from an extra vehicle or an upstream power source which enters the flow, including global and local air pollution and noise pollution. Noise is unwanted sound or sounds of duration, intensity, or other quality that causes physiological or psychological harm to humans.

3.2 Categories Included in the Marginal Cost Case Studies

Taking as a starting point "The Overall UNITE Methodology" (Sansom et al., 2000) a set of classification criteria has been selected to be used in determining the range of cost and benefit categories of relevance to the marginal costs, and in determining the characteristics of any individual category.

In this context, attention has been paid to such issues as: the relation of a cost category to a transport function, geographical aspect, the necessary level of disaggregation, distinction between external and internal cost to the user, fixed and variable, monetary and non-monetary costs, and others.

In drafting the general list of cost categories to be considered in the case studies, the following main principles served as a starting point:

- Comprehensiveness of coverage of all modes and cost/revenue categories;
- Identification of key interrelationships between categories;
- Examination of potential correspondence between items of relevance to the accounts and marginal costs;
- Irrelevance of non-transport related activities (e.g. shops in airports, train stations).

Within the scope of marginal cost analysis in UNITE, all costs which vary with traffic volume are relevant for marginal cost estimations. Generally, this includes both internal and external costs. The internal costs are the costs already met by transport users. Taking into account the efficiency and equity criteria, all costs that are internal to the user have been left out of the scope of the marginal cost analysis in UNITE. External costs are costs resulting from the use of transport infrastructure and falling on users other than those who cause them. External costs include elements of congestion, accidents and environmental damage.

Within the scope of UNITE only costs which are not “internalised” by the users are of direct relevance. Since the UNITE MC case studies generally involve estimation of marginal costs at the current level of transport demand, demand responses to price changes will not be assessed. However, for optimal prices to be determined, demand models would need to be constructed, and iterations carried out to establish new prices on the basis of price/demand/cost interactions. Such demand modelling would require more comprehensive information on the internal components of transport costs.

Following the directions of “The Overall UNITE Methodology” (Sansom et al., 2000) a distinction has been made between “ideal” and “pragmatic” cases. Table 3.1 summarises the cost categories which fall within the pragmatic case and will form, therefore, the basis for the case studies[4].

Table 3.1: Marginal Cost Categorisation in the Analysis

Infrastructure	Supplier operating	Transport user	Accidents	Environment
Capital costs (renewals) -replacement of assets *Running costs (partly)* -maintenance of infrastructure -operation of infrastructure	*Vehicle related costs* -wear and tear of vehicles -tyres and other consumables -net fuel costs -wages of drivers -vehicle cleaning, service, maintenance -liability costs -other operating costs *Service related costs* -general services -external services *Infrastructure related costs*(1) -building maintenance *Administrative and Commercial Costs* -staff wages -general administrative costs	*Extra Time costs* -extra waiting/access time -extra travel time -crowding effects -extra search time *Extra operating costs* -fuel consumption -driving and handling personnel -depreciation/capital costs -vehicle wear and tear -administrative costs *Mohring benefits* -access time savings -travel time savings -crowding costs savings -queuing coast savings	*Risk value* *Material damages* -Medical cost -Administrative cost -Production losses	*Air pollution* -human health -natural environment -building materials *Global warming* -damage costs (agriculture, health, energy use, water availability, coastal impacts) -avoidance costs *Noise* -human health -amenity losses *Soil and water pollution* -heavy metals, oil -de-icing salts *Nuclear risks* -operation of power plants -accident risks

Note: (1) Infrastructure costs specific to the operating company (e.g. ticket offices).

[4] The relevance of these categories differs by mode. The detailed discussion can be found in the annexed reports on marginal cost methodology for individual cost categories.

Infrastructure

The categorisation of infrastructure marginal costs is based on one hand on the type of costs and on the other hand on the type of asset. From the point of view of type of costs, the infrastructure costs consist of capital and running costs. Not all these costs are variable, consequently, not all of them are considered in the analysis. Since capital costs for replacement of assets may vary with the traffic volume, they are included in the analysis. As opposed, capital costs for new investments and overhead costs are excluded from the analysis since they are considered to be fixed from a short-term marginal cost perspective. The running costs will be included fully into the analysis.

Of course the way infrastructure capacity is handled within the short-term marginal cost perspective of UNITE does not provide all information needed from a fair policy perspective. In this regard infrastructure capacity issues will have to be evaluated regularly (based on a social cost-benefit analysis perspective), and price setting will also take into account transport policy objectives on investment recovery rates, etc.

The asset-based classification approach helps to sort out the assets that cause only fixed costs, or to identify the assets for which wear and tear as an important part of marginal costs matters particularly. Another useful tool in identifying whether and to what extent the costs vary with traffic volume is the service-based approach. It refers mainly to the examination cost elements based on the quality and level of service on a given infrastructure type which depends on the intensity of use (e.g. street lighting, snow sweeping, etc.). This will probably prove especially relevant in the case of airports and ports, which has to be further examined in the respective marginal cost case studies.

In the context of *infrastructure* costs, marginal cost functions for rail stations, for urban public transport infrastructure and for intermodal freight terminals (road/rail) will not be estimated[5]. In addition, the following cost categories are left outside the scope of UNITE:

- fixed costs (capital costs for new investments, overhead costs),
- certain assets such as parking facilities, which can be assumed to have fixed costs only[6] (i.e. not much cost variability with traffic volume),
- assets costs which relate to supplier operating costs (e.g. ticket selling facilities),
- non-transport related assets such as shops, restaurants etc. in airports and rail stations.

Supplier operating costs

Supplier operating costs are divided in three main categories: a) costs related to vehicles, b) costs related to services, and c) costs related to infrastructure.

[5] The ongoing RECORDIT project focuses on internal and external costs associated to intermodal freight transport services. In particular, it will cover a number of costs which are not included in UNITE (e.g. intermodal freight stations).
[6] Strictly speaking, since the MC approach set out in this document allows for rolling stock to vary, it should also be the case that parking provision may adapt to demand. Thus the opportunity cost of parking could be considered relevant.

Another cost category relates to administrative and commercial costs. In the ideal case the staff costs should be separated into vehicle-related (drivers, pilots, masters and maintenance related staff), general services staff and administrative and commercial staff, as well as to its role in the service (e.g. bus driver and ticket seller). This kind of disaggregation would be difficult from practical point of view. Therefore, the most appropriate differentiation for the case studies seems to be administrative staff and 'operational' staff.

The cost of protection falls outside the scope of operating costs. It will be included in the accident costs analysis.

User Costs

Congestion and Mohring effects represent typical marginal cost and benefit components resulting from economies of density at scarce capacity.

While congestion describes the inconvenience and/or increased operating costs of users, assuming that infrastructure or public transport carrying capacity is fixed, the Mohring effect accounts for the benefits of users arising when the operator increases frequencies as a reaction to increasing demand.

Mohring effects are only relevant for scheduled transport system because the influence of additional demand on the extension of infrastructure is a long-term investment problem and thus out of the scope of short run marginal user costs.

In contrast to passenger transport, the majority of freight services are on-demand services, that is, usually provided in accordance with demand. Additional departures hence are only utilised by the customer who has ordered it. Therefore, no direct economy-of-scale effects seem to occur, especially for the road and the maritime sector. UNITE, however, will consider the Mohring effect for freight transport, too. The proposed case study will examine the response of freight operators to increased demand by mode and commodity type. External benefits exist only if operators respond to increased demand by increasing the service frequency. Other external benefits – e.g. as a result of infrastructure investments, adjustment of the network density – are not considered in the analysis.

A further cost component discussed is personal security, which may well be positively affected by increasing demand. As valuation in monetary terms is not possible, and as an increased perception of security entails additional demand, the consideration of this effect is not followed further in the UNITE MC analysis.

The following *user* cost categories fall out of the scope of user costs:

- operating costs of scheduled transport system (included in operating costs analysis),
- congestion due to road maintenance activities (not pricing relevant),
- increased perception of personal security due to rising occupancy of PT stations, vehicles or access routes,

- road maintenance activities (included in infrastructure costs analysis),
- additional environmental cost due to congestion (included in environmental costs analysis).

Also the benefits due to demand-induced infrastructure investment, and the effects on non-motor vehicles as non-marginal are left outside the scope of UNITE in general.

Accident costs

UNITE will focus on accident costs that involve the use of infrastructure and are relevant for pricing issues. Consequently, accidents that occur on workplace of infrastructure construction and under racing are irrelevant for UNITE-purposes. On the other hand, accidents generated by traffic flow and injuring constructors of infrastructure will be treated as traffic related accidents.

A rather difficult measurement issue rises from the distinction between leisure and commercial traffic: should accidents during sailing, fishing trips or private aviation be included? It seems unreasonable to drop them since they fulfil UNITE-purpose: they occur during the use of infrastructure and it is possible to price them. In addition, road accidents may occur while cruising for leisure. The equal treatment of modes calls for inclusion of this type of accidents.

An open question is the consideration of accidents that involve bicycles. Although it appears to be country specific issue, it is still relevant from the marginal point of view and respective pricing principles could be applied. However, within accident costs UNITE considers only the external cost of motor vehicles, and therefore, all accidents where at least one motor vehicle is involved should be recorded. Consequently, bicycle-bicycle and bicycle-pedestrian accidents as well as single bicycle and pedestrian accidents are out of scope.

Motorised traffic causes external costs that affect non-motorised traffic. These costs could be measured in terms of the cost of protection, risk-avoiding behaviour of unprotected bicyclist or pedestrians. Nevertheless, UNITE will not consider these costs in detail.

Single accidents generate externalities for the general public and are possible to price, and should therefore be included. Suicide accidents will be excluded from the analysis.

The following accident cost categories has been left out of scope of accident costs analysis:

- Accident involving only pedestrians or bicyclist,
- The cost of risk avoiding behaviour,
- The cost of environmental damages due to accidents,
- The cost of congestion caused by accidents,
- Workplace accidents during the construction of infrastructure,
- Suicide accidents.

Environmental costs

Environmental costs can be classified as follows:

- Air pollution, which has impacts on human health, natural environment and building materials;
- Global warming as a result of greenhouse gas emissions (CO_2, CH_4, N_2O, etc.);
- The emission of noise which has impacts on amenity and human health. Vibrations lead to amenity losses and damages of buildings;
- Nature and landscape deterioration including ecosystems and biodiversity, and landscape;
- Soil and water deterioration which includes soil pollution by heavy metals, oil, etc., and water pollution by de-icing salts, heavy metals, oil, etc;
- Nuclear risks which arise as a result of electricity production.

The cost category “nature and landscape” includes the economic assessment of damages the presence of traffic infrastructure and its use is causing to the habitats of rare species. The costs are mostly related to the separation effects due to the existence of roads, rail tracks, airports and artificial waterways and thus are fixed in the short run. They are not marginal and therefore not relevant for the quantification of marginal costs. The same is true for the impairment of landscape. Therefore, this cost category is not relevant for marginal cost assessment.

To obtain a full picture of the environmental effects of all transport modes, not only the operation of vehicles and vessels has to be considered, but up- and downstream processes associated with the transport activity too. Examples of those are vehicle manufacture, vehicle use, vehicle maintenance and support, vehicle disposal, fuel/electricity production, maintenance and disposal, etc.

In practice, however, not all of the process/cost category combinations are relevant or cause relevant marginal costs. In marginal terms, environmental costs are caused by vehicle use and maintenance, fuel/ electricity production and infrastructure construction, maintenance and disposal. However, marginal environmental costs due to vehicle maintenance and infrastructure maintenance can be expected to be very small and will, therefore, not be included in the analysis. Consequently, only vehicle use and fuel/ electricity production is relevant for the pragmatic approach.

The cost categories noise, and soil and water pollution are to a high degree location specific. Considerable modelling effort would be required to cover them for up- and downstream processes, which is beyond the scope of UNITE. For this reason, these cost categories will only be quantified for vehicle operation.

The cost category “habitat losses and biodiversity” represents the economic assessment of damages the presence traffic infrastructure and its use is causing to the habitats of rare species, and thus to biodiversity. The costs are mostly related to the separation effects due to the existence of roads, rail tracks, airports and artificial waterways and thus are fixed in the short run. They are not marginal and therefore not relevant for the quantification of marginal costs. The same is true for visual intrusion in urban areas.

3.3 Treatment of Overlaps

For efficient pricing principles, there is a need to explain and delimit the interrelations between different specialist cost categories in order to avoid double counting of the respective costs. The identification of the overlaps is based on the fact that marginal cost is computed by taking the design of infrastructure as a fixed variable and vehicle kilometres as variable.

Table 3.2 identifies areas in which different cost headings overlap. Each cost category is to be considered in the work area identified by the row heading. For example, "costs of infrastructure for accident prevention" could potentially be included under the "accident" or "infrastructure" heading – but the row heading indicates that it will be considered under "infrastructure".

The running costs of infrastructure for ticket selling, and facilities for repairing buses, rail vehicles are clearly out of scope of infrastructure costs. The overlaps with accident and environmental costs, namely infrastructure costs for accident prevention and costs of infrastructure for environmental protection represent external costs. These costs are internalised in the form of infrastructure costs. However, since these costs vary only to a very limited extent with traffic volume they can be assumed to be negligible. Therefore, they do not matter for the estimation of the marginal costs.

Making clear distinction between infrastructure costs and supplier operating costs, it is worth underlining that the supplier operating costs refer to operating cost of the transport providers (e.g. ticket selling), while infrastructure costs for operation refer to operating costs of infrastructure providers (e.g. lighting, cleaning, ice-breaking, snow sweeping etc.).

The following cost categories have been included into the supplier operating costs analysis:

- Cargo terminal and passenger terminal-transport provider side in aviation;
- Constructions for traffic operation and ticket selling infrastructure, loading areas in freight railway stations[7], combined terminal facilities in the case of railways when they are the responsibility of the transport provider;
- Constructions for traffic operations and ticket selling infrastructure, utilities on stations and stops (e.g. shelter, timetable info etc.) in the case of roads when they are the responsibility of transport provider.

[7] Note that identifying freight loading areas with the transport provider is not consistent with Regulation 2598/70.

Table 3.2: Overlaps Between Specialist Cost Categories

	Infrastructure	**Operating cost**	**Transport user**	**Accident**	**Environment**
Infrastructure			Road maintenance activities	Running Infrastructure costs of accident prevention (for example crash barriers)	Running costs of environmental protection (noise-walls, ventilation systems in tunnels, etc.)
Operating cost	Running costs of ticket selling facilities for traffic operation		Additional operating costs due to congestion		Operating costs caused by pollution or legislation on environment
Transport user	Delays due to road maintenance activities	-Delays due to operational failures - Individual transport's operational costs		-Congestion caused by accidents	
Accident	-Cost of protection (excluding infrastructure) -Cost of police	-Cost of protection - Accident costs not covered by insurance companies	-Additional accident costs due to congestion		
Environment			Additional environmental cost due to congestion	-Environmental damages due to accidents	

The generation of a traffic jam may have multiple reasons, such as a combination of high traffic volumes, bad weather conditions, infrastructure maintenance activities and/or accidents. Although only increasing user costs due to capacity bottlenecks of the transport systems are pricing relevant, the case studies 7a (High-quality passenger transport, Paris-Brussels) and 7d (Bulk freight transport, Duisburg-Mannheim) will examine the importance and frequency of externally caused congestion for road and rail traffic.

A further overlap relates to the costs of vehicle operation in individual transport, which are fully covered by the transport user. These costs, which affect private and business car and goods vehicle trips, are to be recorded under user costs.

Considering the overlap of environmental costs with accident costs - namely valuation of health effects of accidents and risk of accidents decontaminating soil or water - it is proposed to record the risk whenever possible in accident costs analysis, and to evaluate them in environmental costs analysis.

The above text summarises the scope of the marginal cost in UNITE. In particular it determined the range of cost and benefit categories of relevance to the marginal costs, that is cost categories which fall within the pragmatic case and will form, therefore, the basis for the case studies. The overlaps have been identified and attributed to specialist cost categories.

4 General Methodological Issues

4.1 Common Issues

To perform the case studies, a range of technical issues has been agreed upon. This refers in particular to:

1. The base year for marginal cost estimates, as for accounts, is 1998 and is common in UNITE. This is the year for which values for marginal costs will be presented, or respectively discounted back to.
2. For use in discounting all non-environmental costs, a default rate for the social time preference of 5 percent is proposed.
3. The factor cost will be the unit of account to be considered in UNITE;
4. All the results will be presented in Euro, with exchange rate conversion from national currencies to Euro using 1998 ECU Purchasing Power Parity exchange rates.

In the case of basic statistical data (e.g. transport flow information) national databases are to be used in preference to more aggregate, Eurostat databases.

A number of specific issues relate to individual cost categories. In particular, within the accident analysis the estimation of costs will be based on damage costs. The unit to be evaluated is "years of lost life". The corresponding monetary value is the "value of a life year lost". Since empirical values for the latter are not directly available, this approach has to use the observable average value of a statistical life and the estimated average further life expectancy of the population underlying the studies.

As concerns the other issues, they are discussed in greater detail in the annexed interim reports where standardised principles for valuation are proposed. Among other issues, they cover topics such as acceptable unit values consistent with valuation methodologies, deflating methodologies, ways to ensure the transferability of the estimates, etc.

4.2 The Implication of the Cost Drivers for Case Study Disaggregation

The change in costs with an additional transport unit (e.g. road vehicle or train km) is the focus of interest. However, it is important to maximise the level of disaggregation at which calculations are performed and results presented because this:

- Improves the accuracy of cost estimation,
- Provides full information for policy application,
- Increases the opportunities for adaptation to other contexts.

Underlying each individual cost category is a number of cost drivers, which effectively determine the types of disaggregations that are suitable in the case studies. The most important of these cost drivers are:

- Vehicle type – e.g. train axle weights strongly influence infrastructure wear and tear;
- Infrastructure type – e.g. when supply capacity and traffic level jointly determine congestion costs;
- Traffic level – e.g. high traffic volume leads to travel speed, and consequently to high emissions;
- Location type – e.g. accident rates vary strongly between urban and rural settings.

Table 4.1 provides a broad summary of the relative significance of these cost drivers for the main cost categories.

Table 4.1: Significance of Cost Drivers

		Cost Drivers*			
		Vehicle type	*Infrastructure type*	*Traffic type*	*Location type*
Cost categories	*Infrastructure*	√√√	√√√	√√	√
	Supplier operating	√√√	√√√	√√	√
	Transport user	√√	√√√	√√√	√
	Accidents	√√√	√√√	√√	√√√
	Environment	√√√	√√√	√√√	√√√

*) √√√ - highly significant, √√ - significant, √ - limited significance.

The permutations of these four main cost drivers generate a large number of overall cost drivers (e.g. intensity of use, service level, interaction with weather conditions, time of emissions etc.). Clearly other cost drivers are fundamental – such as weather conditions, time period and public transport service level. Annex 1 provides an exhaustive set of cost drivers by mode and cost category.

4.3 Level of Disaggregation

The cost drivers determine the types of disaggregation needed in the MC case studies. High level of disaggregation of inputs is needed because it implies accuracy of estimates, provides full information –potential for highly differentiated policy measures, and allows for generalisation. The main disaggregations that the case studies should reflect are given in Table 4.2, and discussed in the subsequent text.

Infrastructure

The categorisation of infrastructure cost should cover both infrastructure elements and infrastructure services. Nodes will be distinguished from links. Ports and railways stations are treated as nodes within respective modes. Road and rail elements of urban public transport will be distinguished and allocated to the respective mode.

Supplier operating costs
The supplier operating cost categories will be disaggregated across types of vehicles in order to differentiate vehicle-related costs; and across types of infrastructures to differentiate the infrastructure related costs.

Table 4.2: Desirable Level of Disaggregation in the Case Studies

	Infrastructure	Supplier operating	Transport user	Accidents	Environment
Roads	-Total road network -Motorways	-Urban / interurban -Toll / free	-Road class -Traffic condition -Traffic mix -Vehicle type	-Urban/interurban -Motorways, trunk roads, other roads -Toll roads, public roads -(Low, medium, high –density)	-Urban/extra-urban -Motorway/urban road/ extra-urban road -Passenger/goods -vehicle category (HGV, LGV, Passenger car, Van, Bus) -Fuel used -Engine technology
Railways	-Passenger/freight -electrified/non-electrified (evtl)	-Electric / diesel -Rail/tram/metro	-Type of station -Density of service -Traffic mix -Train class	-Level crossings/links -Tram, metro -Marshalling yards -(Low, medium, high –density)	-Urban/extra-urban -Passenger/goods -Fuel used -Train type (high speed, Inter-city, local train)
Aviation	-Single airport case study proposed (air traffic management, runways, taxiways, apron gates, non-commercial terminal services)	-Short & medium / long distance (usually intercontinental) -Disaggregation per tax (on route, airport, fuel etc.)	-Airports -Density of service -Traffic mix -Type of aircraft	-Airports -Route -(Low, medium, high –density)	-Urban/extra-urban -Passenger/goods -Aircraft type -Engine technology
Inland Waterway	-Single waterway case study proposed (links and nodes, size of waterways, traffic mix)	-Links and nodes -Size of waterways -Vessel type	-Type of port -Traffic density -Traffic mix -Type vessel	-Type of infrastructure (channels and other waterways) -(Low, medium, high-density)	-Urban/extra-urban -Only goods transport -Vessel type
Maritime	-General ports case study proposed (type of vessel, port links)	-Type of vessel -Link and nodes -Traffic mix	Type of port Traffic density Traffic mix Type of ship	-Ports -Fairway -Open sea -(Low, medium, high-density)	-Harbour/sea -Passenger/goods -Vessel type

Transport user costs
User-externalities can be computed and presented with a high level of disaggregation regarding level of demand, infrastructure characteristics and mode. The disaggregation proposed for the ideal case can be used for the pragmatic approach since the data needed can be generated by computer simulation models.

The regional aspect becomes less relevant for the cost function since congestion and Mohring effects can be completely determined from infrastructure- and demand data.

One of the most important elements for the generation of marginal cost/benefit functions is the infrastructure condition. For the determination of the user costs as function of traffic load of relevance are the type of infrastructure, speed and current condition of the infrastructure.

One of the driving sources of congestion is the size and speed of the transport unit. Therefore, there should be made disaggregation across different types of transport units competing for the same segment of infrastructure. The Mohring benefits are determined by the current service levels, vehicle occupancy factors and the operator's expansion path, which is the most relevant factor and the most difficult to quantify.

Accidents
For the marginal cost estimates (and pricing policy) it is important to make distinction between different types of vehicle involved in the accidents. The driver's characteristics are important as well, but difficult to collect the respective information. The legal and insurance system is necessary to understand but could probably not be recorded on the detailed level. An overview over the country specific situation and aggregate information is probably the best thing to do.

As concerns the necessary disaggregation of the infrastructure type, weather and traffic volume, the most difficult area to find information on is the risk elasticity[8]. Consequently, the level of possible disaggregation for risk elasticity will decide the necessary disaggregation for risk.

The risk elasticity on roads differs between links and intersections. Accordingly, as the number of intersections increase, the elasticity changes. This leads to different elasticities in urban and interurban areas. In addition, the elasticity may depend on the traffic volume. Some evidence on risk elasticity by road type (motorway, two-lane wide respectively two-lane narrow road) exists.

The risk on rail and air should follow a similar disaggregation as for the risk elasticity used for roads. Although there is not much information as concerns the elasticity for railways, aviation or maritime transport, it is believed that for rail the elasticity is different between level crossings, links (single or double) and marshalling yards. For aviation the difference exists between landing, take-off and route. Therefore, it is proposed to differentiate within aviation between take off, landings, and route risks. Maritime should distinguish risks at ports from risks in the fairway and in the open sea. Inland waterways should be treated separately. In addition to these classes, all elasticities may depend on the traffic volume.

Environment
Marginal external environmental costs are to be disaggregated by vehicle types and technologies, geographical scale of impacts and the type of infrastructure.

[8] The information on risk elasticity will be taken from case study estimates, literature review or planning models. More details on elasticities will follow in chapter 5.4.

The scale of the impact of environmental cost categories is very different, both in space and time. Whereas airborne pollutants are mainly a problem at the local and regional (e.g. European) scales, the effects of greenhouse gas emissions are global in nature. Noise impacts, are restricted to the very local scale of several hundred meters from the emitting source. Water pollution on the other hand may affect areas in the range of up to several hundred kilometres. The same is true for nuclear risks, which in case of an accidental release may affect all of Europe. Consequently, the treatment of environment costs will cover the local, regional and global impacts.

As regards the time scale of the effects treated here, the nuclear risks have the longest time scale, according to the long lifetime of radionuclides, which may reach several thousand years. Due to the long atmospheric lifetime of the relevant greenhouse gases, several hundreds of years have to be taken into account when quantifying impacts of greenhouse gas emissions. Airborne pollutants (e.g. CO, SO_2) have shorter lifetimes; they cause short-term effects occurring within hours (e.g. peak concentrations) as well as effects over several days (e.g. ozone episodes). Noise has the most limited effect, as it disappears soon after the emission source has disappeared. However, after pollution or noise have dissolved, the impacts of the exposure, e.g. an increase in chronic mortality, may occur several years after the exposure.

With regard to environmental costs not only the operation of a vehicle or vessel is relevant, but as well up- and downstream processes associated with the transport activity. For instance, if only the direct impacts of vehicle operation would be taken into account, practically no environmental effects of electric vehicles would be recorded. It is obvious that this would be inappropriate as electricity production may cause considerable environmental burdens, depending on the type of electricity generation. In addition, the production, maintenance and disposal of vehicles and transport infrastructure might be relevant. Hence up- and downstream processes have to be considered when quantifying environmental costs.

A list of potential cost drivers was identified to have an impact on cost behaviour. The question to what degree these cost drivers influence costs remains unanswered at this stage but will be examined within the case studies. Also the question to what extent the identified cost drivers and desirable disaggregation can be used in the estimation procedure will be answered during the implementation of the case studies.

5 Methodologies for Individual Cost and Benefit Categories

The interim reports included in the annex describe in detail the methodological approaches for computation of MC estimates in the case studies, step by step. Below is presented a summary of the proposed estimating methodologies for the pragmatic cost elements (those which are possible to asses within UNITE time framework) proposed within each specialist cost category.

The chapter is organised as follows: for each specialist cost category from the marginal cost equation (section 2.2) an estimation methodology is proposed and discussed along with an alternative approach. In addition, preliminary sources of uncertainty for individual MC components are identified.

For every specialist cost category assumptions on which the estimation method is based (when performing the case studies, data limitations will most probably imply other assumption, too) are specified. These specific assumptions will play an important role for the sensitivity of the results. The case studies will provide low and high estimates along with the approximate level of confidence.

The most probable major sources of uncertainty or weaknesses of approach in estimates of the marginal costs are:

- The definition of the cost
- Omission of certain cost categories
- Problems with data
- Insufficient data
- Oversimplified cost function

With the help of sensitivity analysis, the critical parameters and main sources of uncertainty in the estimates will be identified.

5.1 Infrastructure Costs

A scientifically and empirically adequate approach for the estimation of marginal infrastructure costs has as its basis the cost function. Cost functions for infrastructure can be derived either with econometric methods or with engineering approaches. In contrast to econometric approaches for estimating cost functions, engineering methods are bottom-up approaches.

The bottom-up estimation typically analyses single infrastructure sections or lines and generalises the results afterwards. On contrast, top-down approaches start from the real occurring total costs, or total cost components, and seek for a functional form for the total costs and the marginal costs. Within both approaches cost function can be derived by using, either cross section analysis or regression analysis based on time series. In the first case different sections of infrastructure are compared and infrastructure costs are analysed according to traffic volumes, vehicle weight etc. In the second case the change of traffic volumes and weights and the related development of costs and time are analysed.

5.1.1 Suggested Methodology

The main idea behind estimating infrastructure costs is to find the adequate relationship between cost drivers and the development of infrastructure costs. An important question in this respect relates to the form of the cost function. An assumption of a linear cost curve means that marginal costs are constant (consequently not varying with traffic volume). Such an assumption is generally not justified and not confirmed by empirical evidence. Thus, it will not be considered in the current study. On the contrary, a more complex cost function – which theoretically and empirically satisfies and follows the theoretical principles of social marginal cost - will be estimated.

There are different approaches for estimating costs functions in different modes. For the estimation of marginal infrastructure costs in UNITE it is foreseen to use both an econometric approach and an engineering cost estimation technique for road and an econometric approach only for rail. For infrastructure costs of airports, seaports and inland waterways a case study approach will be chosen.

A case study approach relates to certain parts of infrastructure for one mode, e.g. only one or a limited number of ports, airports, waterways etc. Therefore, the respective case studies will have an approach specific to the characteristics of the location being examined. In particular, the inland waterway case study will focus on cost of terminal facilities, channel maintenance and locks of channels feeding into the Rhine. The aviation case study will be based on disaggregation of existing cost data for an airport. The costs will be disaggregated based on used facilities of aircraft and passengers. The seaport case study will use the engineering approach using “the average cost of the marginal plant” as a marginal cost proxy.

a) Econometric Approach

UNITE seeks to identify a functional relationship between cost behaviour TC_{infra}, traffic volume Q and **impact** factors, rather than **input** factors. Impact factors could be for example infrastructure characteristics (I), vehicle weight (W) and speed (S), weather conditions (Z), that is all cost drivers identified in section 4.4. This would lead to a function

$$\mathbf{TC_{infra} = f\,(Q, P, W, S, I, Z).}$$

The factor price input vector will be not considered in the first stage of the analysis because no differences between the infrastructure segments are assumed. However, the analysis of the collected data will show whether it is reasonable to maintain this assumption. Furthermore, depending on whether or not cross-sectional data are available for more than one year, the price vector P has anyway to be introduced into the cost function.

The type of the function can be treated from two perspectives: i) theoretical with pre-determined functional form[9], and ii) empirical with the use of explorative data analysis techniques. Given the fact that so far not much empirical evidence on cost function for pure infrastructure costs does exist, a parallel approach of estimation procedures is suggested:

- Cost behaviour will be analysed in relation to the identified cost drivers by using the flexible functional form of the translog function;
- In parallel, the empirical approach will be followed and explorative data analysis methods applied.

The translog function is suggested due to several advantages. First, it is a theory-based systematic approach, which enables us to analyse cost behaviour starting with the general case and specialising the function stepwise to our field of application. Second, this form is a flexible mathematical tool, a second order approximation of an unknown production function. It imposes only few restrictions on the underlying production technology and it contains all relevant properties of neo-classical production theory such as factor substitution, economies of scale and technological change.

In order to apply the general translog function to cost functions for road and for rail tracks, it is necessary to define the respective output vectors, impact factors vector and to set a set of hypotheses on negligible cross-relationships between variables. Following this, a full translog function can be obtained for road infrastructure costs (see Annex 3) and rail tracks costs.

Due to its complicated and sizeable form, the full translog function has to be reduced in the next steps by theoretical considerations of existing or non-existing relationships between variables, and by statistical hypothesis testing.

b) Engineering approach

Besides the econometric approach, a case study (restricted to Sweden) for an engineering-based road cost function will be considered too. Since engineering knowledge in that context refers mainly to weight-dependent costs the case study deals only with heavy goods vehicles (HGV).

There is an inverse relation between the quality of the road and the cost of use and future maintenance cost. Under an optimal design, the incremental capital cost of additional durability do not exceed the incremental saving in maintenance and road user costs for any given level of traffic. With an optimal investment policy, long- and short-run marginal

[9] In particular first and second order approximations to a general cost function such as the translog functional form or Cobb-Douglas form as the special case of the translog function.

costs are equal. The form of the „durability„ production function determines the relationship between average cost and marginal cost, as well as expected cost recovery.

The short-run marginal cost in relation of wear and tear consist of road producer cost and user cost. Although the user costs due to reduced quality of the road are difficult to estimate, a number of convenient shortcuts have been developed. Under some circumstances user cost is irrelevant and marginal maintenance cost equals the average maintenance cost.

There are several assumptions to be made in regard to pavement practices. First of all, estimates will be obtained under an optimal investment policy. Secondly, since the deterioration is heavily dependent on the axle load, we assume that the road surface deteriorates as a function of the number of cumulative "standard axles" rather than "number of vehicles". The Case Study will explore the state-of-the-art for deterioration functions and suggest when the 'forth power law' is applicable and when other values should be used.

Subsequently, the assumed relationship between pavement life and pavement durability is important. The cost of shortening of the period between overlays is one of the marginal cost components of road wear. In principle the maintenance cost may be calculated as a present value over an infinitive horizon. The marginal cost is then the change in the present value due to the shortening of the intervals as the number of standard axles increases.

This means that the marginal cost will vary cyclically over a period. The average marginal cost is often considered over a large road network where the pavement ages are evenly distributed. The marginal costs per standard axle can then be obtained by differentiating the annualised maintenance cost with the annual traffic loading. The Case Study will examine the reconstruction production knowledge in more details and will propose an appropriate range of estimates.

The increase of the user costs due to the deterioration of the pavement will be limited as the road authority responds to the deterioration with resurfacing. It can be shown[10] that under some approximation the average user cost over a whole pavement cycle is independent of the increase in wear. The increased wear just shortens the period between pavements. This fact will increase the user cost estimated as present value.

Another factor that might affect the marginal infrastructure costs is the institutional or/and regulatory arrangement. Public or private organisation can have different cost curves, lead to different levels of cost components, and consequently different cost structures. In this regard, with a high degree of probability, we assume that cost curves and the direction of the relationship between costs and costs drivers will not vary within different institutional arrangements. What we expect to have major relevance is capital valuation and derivation of capital costs which in private frameworks is realised in a different way than in publicly financed infrastructure. Different efficiency levels of

[10] The interim report 5.3 (Link H., Lindberg G,. Marginal Cost Methodology for Infrastructure Costs, September 200) annexed to this report provides the relevant evidence to this and other statements regarding the engineering approach.

maintenance and operation of private versus public infrastructure result in different cost structures. The different institutional arrangements will be treated by estimating separate cost functions for public and private infrastructure in a number of case studies (e.g. Swedish rail vs. British Railtrack and others).

Summarising, marginal infrastructure costs can be calculated in two steps. First, to estimate a total cost function, and then, from this relationship to compute the change in the total cost with change in use. However, the key methodological steps vary between approaches.

5.1.2 Alternative Methodology

An alternative method in particular to the suggested type of econometric cost function research is to use aggregated time series data in contrast to the proposed use of cross-sectional data. The advantage of this approach is that it is much less data-consuming than the cross-sectional analysis we proposed for UNITE. The disadvantage and the reason why we do not consider this approach as our first choice is that it is a very simplified approach with high probability of multi-collinearity problems. However, this approach remains a possible but not ideal alternative despite of these disadvantages if we do not succeed to collect the necessary cross-sectional data for our preferred approach.

5.1.3 Treatment of Uncertainty

Unlike work packages which deal with non-monetary values (e.g. environment costs, accident costs), and consequently have to deal with input parameters which influence substantially the whole cost estimation, the weakness of the proposed method could arise from the oversimplified function, insufficient data and the problem of extreme values.

It is difficult to assess the potential data quality at this stage of the project. However, we can refer to usual statistical procedures to treat extreme value, that is the calculation of confidence intervals, residual analysis etc. Furthermore, it should also be borne in mind that the translog cost function estimation is done along statistical optimality criteria that could, however, not be fulfilled for the back-transformed data.

5.2 Supplier Operating Costs

5.2.1 Suggested Methodology

The experience[11] of econometric and empirical studies of supplier operating cost functions suggest that the relationship between cost and service output is difficult to estimate for different reasons (e.g. the output – number of trips - is heterogeneous and difficult to estimate, the service quality is different for different output levels etc).

[11] In particular see e.g. Harris (1997), Waters (1985), Jara-Diaz, Cortes (1996), and Oum, Waters (1998).

Therefore for estimation of marginal cost an engineering approach is preferred. It focuses on the relationships between output and inputs in terms of a specific technical description of the production process, and applies relevant factor prices to the resource requirements.

The equation below illustrates the production function the basic idea of which is that the system of scheduled public transport production consists of a number of vehicles and that the output of this production system can be increased in different ways:

$$\mathbf{B = f\,(N, S, V, H, \phi),}$$

where **B** denotes the number of trips, **N** – the number of equi-sized scheduled public transport vehicles, **S** - vehicle size in terms of holding capacity (e. g. the maximum number of passengers), **V** - speed, **H** - "handling capacity", i.e. the number of passengers boarding and/or alighting per unit of time, and ϕ - occupancy rate (that is holding capacity utilisation).

It should be noted that in the engineering approach, specific service production designs variables rather than general factors - such as labour and capital - appear as independent variables. Consequently, the above-mentioned function is of no direct/relevant use. For the purposes of the analysis, therefore, cost–output relationships should be obtained taking into account the industry-specific engineering knowledge. As a result, the relationships between output and inputs can be treated in terms of a specific technical description of the production process, and relevant factor prices to the resource requirements can be applied.

Having defined the social total operating cost function, next step is to define the respective marginal cost independent of the design variables. A marginal cost proxy in passenger transport is the incremental system cost of another unit of supply (a round trip of a vehicle, or a round trip of an additional carriage) divided by the number of additional passenger trips produced by another vehicle or carriage round.

Operating costs of the vehicle/carriage include such costs as a) traffic operation costs; b) wear and tear of the transport infrastructure[12]; c) congestion and accident costs; d) other user costs and benefits, e.g. in the form of more frequent services that is the Mohring effect; and e) the so called overhead costs. However, taking into account the definition of operating costs and the overlap with other specialist cost categories, the operating cost analysis will consider only cost categories a), e) and partially d).

Summarising, the price-relevant marginal operating cost proxy is obtained by first dividing the total traffic operation costs by the number of vehicle round trips produced in the system and then subtracting the positive Mohring effect of another vehicle round trip. In the case of urban bus transport, the model is illustrated by the following equation:

[12] A proportion of infrastructure operating costs can also be considered as marginal as individual trains need to be scheduled and signalised for safe operation.

$$\mathbf{MC_{operator} = dC/dQ - \nu Qdt/dQ,}$$

where Q denotes the number of passengers, t – waiting time per passenger trip, and ν - value of one minute waiting-time saving.

5.3 Transport User Costs and Benefits

5.3.1 Suggested Methodology

The overall methodology for estimating marginal user costs covers the following three groups:

- Congestion costs in individual and commercial transport;
- Congestion and scarcity in public transport
- Mohring benefits in scheduled transport.

Individual transport includes all those traffic activities, where individuals operate vehicles on their own account. *Commercial* transport is distinguished from individual transport by the fact that not only the preferences of the service subscriber, but also the operator's business accounts determine the decisions taken by the operator. Commercial transport includes in-demand services for passengers and freight, such as road, air and water taxi, delivery services and road haulage. Excluded are regular services by buses, rail, air and ferry.

Public transport subsumes all kinds of collective or mass transport, which are used by passengers or freight shippers by paying a previously fixed fare. The modes embraced by "public transport" are scheduled bus services, tram, rail, aviation and waterborne transport.

The definition of *Mohring* effect was mentioned in section 3.2. Mohring benefits are relevant for road, rail, air and waterborne passenger transport services.

Congestion costs in individual and commercial transport

The preferred methodology starts from the *assumption* that the capacity of the commonly used infrastructure (roads, airports, seaports, watergates) is limited and that operating costs increase when these limits are approached. The marginal external costs that users impose on each other in individual and commercial transport can be written as follows:

$$\mathbf{MEC_{user}(Q) = Q \cdot \partial AC_{user}(Q) / \partial Q,}$$

where:
MEC_{user} denotes the marginal external costs of a user perceiving his private (average) operating costs $AC_{\mathbf{user}}$ at the current traffic level Q. $AC_{\mathbf{user}}(Q)$ is to be defined in such a

way that in addition to the capacity-related user costs, also the average costs caused by accidents, bad weather conditions or maintenance activities are considered.

External congestion costs are extremely sensitive to small changes in traffic demand and thus their internalisation by means of pricing will influence their level strongly. Therefore, the appropriate congestion price level is well below the current external cost. It may be determined by the following model.

If $D(\Delta p)$ describes the relative change of Q due to a relative change of the user costs at the current traffic level ($AC_{\mathbf{user}}(Q)$) of the level $\Delta p=(AC_{\mathbf{user}}(Q)+MEC_{user}(Q))/AC_{\mathbf{user}}(Q)$, the equilibrium traffic level Q* is described by the intersection of D and $AC_{\mathbf{user}}+MEC_{user}$. In a formal way:

$$\mathbf{Q^* = \{q \in [0...Q] \mid AC_{user}(q)+MEC_{user}(q) = Q \cdot D((AC_{user}(Q)+MEC_{user}(q))/AC_{user}(Q))\},}$$

where:
$MEC_{user}(Q^*)$ denotes the price to be charged in order to reach the efficiency-optimum Q*, which is the second output of the marginal cost estimated to be presented.

Finally, as an information which will be useful for further modelling work, pricing-relevant user cost functions $AC_{user}(Q)$ serve as both, the core input for the marginal cost calculations and an output to be presented.

The general procedure to calculate the marginal external congestion cost for individual and commercial transport consists of three main steps:

- Estimate the relationship between traffic volume and speed. This relationship depends on the type of facility, traffic volumes and composition, and vehicle characteristics;
- Estimate the relationship between accident, maintenance and weather-determined user costs and traffic volumes;
- Determine the average user costs functions;
- Estimate the marginal external cost.

Congestion and scarcity in public transport

Estimation of user costs in public transport is similar to the one for individual and commercial transport. In this case, it is split between cost of scarcity and cost of crowding. Consequently, the determinant of the average user costs is now not only the number of users in the system (Q), but also the number of carrying units (R(Q)) (trains, aeroplanes, vessels, etc.), which of course again is dependent on Q. The formal description of the equation is now expressed separately for scarcity- of for delay time costs:

$$\mathbf{MEC_{Scarcity}(Q) = Q \cdot \partial AC_{Delay}(R(Q)) / \partial Q,}$$

and for crowding costs:

$$\mathbf{MEC_{Congestion}(Q) = Q \cdot \partial AC_{Crowding}(Q) / \partial Q.}$$

The total marginal external costs then results as the sum of $MEC_{Scarcity}$ and $MEC_{Congestion.}$ R(Q) represents the decision framework of the operator. The determination of the optimal user volume Q* and the resulting optimal congestion charge MEC(Q,R(Q*)) is similar to the case of individual and commercial transport.

Mohring benefits in scheduled transport

For estimation of the Mohring benefits in scheduled transport, the application of a robust estimation model (as used in PETS) is recommended. The basic assumption is that the layout of lines, vehicle sizes and occupancy rates are kept constant. The only variable parameter is departure frequencies, which directly influences the average waiting time of passengers. The inter-relationship between user benefits expressed by the Mohring effect and user costs in form of congestion, scarcity and crowding will be assessed by means of the relevant case studies in UNITE[13].

The value of time (VOT) in the case of scheduled services is highly dependent on the mode's quality and speed. Consequently, in contrast to the time values for air and urban underground travel, the values of time for travelling by bus or tram are considerably lower. The issue of waiting times is extremely simplified in the model below, as in reality the passengers will consult timetables as the headway of a service exceeds 10-15 minutes. In the case of headway reductions above this order of magnitude, passengers only benefit from increases in their flexibility of departure time choice, which is valued well below waiting time reductions.

The marginal user costs then are determined by the following equation:

$$\mathbf{MEB_{Mohring} = Q \cdot \partial AC_{User}/\partial Q = -0.5 \cdot VOT_{Departure} \cdot OR / Q,}$$

where:
OR is the occupancy (passenger per vehicle);
Q is the demand (passengers per hour);
$VOT_{Departure}$ is the value of departure time shift per hour per vehicle.

5.3.2 Alternative Methodology

For the calculation of marginal external congestion costs in road transport there is simply no real alternative to the consideration of speed-flow functions. Some degree of freedom, however, is given by the selection of the system to be considered. This means, in the proposed methodology single links and demand elasticities are considered as the system of relevance.

[13] Of particular interest here are case studies 7b (Swedish rail transport), 7h and 7i (air transport).

An alternative approach towards the quantification of marginal external user costs in public transport for urban areas is developed by the TRENEN II STRAN project (Proost et al., 1999). Here, link-related speed-flow relationships have been replaced by area-related functions, which have been estimated using a set of relationships between total mileage performed in the network and the related average travel speed in the area considered. In general in the UNITE approach it is recommended to compute marginal costs on a link/node-cluster basis. However, in a pragmatic way also the TRENEN-approach might be applied in here. Alternative approaches for inter-urban public transport for passengers and goods are not known.

A real alternative for the Mohring effects approach would be the application of a full-scale traffic model, which is capable to predict the expansion activities of the supplier due to increasing demand. However, the problem of the predictability of the supplier's decision is a very serious one and thus for reasons of the robustness of the results the additional value of such an approach is at least doubtful.

5.3.3 Treatment of Uncertainty

The major sources of uncertainty in the proposed methodologies might appear to be the form of the speed-flow relationship and the influence of factors such as size and performance characteristics of the vehicle (e.g. a truck implies higher marginal costs due to its size, speed and other characteristics). The influence of the shape of speed-flow functions on the level of external costs is enormous. Even if the free-flow speed and the capacity limit of two road segments are equal, a flat curve will have much lower marginal costs than a curve which is declining exponentially.

Taking into account its importance in the transport user cost analysis, the value of time should be subject to sensitivity analysis. Uncertainty ranges for values of time by travel purpose are presented in INFRAS (1998). The uncertainty range of the relative value of congested or crowded time to "normal" travel time is not known, but it can be expected that it is also considerable. Therefore, a sensitivity test concerning the value of time is required.

5.4 Accident Costs

The total marginal accident cost is the extra cost imposed by a user on all other users (including himself) and the general public due to his travel decision. The relationship between imposed cost and travel decision is decided by the relationship between traffic volume and risk, that is, risk elasticity. When he becomes a victim the only externality is the cost imposed on the general public due to his travel decision, the risk value is internal. When he is an injurer all costs are external except for paid compensation and fines. External cost depends on elasticity.

The property damage consists (for the road sector) basically of the vehicle damage cost and is measured as repair or replacement cost. Property damage can be measured as number of ‘property damage only accidents’ for road accidents. For less frequent accidents in other modes it s possible that the measure has to be monetary directly; it is probably difficult to find a ‘standardised air crash’ for example.

The general modal proposed for the estimation of external marginal cost covers all modes and al types of accidents. The three main parameters of the methodology are risk, elasticity and differences in the legal system. The model assumes that the victim in his decision generally internalises his risk value. The key function which will determine the magnitude of the external accident cost will be determined by the relationship between risk and the number of users, that is elasticity. The model can be adjusted to risk avoiding behaviour and to the liability system, which affect the external marginal cost estimates.

5.4.1 Preferred Methodology

The total cost for one years accidents can be written as below where **A** is the number of accidents and (a+b+c) the cost components. Briefly we can define **a** as the ’value of statistical life’ (VOSL), **b** ditto for relatives and friends and **c** as costs, mainly material, for the rest of the society. The marginal cost with respect to the traffic volume (**Q**) for a certain vehicle category follows then and we derive the external marginal cost. Where **MPC** is the marginal private cost already internalised.

$$\mathbf{TC_{accident} = A\ (a+b+c)}$$
$$\mathbf{MC_{accident} = dA/dQ\ (a+b+c)}$$
$$\mathbf{MEC_{accident} = MC_{accident} - MPC_{accident}}$$

This expression of the external cost is equivalent to the more traditional ‘congestion externality’. However, in congestion all users suffer equally from congestion and therefore the individual internalised cost ($MPC_{accident}$) equals the average cost. Not all users suffer from the accident; only the victim. The $MPC_{accident}$ will therefore be different for a victim (v) and an injurer (i). The former may internalise the value of statistical life **a** and possible **b** while the latter has a zero $MPC_{accident}$.

The users are divided into victims ($\mathbf{Q_v}$) and injurers ($\mathbf{Q_i}$), the first group is hurt and the latter is the other part in the accident, the question of fault and negligence is not important here. The victim’s risk is $\boldsymbol{\pi}$ (A/Q_v) and the injurer’s is $\boldsymbol{\theta}$ (A/Q_i). The derivation of accidents with respect to traffic volume is expressed as a risk elasticity **E** ($E_v=d\pi/dQ_v\ Q_v/\pi$; $E_i=d\theta/dQ_i\ Q_i/\theta$).

$$\mathbf{MEC_{accident,\,v} = \pi(1+E_v)(a+b+c) - \pi(a+b) = \pi E_v(a+b+c) + \pi c}$$

$$\mathbf{MEC_{accident,\,i} = \theta(1+E_i)(a+b+c) - 0 = \theta(1+E_i)(a+b+c)}$$

Finally, we can expect that the user may be both a victim and an injurer with the probabilities β and (1-β) respectively. The expected marginal cost is a sum of the cost as a victim and the cost as an injurer (equation A).

A. $$\mathbf{MEC_{accident} = \beta\pi E_v(a+b+c) + (1-\beta)\theta(1+E_i)(a+b+c) + \beta\pi c}$$

where:
(a + b + c) - cost components,
π - the risk to become a victim,
θ - the risk to become an injurer,
E_v, E_i - the risk elasticity of respectively victim an injurer.

Three main questions have to be discussed based on this model;

i. The relationship between the number of accidents and the traffic volume (dA/dQ),
ii. The value on the cost components (a+b+c) and
iii. The marginal private cost ($MPC_{accident}$).

The proposed general model of marginal external accident cost is suitable for all situations (homogenous and heterogeneous), for all modes and for both intra- and intermodal accidents. The empirical result on risks will decide whether this model collapses to a model for 'homogenous' traffic or a model for 'heterogeneous' traffic or anything between.

The liability system may transfer the responsibility for the cost ex-post from the victim to the injurer. If we assume that this ex-post cost is perceived as an expected private marginal cost the type of liability system and level of fines and compensation will affect the external marginal cost. With a negligence rule it is only in the case where the injurer are guilty that the responsibility of the cost is transferred from the victim to the injurer. This increased responsibility of the injurer will increase his MPC while it will reduce the victims MPC. We will have two expressions for the external marginal cost of the injurer (B1) depending on if he is guilty or not and for the victim depending on if he gets compensation or not (B2).

B1. Legal injurer: $\mathbf{MEC_{accident,\,i} = \theta(1+E_i)(a+b+c) - 0}$
Criminal injurer: $\mathbf{MEC_{accident,\,i} = \theta(1+E_i)(a+b+c) - \theta(d+M)}$

B2. Not compensated victim: $\mathbf{MEC_{accident,\,v} = \pi E_v(a+b+c)}$
Compensated victim: $\mathbf{MEC_{accident,\,v} = \pi E_v(a+b+c) + \pi d}$

In some cases potential victims may react to the increased risk with a costly risk avoiding behaviour. When adding this cost to the external cost of as expressed in the formula above, the total external cost for injurer will take the following form:

C1. $$\mathbf{MEC_{accident,\,i} = \theta(1+E_i)(a+b+c) + Q_v\ dg/ds_v\ ds_v/dQ_i,}$$

where "g" denotes the cost associated with the safety level "s", and Q_v and Q_i number of victims and injurers respectively. While this may be difficult to estimate an upper limit on the cost can be found based on the pure risk change.

C2. $$\mathbf{MEC_{accident,\ i} = dA/dQ_i\ (a+b+c)}$$

We have found a lower bound on the external marginal accident cost when only the accidents are included and an observed risk elasticity is used (A or B1). An upper bound is found if the 'pure' risk elasticity approach above is employed (C2). In between we have the preferred approach for the estimate on the total external marginal accident cost, i.e. to separately add a component of risk avoiding behaviour (C1).

To summarise, the estimation method developed for accident costs goes through four steps:

- Estimate the risk of injurer and victim;
- Estimate the relationship between traffic volume and accident frequency A(Q); and calculate the marginal increase of the expected number of accident according to this relationship dA/dQ, that is the risk elasticity;
- Evaluate the monetary value of these changes (by the means of willingness to pay/ avoid method). The marginal cost is the change in frequency of accidents dA/dQ multiplied by the costs per occurrence (a + b + c);
- Estimate the parts of this added cost that are internal and external. The difference between the marginal accident cost and the internal/private cost gives the external marginal accident cost ($MEC_{accident} = MC_{accident} - MPC_{accident}$).

The external marginal accident cost depends on risk, risk elasticity, and private marginal cost. At its turn, the risk depends on vehicle and infrastructure type (including mode), driver characteristics weather and time. The risk elasticity depends on vehicle and infrastructure type and the traffic volume. Finally, the private marginal cost depends on the legal and insurance system. Having said that, the general equation for marginal cost can be modified taking into account the respective independent variables.

5.4.2 Alternative Methodology

An alternative approach is to use planning models. For example, the manuals for the Swedish Road Administration propose a model to estimate the number of accidents in level road crossings (BVH106 p. 4-61). From this model the relevant elasticity can be derived. This method was used in PETS (1998) that heavily used the road planning models in Sweden and UK.

5.4.3 Treatment of Uncertainty

The results of the estimation of the external marginal cost will depend on i) risk and underreporting, ii) risk elasticity, iii) economic values, and iv) MPC.

Although accident risk is a difficult area and a lot of uncertainty exists it is still one of the more reliable pieces of information in the estimate of external MC. The risks should be corrected for underreporting. Given the huge uncertainty in the other components we propose to only use the best estimate of risks.

Reliable estimates on the risk elasticity are difficult to find[14]. We will use the best estimate and where this estimate is uncertain a low and a high range. The low range will be the traditional 'cost allocation method assumption' – i.e. that the risk elasticity is zero (E=0). The high range could be a 33 percent increase in the best estimate.

The risk value is the main cost component and overshadows all the others both in magnitude and in uncertainty. The sensitivity test of the cost components will therefore concentrate on this value. The estimates will be made with one 'best estimate' supported with a low figure which is 33 percent below the best estimate and one high figure which is 33 percent above the best estimate.

Our best assumption is that the private marginal cost consists of the users own expected risk value and his relatives and friends value (i.e. $MPC_{accid} = r * (a+b)$). As a higher range (which will give a higher MC estimate) the so-called 'Turvey's case' will be used, i.e. that the user does not consider any risks when making trip decisions ($MPC_{accid}=0$).

The proposed sensitivity tests for accident cost analysis are presented in Table 5.1.

Table 5.1: Sensitivity test and Best Estimates in the Accident Analysis

MC	Risks	Elasticity	Unit value	MPC
Best	best estimate	best estimate	best estimate	MPC = r*(a+b)
Low	E=0	low range	0.66 best estimate	-
High	E=1.33 best estimate	high range	1.33 best estimate	MPC = 0

5.5 Environmental Costs

The overall methodology for estimating environmental costs consists of three aspects: air pollution; global warming; and noise. Damages due to air pollution include impacts on human health, natural environment and building materials. Global warming damage cost estimates cover impacts on agriculture, health, energy use, water availability, and coastal impacts. Noise costs consider human health and amenity losses.

5.5.1 Preferred Methodology

The estimation of environmental costs is based on the Impact Pathway Approach. The principle of this approach can be applied to all modes. However, there exist mode specific differences that have to be betaken into account, so that the respective modes specific models are adjusted appropriately. The application of the same approach for all modes ensures consistency of the resulting estimates.

The estimation of environmental marginal costs consists of the following steps:

[14] This fact, in particular, makes the estimation of marginal external accident costs more difficult than for the other cost categories. The estimation of the elasticity will be a major problem. When derived from other models, the quality of such elasticities might be questionable.

- Estimate the emission from the source respectively of airborne pollutants, greenhouse gases and sound;
- Determine the type of impact (e.g. to human health, agriculture, natural environment etc.);
- Estimate the number of persons, animals, plants exposed to various ambient concentrations/noise levels over time;
- Establish the relationship between exposure to each pollutant/noise and the various health and welfare effects, and predict the physical effects of the emissions on the basis of these relationship;
- Calculate the monetary value of effect on health and other. An appropriate method would be the market prices if market exists, and otherwise the willingness to pay to avoid or to accept small changes in risks if no market price is available.

Changes in noise levels due to a single vehicle are very small and indistinguishable from the background by the human ear. Therefore it could be argued that there is no externality. However, as the sum of all increments has obviously some effect on human beings, each increment can be assigned to the same increment of cost. This is the approach that has been taken also for small increases of air pollution and the resulting impacts on e.g. crops or human health.

The willingness to pay/accept can be measured either directly or indirectly. Direct methods measure the willingness to pay for environmental goods by surveys, while indirect methods derive the willingness to pay from observed market data. Direct methods measure stated preferences while indirect methods measure revealed preferences.

In the case of global warming, the same damage cost factors can be applied to all modes. The method basically consists of multiplying the amount of greenhouse gas emitted by a cost factor. Due to the global scale of the damage caused, there is no difference how and where greenhouse gases is emitted.

As for the noise cost category, the impact pathway approach across modes must be treated individually. The reason for that is the complexity of the nature of sound. Different sound sources have different effects. This fact is more accentuated in the context of time depending appearance of sounds and their different perception by human beings. The mode specific methodological details are discussed in detail in interim report 9.3 “Marginal Cost Methodology for Environmental Costs”.

In the case of road transport, an interesting topic results from analysing the relationship between the speed of the vehicles and the volume of pollutant emissions. An extra vehicle entering the system acts in two ways: on the one hand it emits itself pollutants, and on the other hand, by affecting the average speed of the others it influences the volume of emissions by others. Assessing the costs due to the second aspect would require traffic modelling, consuming considerable resources. This is beyond of the scope of the current project. Furthermore, in view of the uncertainties involved in emission estimation the effort of traffic modelling appears not to be justified.

5.5.2 Alternative Methodology

The impact pathway methodology has been used in a large number of research projects and policy application related studies. In spite of still significant uncertainties in some areas, the Impact Pathway Approach is widely recognised now as the most reliable tool for environmental impact assessment that - in contrast to other methodologies - allows the estimation of site-specific marginal external costs. Top-down approaches, that is approaches that derive average values from aggregate demand estimates, are not capable of adequately measuring the impacts of an additional vehicle, in particular when it comes to site-specificity.

5.5.3 Treatment of Uncertainty

Most of these uncertainties in the estimation of environmental costs are due to insufficient knowledge of the physical phenomena associated to the various impact chains.

The possible sources of uncertainties could be:

- Insufficient data;
- Estimates for the effects on climate change (global warming) are poorly understood;
- The marginal pollution costs arising from the effect of an extra vehicle on the speed of the others is yet scarcely understood.

The correlation of greenhouse gas emissions with climate change and especially the damage caused by climate change is still very uncertain and controversial. The assessment of the impact of climate change on human health, agriculture, water availability, etc. provides quantitative estimates of cost ranges. As the uncertainty associated to such damage estimates is still very high, it is recommended to use avoidance cost approach as alternative to the damage cost approach. This will offer a range of potential costs of greenhouse gas emissions.

The preceding chapter has set out the main methodologies for the estimation of marginal costs in the case studies. Each case study's overall methodology is set out transparently and provides a step-by-step guide for its application. Although the methodologies are reasonably well established at a theoretical level, there is a clear need for their adjustment to every specific case study depending on data availability.

6 Generalisation Issues

6.1 Initial Views on Generalisation

The previous chapter developed basic methodologies for the marginal cost case studies. The marginal cost case studies will provide valuable empirical output for a large number of cost categories and modes. This output will relate to a specific context - which will include the case study location, infrastructure characteristics, vehicle characteristics, traffic volume and year (1998).

For the policymaker seeking to develop a set of marginal costs that reflect her circumstances, the questions then arises "which aspects of these case studies can be adapted to suit my needs?". When adaptation is not possible – either completely or partially – new analysis needs to be carried out to fill in the gaps.

The purpose of the generalisation work in UNITE is maximise the opportunities for adaptation of the case studies; this necessarily involves highlighting the limitations that exist and make transfers unwise. To achieve this goal, the empirical values produced by the case studies will be compared and integrated with empirical values obtained by other studies. The strengths and limitations of the different estimates will serve to underline the transferability potential of each data set. Adaptation can take many forms, and does not only refer to transferring values from one situation to another. It can include adaptation of:

1. **overall methodology** – is the approach clearly set out, enabling its replication for a different situation?
2. **inputs to the methodology** – which basic inputs (e.g. vehicle emissions) can be used again?
3. **economic unit values**[15] - where can values (e.g. the value of life, the unit cost of construction) be used again?
4. **output values** – which empirical outputs can be transferred?
5. **output functions** – if a cost function is produced, how can this be used?
6. **output ratios or relationships** – can the ratio of, for example, marginal to average cost, be applied elsewhere?

The basic requirement of UNITE is that each case study's overall methodology (point 1, above) is set out transparently. This will provide a step-by-step worked example for future studies.

The situation for points 2 to 6 differs. For each cost category different circumstances apply. For this reason, it would be absurd and extremely misleading to expect that all of these aspects can be adapted. The requirements of UNITE must be flexible.

[15] This is a special sub-set of the inputs to the methodology".

An initial summary of the aspects that may be generalised and should not be generalised is given in Table 6.1. These represent a proposed "level of ambition" for the UNITE case studies – this "ambition" may not be fully achieved, but purpose of the table is to make clear the project's intentions by main cost component.

Table 6.1: Methodological Approaches and Generalisation

	Main cost elements	**Proposed Methodology**	**Generalisation – initial view[16]**	
			Possible	**Not recommended**
Infrastructure	Maintenance and renewal (mainly rail and road)	Econometric approach (translog cost function approach)	-Overall methodology: although application is heavily data-dependent -Inputs: functional form and "weight" variables -Output ratios or relationships: ratio of MC/AC	-Economic unit values: unit costs (e.g. costs/m^2 road surface) - these are usually country specific; -Output values -Output functions
	Weight dependent costs (mainly rail and road)	Engineering approach	-Overall methodology -Output functions: e.g. axle-damage rules for road damage -Output ratios or relationships: ratio of MC/AC	-Economic unit values: as above -Output values
	Aviation, short-sea shipping, inland waterway	Cost disaggregation approach	-Overall methodology -Inputs: functional categorisations of disaggregate costs	-Economic unit values: unit costs -Output values -Output functions -Output ratios or relationships
Supplier operating costs	Energy costs, consumables, Maintenance costs and wages/salaries	Cost disaggregation approach	- Overall methodology	-Economic unit values: unit costs -Output values -Output functions -Output ratios or relationships
User costs	Delay and operating costs in road transport	Estimation of additional time and operating costs by applying speed-flow and speed-operating cost functions.	-Overall methodology, -Inputs: passenger car equivalence factors -Economic unit values: values of time	-Inputs: Speed-flow-, junction delay- and speed-operating cost functions -Output values
	Delay costs in scheduled transport (rail, aviation, inland navigation, shipping)	Demand-delay modelling for classes of stations, airports and ports.	-Overall methodology. -Inputs: vehicle-class equivalence factors -Economic unit values: values of time	-Inputs: Demand-delay statistics by type of station, airport, inland waterway port or seaport. -Output values

[16] The initial view of what is possible/not recommended is subject to confirmation in later stages of the project.

Continuation from previous page

	Main cost elements	Proposed Methodology	Generalisation – initial view	
			Possible	**Not recommended**
User cost	Mohring benefits	Frequency benefits to existing passengers and freight	-Overall methodology -Economic unit values: values of time	-Inputs: constraints specific to individual services (e.g. train lengths, free paths for increased frequencies)
Accident costs	Accidents (all modes)	Risk elasticity approach	-Overall methodology -Inputs: risk elasticities (relevant studies or data-sets rare) -Economic input values: human cost related	-Inputs: accident risk rates (usually readily available) -Economic input values: non-human/ damage related costs
Environmental costs	Air pollution (all modes)	Impact pathway approach	-Overall methodology -Inputs: emission factors for specific vehicle technologies; dose-response functions -Economic input values: human cost related -Output values: Local costs per unit emission per location type (same economic values); local physical impacts per unit emission per location type (different economic values); regional costs per unit emission per country	-Inputs: Infrastructure characteristics (e.g. gradient, vehicle speeds) ; emission factors for vehicle fleets; local dispersion model inputs (meteorology); receptor density/distribution -Economic input values: material damage costs -Output values per vehicle km
	Noise (all modes)	Impact pathway approach	-Overall methodology -Inputs: emission factors for specific vehicle types; dose-response functions -Economic input values: human cost related -Output values: e.g., cost per person at 400m from X dBA noise emission if characteristics similar	-Inputs: infrastructure characteristics (e.g. gradient, vehicle speeds, barriers, mitigation measures (e.g. double glazing); background noise level -Output values
	Global warming (all modes)	Damage cost factor Avoidance cost factor (multiplication of emission times cost factor)	-Overall methodology -Inputs: emission factors for specific vehicle technologies; relative weight of pollutants compared to CO_2 -Economic unit values: damage cost per tonne of CO_2-equivalent; modification for emission in high altitudes	-Inputs: infrastructure characteristics (e.g. gradient, vehicle speeds) ; emission factors for vehicle fleets -Economic unit values: avoidance costs per tonne of CO_2-equivalent; modification for emission in high altitudes

6.2 Generalisation Issues per Specialist Cost Category

6.2.1 Infrastructure

As has been already stated, three different approaches for infrastructure cost estimation are considered: econometrics, engineering based approach, and specific case studies. Each of these approaches has to be treated separately for the generalisation issues.

To start with the econometric approach one has the advantage to deal not with selected lines or infrastructure parts but with whole networks. In that respect there is no problem of generalisation. Furthermore a theory-based and systematic methodology that can be transferred for example to other countries is used. However, it might yield results (for example types of functional forms, parameter values and finally marginal costs) which differ from country to country. A final answer on the extent of a generalisation problem can thus hardly be given at this stage of the project. However, for generalisation and comparison matters, a number of case studies may attempt to test certain country specify characteristics (e.g. how the quality of the infrastructure in different countries influences the cost estimates).

As far as the case studies are concerned at least the methodology of analysis could be generalised. For generalising quantitative results, for example transferring the results for Helsinki-airport to other airports in Europe, it is certainly necessary to elaborate those characteristics of the infrastructure investigated which can be generalised (institutional background, type and size of infrastructure, topography, climate etc.) and to identify the „specialities".

6.2.2 Supplier Operating Costs

The overall methodology for estimating operating cost is transferable in circumstances where detailed data on costs are available.

On the side of the inputs to the methodology, alternative definitions for the unit cost of capital can be considered for other contexts.

As for the unit values, prices computed for the factors of production can be used as a reference to compare the performance of European airline for example with those of other regions.

The output values - average and marginal costs - can be used to compare their performance in one region with those in other regions, or to compare their performance across different modes.

Cost functions and cost ratios and indexes are transferable to different modes.

6.2.3 User Costs

For some user cost categories, complete generalisation will be possible. For other cost categories, only one or two of the following items will be capable of generalisation:

- *overall* methodology
- *inputs* to the methodology
- economic *unit values*
- output *values*
- modification of output *values* over time
- output *functions*
- output *ratios or relationships*

The generalisation of time values must be considered with care, but in principle it is possible. The estimation methods for scarcity of rail, air and water transport infrastructure in general is not capable for generalisation because the conditions in each station/track, airport, seaport or inland waterway port are different. In principle for each of those facilities a characteristic relationship of traffic volume and delay must be estimated. The same holds for urban public transport concerning congestion costs and Mohring benefits. However, for urban areas a TRENEN-style approach can be applied and thus the basic methodology is well transferable.

6.2.4 Accident costs

Some aspects of the proposed marginal accident cost methodology can be generalised and some may not be generalised. However, it should be noted that such a generalisation often is ‘second-best’ and the availability of data will often decide where generalisation is necessary.

- The proposed method is general and can be used for all modes everywhere.
- Risks should not be generalised as these are reasonable easy to collect. However, they should be compared and controlled.
- Risk elasticities need to be generalised as we can not make specific studies everywhere and for all modes.
- Risk values can, with a benefit transfer function, be generalised as studies are not available everywhere.
- Other costs should not be generalised.
- A trend function for reduction in risk over time should be used and the function is thus general (even if it might not be linear).

6.2.5 Environmental costs

The overall impact pathway approach is generally transferable for all three categories.

Air pollution
The generalisation of the cost estimates is highly dependent on the scale effect of the air pollution. On the *local* scale, that is up to ca. 25 km from the emission source, the

damage depends mainly on the density of population in that area. In this case, the transferability of estimates to locations could be realised as follows:

- Costs per unit emission per location type can be transferred to locations where the same economic values are to be applied.
- Physical impacts per unit emission per location type can be transferred between countries if different economic values are to be applied.
- On the *regional* scale, that is covering Europe, important becomes the air chemistry (which implies non-linearity), and the geographical location within Europe. In this case the estimates are transferable for adjacent countries, with the same environmental characteristics. To facilitate a generalisation of the damage estimates on the regional scale, unit values per country could be produced.

Global warming
Due to the global scale of the damage caused, the location of emission is irrelevant. The costs are calculated by multiplying the amount of greenhouse gas emitted by a cost factor. Further generalisation is not required.

Noise
Noise cost estimates are generally difficult to be generalised due to the their very local nature and dependence on the background noise level. For rough estimates of the order of magnitude a cautious transfer of output values may be undertaken for locations with similar characteristics and background noise.

This chapter made an initial attempt to summarise the aspects that may and may not be generalised. These aspects present a proposed “level of ambition” for the UNITE case studies – it depends on the outcome of the case studies whether this “ambition” will be achieved. However, the case studies will make clear what are the cost components that can be generalised and under what assumptions, and possibly through what techniques.

7 Summary of Proposed Marginal Costs Case Studies

Marginal social costs depend on the time, place, route, vehicle, and other characteristics of a particular transportation. Given the variability of marginal cost, it is important to examine several types of transportation rather than to identify an "average or typical" way of transportation within any given mode.

The proposed case studies were selected in the way that they are to reflect a common movement type allowing the transferability of results between different contexts. However, they do not represent a sample of transportation within a certain mode. Instead, the intention is to explore the degree to which common transportation types might differ in different contexts.

The main criteria that were considered in the selection of the case studies were:

- The relevance of the proposed case study;
- Any constraints in relation to achieving consistency with the state-of-the-art methodology;
- The degree of transferability of the results of the study;
- The availability of needed data and existing constraints for getting it;
- Existing risks for the execution of the case studies;
- The innovative aspect of the case study.

The objective of the case studies is to provide more empirical evidence for the modes and cost categories where studies already exist and to build up new evidence for those aspects where little or no evidence exists. The existing gaps for modes and cost categories will be covered by applying when possible the state-of-the-art techniques, or developed techniques as presented in the previous chapter. Table 7.1 provides an overview of the number of case studies by cost category and mode.

Table 7.1: Distribution of the Marginal Cost Case Studies

Category	Road	Rail	Air	Inland Waterways	Maritime	Total – by cost category
Infrastructure costs	2	2	1	1	2	8
Supplier operating costs	0	2	1	0	0	3
Congestion costs	6	5	1	0	0	12
Mohring effect	0	1	1	1	1	4
Accident costs	3	2	0	1	1	7
Environmental costs	6	4	1	1	1	13
Total – by mode	17	16	5	4	5	47

Table 7.2 illustrates the distribution (across modes and cost categories) of the case studies proposed to be carried out in the *Specialist Category* analysis. The final list of case studies to be performed within UNITE will have to be approved by the UNITE Steering Committee and the Commission. The Annex 2 includes summary information about each particular case study.

Table 7.2: Contribution of the Marginal Cost Case Studies

		Months	More evidence	New evidence
	0A. Inland Waterway case Study, the Rhine (*infrastructure, accident and environment costs*)	4		√
Infrastructure costs	5A Econometric Analysis for the Road Sector Applied for Various Countries	5		√
	5B Engineering-based HGV (Nordic)	1.5	√	
	5C Rail Econometrics Case Study, Sweden	1.5		√
	5D Rail Infrastructure Case Study, UK	2	√	
	5E Airport Infrastructure Case Study, Helsinki	2.5		√
	5F Price relevant MC of Swedish seaport services	2		√
	5G Mediterranean Short-sea Shipping including Piraeus Port MC Case Study	3		√
Supplier operating	6A Urban Public Transport Case Study, Lisbon	1	√	
	6B Swedish Rail Case Study	1.5		√
	6C European Air Transport Operating Costs	2		√
Transport user costs	7A High-quality passenger transport, Paris-Brussels	0.5	√	
	7B Long Distance Passenger Transport Paris-Stuttgart – Munich	0.5	√	
	7C Container Freight Transport Cologne – Milan	0.5	√	
	7D Bulk Freight Transport Duisburg-Mannheim	0.5	√	
	7E Brussels Urban Transport	3	√	
	7F Urban Road Case Studies, Leeds, Athens, Helsinki, Salzburg	4.5	√	
	7G Swedish Railways Case Study	2.4	√	
	7H Mohring Case Study for Air	2		√
	7I Air Congestion Case Study, Madrid Airport	2		√
	7J Mohring Effect for Freight Transport	2.6		√
Accident costs	8A Full Country Study, Switzerland (all modes)	3		√
	8B Stockholm Case Study with a Lisbon Comparison	2.5	√	
	8C Railway Accident Case Study, Sweden	1.5		√
	8D Heavy Goods Vehicles, Sweden	1.5	√	
	8E Short-sea Shipping Case Study	1		√
Environmental costs	9A Urban Passenger Car Case Study for Finland	1.5	√	
	9B HGV Case Study for Finland	1.5	√	
	9C Nordic Short-Sea Shipping Case Study	1.5		√
	9D Urban Road and Rail Case Studies, Germany	4		√
	9E Inter-Urban Road and Rail Case Studies, Germany	4	√	
	9F Air Transport Case Study, Munich-London	2		√
	9G Urban Road and Rail Case Studies, Italy	1.5	√	
	9H Inter-Urban Road and Rail Case Studies, Italy	1.5	√	

Glossary of Terms

Accident Cost	Cost mainly related to vehicle repair and medical cost and the cost of "suffering" associated with accidents.
Accident Elasticity	Percentage changes in the number of accidents in response to a one percent increase or decrease in the traffic volume. The accident elasticity = 1 + risk elasticity
Accident Insurance	Voluntary or mandated insurance against the risks of accidents (property and health). The premia serve to partly internalise external costs.
Administrative and Commercial Costs	Costs incurred by administrative and commercial activities of the supplier. It can be considered as fixed cost or variable only at large intervals (discrete distribution).
Commercial Transport	On-demand transport services offered by non-official transport suppliers. It is a business activity were the final users are considered as the operator's customers getting charges the full range of operating costs recorded by business accounts.
Contingent Valuation Method	Valuation technique that asks people directly method how much they are willing to pay / to accept for improving/deteriorating environmental quality. The method is based on the stated preference approach; it is the only method that allows the estimation of existence value.
Cost category	Category within which the cost has same characteristics, or in other words is attributed to the appropriate network user (e.g. network or vehicle type).
Cost driver	The variable which denotes the key cause of various transport costs (e.g. axle weight).
Dose-Response Function	Used more or less synonymously with "exposure-response function" even though what is meant is the response to a given exposure of a pollutant in terms of atmospheric concentration, rather than an ingested dose.
Exposure-Response (E-R) Function	Functional relationship relating changes in human health, material corrosion, crop yields etc. to unit changes in ambient concentrations of pollutants. Used more or less synonymously with dose-response function.
Heterogeneous traffic	Traffic with different types of vehicles or users (pedestrian/car, HGV/car etc). Accidents between these different vehicles/users are called intersystem accidents.
Homogenous traffic	Traffic with the same type of vehicles. Accidents between these vehicles are called intrasystem accidents.
Impact Pathway	Methodology for externality quantification developed in the

Approach (IPA)	ExternE project series. It follows the chain of causal relationships from pollutant emission via dispersion (including chemical transformation processes), leading to changes in ambient air concentrations from which impacts can be quantified using exposure-response functions. Damages are then calculated using monetary values based on the WTP approach.
Individual Transport	Transport performed on the own account of users with their own vehicle for private reasons.
Infrastructure Cost	Cost mainly related to damage cost (maintenance and repair), some services and operation.
Infrastructure-Related Supplier Operating Cost	Costs incurred with infrastructures. In this case, it could be considered a fixed cost.
Injurer	In a collision accident the injurer is the user that is not hurt in the accident. The injurer does not have to be guilty of the accident.
Internalisation	Incorporation of an externality into the market decision making process through pricing or regulatory intervention. In the narrow sense internalisation is implemented by charging the polluters with the damage costs of the pollution generated by them according to the polluter pays principle.
Marginal Accident Cost	When a user enters the traffic he will expose himself to an accident risk. In addition he increases or decreases the risk for other users. When economic values are assigned to these changes in risk they express the marginal accident cost.
Marginal Costs (short and long term)	Costs related to a small increment in demand (e.g. an extra vehicle-kilometre driven). The distinction between short and long term marginal costs is important with respect to infrastructure costs. Whereas short-term marginal costs are defined for a period where capacity is fixed and include scarcity costs, long-term marginal costs are computed including development costs of infrastructure.
Marginal external accident cost	The user perceives already a part of the Marginal accident cost as a Marginal Private Cost (MPC). The difference between the Marginal accident cost and the MPC is the unpaid Marginal external accident cost.
Mode of Transport	Means of transport. UNITE distinguishes between road, rail, inland waterways, maritime and aviation
Prevention Approach	Technique for estimating externalities whereby the costs of preventing damage are used as a proxy for the cost of the damage itself for society.
Private Marginal Cost	The cost the user perceives as an extra cost due to his decision to take one more trip.

Public Transport	PT subsumes all services that are supplied according to a pre-defined timetable in passenger and freight transport. The final user here pays an average fare. Typical PT is rail, bus, air and ferry services.
Public (scheduled) Transport	The transport of an additional person or unit of goods does in the short run not cause additional vehicle kilometres, as scheduled vehicles are used, which are running anyway. In the long run, due to increased capacity use, additional or larger vehicles have to be scheduled. In the former case the marginal costs are zero, in the latter case the marginal costs are the costs per vehicle kilometre divided by the capacity use.
Receptor	Person, animal, plant or building exposed to an environmental burden
Regional Scale	Covering Europe
Revealed Preference	Valuation technique wherein consumers' choices are revealed in the marketplace (e.g. by the purchase of a good).
Risk avoiding behaviour	When a user perceives that the risk increases he changes his behaviour and search for safer alternatives. This means that the observed change in risk due to increased traffic may be an underestimation of the cost; in addition to the cost of accidents the users also have cost of protection.
Risk Elasticity	Percentage changes in the accident risk in response to a one percent increase or decrease in the traffic volume.
Risk Value	A term often used instead of VOSL to emphasise the origin of the value; i.e. a statement about the WTP for risk-reduction. This term is also applicable to non-fatal accidents.
Service-Related Supplier Operating Cost	Costs incurred in activities related to the services provided by suppliers weather they are physically outside the vehicles or inside if they are not directly related to the actual functioning of the vehicle
Shadow Prices	Shadow price is the marginal opportunity cost of the use of a resource (i.e. the loss of benefits caused if this resource cannot be used for the next best purpose).
Stated Preference	Valuation technique wherein monetary estimates are derived from hypothetical statements by individuals about their preferences. The typical method used is a questionnaire approach (e.g. contingent valuation method).
Social Costs	The total sum of internal and external costs.
Social Marginal Cost Pricing	A pricing scheme, which charges marginal costs (e.g. infrastructure use, congestion, and environmental externalities). This scheme is proposed in the EU White Paper on 'Fair Payment of Infrastructure Use' (1998). It is based on a differentiated Road Pricing
Supplier Operating	Costs mainly related to cost incurred by supplier in its

Cost	operations.
Stated Preference	Valuation technique wherein monetary estimates are derived from hypothetical statements by individuals about their preferences. The typical method used is a questionnaire approach (e.g. contingent valuation method).
Target Group	The group towards which the government policy is addressed
Traffic Mode	Category of means of transport (road, rail, aviation, shipping, etc.).
Traffic Pattern	Composition of traffic flow regarding travel purpose and travel mix
Transport User Cost	Cost mainly related to the use of transport network resulting in congestion, scarcity etc.
Vehicle-Related Supplier Operating Cost	Costs incurred in the actual functioning of the vehicle. In limit situations, a supplier without vehicles would not incur in these costs (*see service-related supplier operating cost)*
Value of Statistical Life	A unit often used to express individuals willingness-to-pay (WTP) for safety. The individual state (or reveal) a WTP for a small reduction in risk (dz) for a fatal accident; he is never asked the question about the value of life per se. If this risk change is summed over (n) individuals so that statistical the risk reduction will save one life we can also sum their WTP; this sum of the WTP then becomes the Value of statistical life (VOSL). VOSL = WTP*n = WTP/dz if n*dz = 1
Willingness-to-Pay	The direct or indirect response to questionnaire about individuals willingness-to-pay for a good. For example the WTP for higher safety.

References

AEA Technology (1997) *Economic Evaluation of Air Quality Targets for CO and Benzene*. Interim report prepared for the European Commission DG XI, Harwell, UK.

Bickel, P., Friedrich, R. (1995), *Was kostet uns die Mobilität?*, – Externe Kosten des Verkehrs, Berlin, Heidelberg.

Bickel, P., Schmid, S., Krewitt, W., Friedrich, R (eds.) (2000), *External Costs of Energy Conversion – Improvement of the ExternE Methodology and Assessment of Energy-Related Transport Externalities* ("ExternE Core/Transport"), Final Report to the European Commission, Contract No. JOS3-CT97-0015, Stuttgart.

Calthrop E., Proost S. (1998), *Road Transport Externalities – Interaction between Theory and Research*, Environmental and Resource Economics 11(3-4): 335-348, 1998.

Christensen C, Beaumont H, Dunkerly C, Lindberg G, Otterstrom T, Gynther L, Rothengatter W, Doll C (1998), *Summary of Internalisation of Externalities*, PETS (Pricing European Transport Systems) deliverable 7. Funded by the 4th RTD framework program of the European Commission, Leeds, September.

DIW, INFRAS, HERRY, NERA (1998), *Infrastructure Capital, Maintenance and Road Damage Costs for Different Heavy Goods Vehicles in the EU,* On behalf of the EU-Commission, DG VII, Berlin.

ECMT (1998), *Efficient Transport for Europe: Policies for Internalisation of External costs*.

ECMT (1998), *User Charges for Railway Infrastructure*, Round Table 107, Economic Research Centre of the European Conference of Ministers of Transport, Paris.

ECMT (1999), *Traffic Congestion in Europe*, Round Table 100, Economic Research Centre of the European Conference of Ministers of Transport, Paris.

Elvik, R. (1994), *The external costs of traffic injury: definition, estimation, and possibilities for internalisation,* Accident Analysis and Prevention. 26; 719-732.

European Commission (1998) Transport Research – Fourth framework Programme. QUITS: *Quality Indicators for Transports Systems*, Office for Official Publications of the European Communities, Luxembourg.

European Commission (1994), *Common Market Expert Group,* The Economic Cost of Traffic Accidents, COST 313.

Friedrich R, and Ricci A (1999) *Calculating Environmental costs of transport*. Final Report of the Expert Advisors to the High Level Group on Infrastructure Charging (working group 2). Stuttgart, May 1999.

Friedrich, R., Bickel, P. and Krewitt, W. (eds.) (1998), *External costs of transport*, IER, Stuttgart.

Harris R. (1977), *Economies of Traffic Density*, Bell Journal of Economics, No.4.

Highway Research Board (1961), *The AASHO-Road-Test - History and Description of Project*, Special Report 61 A, Washington D.C.

INFRAS (1998), *Staukosten im Strassenverkehr*, Study for the Swiss Office for Road Transport (ASTRA), Bern

Jansson J.O (1984), *Transport system optimisation and pricing*, Wiley.

Jansson J.O (1997), *Theory and practice of transport infrastructure and public transport pricing*, in de Rus and Nash, *Recent Development in Transport Economics*, ed by Ginés de Rus and Chris Nash, Ashgate.

Jansson J.O and Lindberg G (1998), *Pricing Principles*, in Pricing European Transport Systems (PETS), Deliverable D2 to DGVII of the European Commission.

Janson, J.O. Lindberg, G. (1998a), *Accident externality charges - with emphasis on urban transport problems*, in 1st Asia Pacific Conference on Transportation and Environment 13 - 15 May 1998, Proceedings Volume 1, p 401 - 410.

Jara-Diaz S, Cortes C. (1996), *On the calculation of Scale Economies from Transport Cost Functions*, Journal of Transport Economics and Policy, May.

Johansson P, Nilsson J-E (1998) *An Economic Analysis of Track Maintenance Costs*. Paper no. 881 presented at the 8th World Conference on Transport Research, Antwerp.

Lindberg G (1999) *Calculating Accident Costs*. Final Report of the Expert Advisors to the High Level Group on Infrastructure Charging (working group 3). May 1999.

Link H, and Maibach M (1999) *Calculating Transport Infrastructure Costs*. Final Report of the Expert Advisors to the High Level Group on Infrastructure Charging (working group 1). Berlin, May 1999.

Nash, C.A. et al. (2000, forthcoming). Pricing European Transport Systems, Final Report. Institute for Transport Studies, Leeds.

Nash C, Sansom T (1999), *Calculating Transport Congestion and Scarcity Costs*, Final Report of the Expert Advisors to the High Level Group on Infrastructure Charging, Leeds, May.

OECD (1985) *Co-ordinated urban transport pricing*, Road Transport Research, Paris

Oum T., Waters W. (1998), *Recent developments in cost function research in transportation*, In Nash C; de Rus G, eds (1998) *Recent developments in transport economics*, Aldershot.

Proost, S., Van Dender, K., De Borger, B., Vickerman, R., Peirson, J., O'Mahony, M., van den Bergh, J., Verhoef, E., Roson, R., Kapros, P. (1999), *TRENEN II STRAN* – ST 96 SC 116, Final report for publication, Leuven, Belgium.

Rothengatter W, Doll C, Sansom T, Maccario R, Goller L, Maibach M, Otterström, T, Laurikka H. Jansson K. (1998), *Guide for the Evaluation of Real Transport Costs*, FISCUS (Cost Evaluation and Financing Schemes of Urban Transport Systems) deliverable 3, Funded by the 4th RTD framework program of the European Commission. Lisbon, April 1999.

Sansom T, Nellthrop J, Proost S, Mayeres I, Maibach M, Niskanen E, Quinet E, Schwartz D (2000), The Overall UNITE Methodology, UNITE, Funded by the 5th framework program of the European Commission, May 2000.

Sansom T, Still B, Nash C (1999), *The Cross Channel Case Study*, PETS (Pricing European Transport Systems) deliverable 9, draft report, Funded by the 4th RTD framework program of the European Commission, Leeds, June.

Waters W. (1985), *Rail Cost Analysis*, in International Railway Economics ed. By Button and Pitfield, Gower.

Annexes

Annex 1. **Cost Drivers**

Annex 2. **Proposed Case Studies**

Annex 3. **Marginal Cost Methodology for Infrastructure Costs**

Annex 4. **Marginal Cost Methodology for Supplier Operating Costs**

Annex 5. **Marginal Cost Methodology for Transport User Costs**

Annex 6. **Marginal Cost Methodology for Accident Costs**

Annex 7. **Marginal Cost Methodology for Environmental Costs**

Annex 1. Cost Drivers

	Infrastructure	Supplier operating	Transport user	Accidents	Environment
Road	-vehicle type -axle weight -infrastructure characteristics -speed -weather conditions -wage levels -construction and maintenance standards and -practice	-Type of vehicle (depreciation, consumables, maintenance cost, energy use) -intensity of use, function of the amount of kilometres and the amount of passengers / freight travelling with the vehicle (cleaning, maintenance, consumables, depreciation) -fuel price -wages -cleaning costs -insurance's -toll -geographical characteristics of urban environment e.g. hills	*Time + oper. costs* -road capacity use -speed-flow relationships -fuel consumption functions -other vehicle operating costs -traffic mix -vehicle load rate -vehicle type -travel alternatives *Mohring benefits* -capacity reserve -investment limitations -current passenger volume -current service level	Speed, road type, user error and history, traffic speed, volume and interaction with weather conditions, vehicle type/condition, nature/maintenance level of infrastructure Degree of infrastructure capacity use Level of segregation between systems Technological developments	*Air pollution* -receptor density -vehicle speed -fuel type -vehicle type and age -power plant mix *Global warming* -vehicle speed -fuel type -vehicle type and age *Noise* -population density close to emission source -infrastructure surface -vehicle type and age -vehicle speed -slope of road -time of emission -existing level of traffic
Rail	-vehicle type (freight and passenger trains) -axle weight -number and type of wagons -quality of maintenance of wagons -speed -construction standards -track geometry -number of sleepers -operating requirements -wage levels -construction and maintenance standards and -practice	-Type of vehicle (depreciation, consumables, maintenance cost, energy use) -intensity of use, function of the amount of kilometres and the amount of passengers / freight travelling with the vehicle (cleaning, maintenance, consumables, depreciation) -fuel price -wages -cleaning costs -insurance's -infrastructure charges	*Delay costs* -rail track/station capacity use -demand-delay relationships -traffic mix -train load rates -train class -travel alternatives *Mohring benefits* -capacity reserve -investment limitations -current passenger volume -current service level	Volume and interaction with weather conditions nature/maintenance level of infrastructure Degree of infrastructure capacity use Level of segregation between systems Technological developments	*Air pollution* -receptor density -vehicle speed -fuel type -vehicle type and age -power plant mix *Global warming* -vehicle speed -fuel type -vehicle type and age *Noise* -population density close to emission source -type of track -coach/wagon type -type of brakes -length of train -train speed -time of emission -existing level of traffic

Cost drivers *continuation*	**Infrastructure**	**Supplier operating**	**Transport user**	**Accidents**	**Environment**
Aviation	-type of plane (passenger/freight) -MTOW/MLW -type of infrastructure elements -climate conditions	-Type of vehicle (depreciation, consumables, maintenance cost, energy use) -intensity of use, function of the amount of kilometres and the amount of passengers / freight travelling with vehicle (cleaning, maintenance, consumables, depreciation) -fuel price -wages -cleaning costs -insurance's -airport fees -distance -on route fees	*Delay costs* -airport capacity use -demand-delay relationships -in-vehicle capacity use -traffic mix -travel alternatives *Mohring benefits* -capacity reserve -investment limitations -current passenger volume -current service level	volume and interaction with weather conditions nature/maintenance level of infrastructure Degree of infrastructure capacity use Level of segregation between systems Technological developments	*Air pollution* -receptor density -engine type -time spent in different modes *Global warming* -engine type -time spent in different modes *Noise* -population density close to emission source -engine type -time of emission -existing level of traffic
Inland Waterway	-vessel type -vessel size -speed -draught of vessel -geometry and construction of the waterway -type of bank stabilisation system -electric power for operating locks/ship canal lifters	-Type of vehicle (depreciation, consumables, maintenance cost) -intensity of use, meaning the amount of kilometres and the amount of passengers / freight travelling with the vehicle (cleaning, maintenance, consumables, depreciation) -fuel price -wages -cleaning costs -insurance's -harbour fees	*Delay costs* -port capacity use -demand-delay relationships -traffic mix -shipment alternatives *Mohring benefits* -capacity reserve -investment limitations -current freight volume -current service level	Location, time of the day, boat size nature/maintenance level of infrastructure Degree of infrastructure capacity use Level of segregation between systems Technological developments	*Air pollution* -receptor density -vessel type -fuel quality -operation mode -direction: upstream/ downstream *Global warming* -vessel type -fuel quality -operation mode -direction: upstream/ downstream *Noise* -population density close to emission source -vessel type -operation mode -direction: upstream/ downstream -time of emission -existing level of traffic

Cost drivers *continuation*	**Infrastructure**	**Supplier operating**	**Transport user**	**Accidents**	**Environment**
Maritime	-geometry of the basin -construction of the basin	-Type of vehicle (depreciation, consumables, maintenance cost) -intensity of use, meaning the amount of kilometres and the amount of passengers / freight travelling with the vehicle (cleaning, maintenance, consumables, depreciation) -fuel price -wages -cleaning costs -insurance's -harbour fees	*Delay costs* -port capacity use -demand-delay relationships -traffic mix -shipment alternatives *Mohring benefits* -capacity reserve -investment limitations -current freight volume -current service level	volume and interaction with weather conditions nature/maintenance level of infrastructure Degree of infrastructure capacity use Level of segregation between systems Technological developments	*Air pollution* -receptor density -vessel type -fuel quality -operation mode *Global warming* -vessel type -fuel quality -operation mode *Noise* -population density close to emission source -vessel type -operation mode -time of emission -existing level of traffic