GRACE

Generalisation of Research on Accounts and Cost Estimation

Contract: FP6-006222

GRACE

Generalisation of Research on Accounts and Cost Estimation

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Final Activity Report

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Executive Summary

Objectives

The GRACE project aims to support policy makers in developing sustainable transport systems by facilitating the implementation of pricing and taxation schemes that reflect the costs of infrastructure use. It covers the following areas of research:

- Case study research to address gaps in the existing level of knowledge of marginal social costs for road, rail air and waterborne transport,
- Development and refinement of methods to enable the use of transport accounts as monitoring instrument for the implementation of transport pricing reform in an enlarged Europe,
- Innovative research on the appropriate degree of complexity in transport charges,
- Guidance on the marginal social cost of the different modes of transport in specific circumstances and on simple and transparent methods for determining charges,
- Modelling the broad socio-economic impacts of pricing reform.

Pursuant to these objectives, GRACE has produced ten deliverables setting out its work and its findings. Nine of these deliverables are reports and are available for download on the project website – www.grace-eu.org. The tenth deliverable is an on-line software tool, also available via the project website – with full access permitted by arrangement with DG TREN.

Policy Context

Efficient pricing in transport and the internalisation of the external costs of transport have been key aspects of European transport policy for over a decade now. As the GRACE project comes to a close, the Commission is working to prepare a Communication on the internalisation of the external costs of transport that responds directly to the European Parliament's request for a model for the assessment of all external costs.

The estimation of external costs is absolutely central to the pursuit of the Commission's transport pricing policy, and GRACE is the most recent in a series of research projects to undertake such cost estimation. Understanding the potential impacts of different policy options is also vital to the process of taking the policy forward, and modelling to understand the impacts of different pricing policies on the economy, on the environment and on society at large has been a core part of GRACE. European transport pricing policy is at an exciting juncture and GRACE finds itself drawing its conclusions at a point where policy-makers are actively taking forward the transport pricing policy agenda.

Cost Estimation and Charge Calculation

Road and Rail

The marginal costs of road and rail use are explored via a number of individual case studies conducted within a general framework. The infrastructure cost case studies explore the marginal cost of motorways in Germany and a broader set of roads in Poland and Sweden. A Lifetime model is developed to analyse the renewal costs[1] on Swedish roads. The same approach is used on Swedish railways together with an econometric approach. Pioneering work in the same area is made in Switzerland, UK

[1] Renewal costs are the costs associated with replacing worn out infrastructure, where as construction costs generally refer to the costs associated with constructing new infrastructure. A proportion of renewals costs are generally viewed as being directly related to traffic and hence marginal, as the damage imposed by the passage of traffic brings forward the time at which renewal must take place.

and Hungary. In the area of congestion and scarcity cost the aim is to clarify the variability in current estimates on congestion cost and suggest a more unified approach. Novel research is conducted in the area of rail scarcity where a modelling approach is used to derive estimates. A state-of-the-art survey on Accident cost, including the insurance market, is undertaken. Numerous studies on air pollution and green house gases exist which were reviewed and expanded upon, with the addition of new case studies, while attempting to create a clearer picture of transferable results. The marginal cost of noise is analysed with a review. Finally, the environmental cost of transport in sensitive areas has been discussed in policy documents and the concept is here further developed. Key findings from the case studies are as follows:

- Optimal charges for the use of transport infrastructure will be below average maintenance and renewal costs for road, and a long way below for rail, wherever there is spare capacity and little environmental impact.

- In such cases, charges should be higher for low quality, less heavily used infrastructure, as the low quality nature of the infrastructure makes it more susceptible to damage.

- Where capacity is scarce there is a strong case for a charge to cover marginal congestion costs for roads and scarcity costs for rail. These charges will be very variable in time and space but, as a whole, their introduction will raise overall charge-levels to close to or above average cost.

- Fuel taxes varying with the carbon content of the fuel are the best way of charging for greenhouse gases.

- Environmental charges for noise and air pollution should vary with the characteristics of the vehicle; for air pollution, population density and windspeed are the other key cost drivers; for noise, population density and background noise levels.

- The revenues from environmentally-based charges should not necessarily accrue to the infrastructure manager, as this may create perverse incentives.

- The sensitivity of an area in relation to transport has an effect on the appropriate pricing levels – for example, appropriate charges in Alpine areas may be several times those in flat areas.

Ports, Inland Waterways and Airports

A series of port, airport and inland waterways case studies were undertaken to advance the state of the art in research on marginal costs in the air & water transport sectors, which has been a relatively under-researched area prior to GRACE. For ports, a simulation tool was built in order to calculate the marginal cost of a vessel calling at and leaving a port. For inland navigation, marginal infrastructure costs were assessed through a state of the art review of studies, focusing on cost allocation. Marginal congestion and scarcity costs were divided into three parts - congestion at locks; congestion at bridges; and scarcity on waterways – and analysed through separate sets of case studies. For the air sector, an empirical model is proposed to evaluate economies of scale, economic inefficiency and marginal costs. It consists of estimating a translog model, formed by a cost function and two input cost share equations that allows to estimate the airport parameters under study. Three case-studies are distinguished: AENA (Aeropuertos Españoles y Navegación Aérea) Spanish airports case-study, an international airports case-study and Chicago O'Hare airport case-study. Finally, environmental costs caused by air transport, inland water transport and maritime shipping have been addressed by case studies. Costs caused by emission of airborne pollutants, greenhouse gases and noise (for aircraft) were assessed, based on the Impact Pathway Approach. Furthermore costs due to oil spills from maritime shipping were estimated, based on a review of existing studies. The key findings of the case studies were:

- Within each case-study, the calculation of marginal costs depends on the typology used. In the port sector, a distinction can be made between ports without and with locks. In the inland navigation case-study, marginal costs depend on the level of the already used capacity of the locks. In the airport case study, variances between airports are reported.
- The inserted numerical results should only be used in their own specific context. The figures cannot be used for general statements about marginal costs. Every figure is linked with a specific typology, with a specific time-frame and with specific assumptions.

- Efficient charges for ports and inland waterways will comprise a wear and tear charge for the use of locks, plus congestion, scarcity and environmental charges.

- The methodology developed in the inland navigation case-study could be the basis of a unified European approach to congestion pricing for inland waterways. The full-scale application of such an approach would require the extension and testing of simulation models applicable for the Netherlands only and the extension of databases on locks, bridges, inland waterways and traffic flows for other parts of the European transport network.

- Efficient charges for airports will also comprise a base charge well below average cost plus congestion, scarcity and environmental charges.

- If capacity is expanded in line with demand, and operators reserve blocks of capacity on long run contracts (e.g. in ports) LRMC pricing may be more appropriate than SRMC.

Accounts and Monitoring

Transport accounts, developed in the UNITE project for all EU 15 countries and for Switzerland and Hungary, provide information about the total social costs and revenues of transport for road, rail, other public transport, air, inland waterway and maritime transport, disaggregated by network types, differentiation, transport means and user groups. The major purpose of transport accounts is to serve as a monitoring tool, but it was concluded that improvements are required to enable them to assist with monitoring pricing policy. Work has been undertaken to identify potential methodological advancements, demonstrate the suggested methods and derive conclusions on the necessary data collection procedures. Furthermore, the applicability of transport accounts in New Member States and in European regions has been analysed and tested, and simplified updating procedures were developed. The key findings from the work are:

- To be useful in connection with pricing policy, transport accounts need to:

- Split infrastructure costs into fixed and variable – detailed estimates have been derived for the variability of road and rail costs;
- Split accident costs into internal and external - a more refined methodology to estimate internal parts of accident costs has been established;
- Be based on detailed databases showing capacity utilisation ratios for individual sections of the network, and to categorise these by population density
- It is possible for countries to prepare comparable transport accounts using guidelines tested within the project.
- Data shortages exist in New Member States, but perhaps the most important implementation barriers result from policy maker's unfamiliarity with the accounts methodology, a lack of resources and problem perception, organisational opposition against change, fear of undesirable results, and lack of an organisation responsible for making national transport accounts.
- The elaboration of regional accounts can provide useful insights into relevant policy questions, but data support from regional authorities is the major prerequisite.
- It is worthwhile periodically analysing the availability and quality of new data and studies to develop methods further, and to produce in a next step "new" UNITE accounts based on these improvements. Methodological improvements will be possible where new and improved data is available. The emergence of such new data, but also of new country case studies stimulated the development and testing of methods that were demonstrated within GRACE.

Complexity

It is suggested that, as our ability to assess the marginal social costs imposed by each individual user, and to levy an appropriate charge on that user, becomes practical and affordable, it will become increasingly important to understand how system users might respond to such differentiated charges.

If their responses do not fully reflect the differentiated charges then a trade-off may exist between the theoretical advantages of highly differentiated charges and the simplicity required to allow individual users to respond effectively. These issues are particularly important in the context of road user charges because the user likely to be faced with infrastructure charges is an individual traveller. Work was undertaken to review the state of the art in charge differentiation, and then to collect data on drivers' responses to complex road user charges and assess, using models calibrated on this data, the performance of road user charges of differing degrees of complexity. Key findings from the work were as follows:

- Efficient pricing would require differentiation on the basis of the marginal costs of maintaining, renewing and operating infrastructure, of air pollution, of noise and other environmental damages, and of accidents, and should allow for delay and scarcity costs.

- In the short term, effective differentiation of road-user charges is unlikely to go much beyond the dimensions already being used in existing applications – eg, vehicle type, site characteristics, expected meteorological conditions, expected congestion and type/method of payment.

- It was not thought that there were any major technological constraints on the introduction of highly differentiated charges in the rail or air sectors.

- The costs of implementing the most complex charging regimes appear likely to outweigh the benefits and a simpler scheme is likely to yield higher net benefits.

- A close match between costs and individuals' behaviour cannot be expected in the short term and there is thus little reason to introduce highly differentiated charges unless they are likely to remain stable for a considerable period of time.

- Given that, faced with "difficult" charge structures or unpredictable charges, individuals generally seek to avoid them but are not very sensitive to the precise level of the charges, complex charges (particularly those which vary in more than one dimension) are very unlikely to result in a complete adjustment of behaviour to the pricing signal.

- If individuals can be assisted to estimate distances, distance-based charges appear to offer the prospect of high benefits at relatively low costs.

- Because individuals do not perceive their vehicle operating costs accurately or net of tax, an additional charge based simply on the valuation of externalities can not lead to social-welfare-maximising behaviour; the optimal charge must take this misperception into account.

- Road freight operators are likely to invest time into understanding the cost implications of any charging regime, however complex it might be, and so are likely to be much less affected by problems of misperception and/or lack of understanding.

Generalisation and Transferability

Marginal costs estimates for the use of transport infrastructure have been produced for a wide range of situations, and using a variety of different approaches. The known case studies (including the ones recently developed within GRACE) have in general shown that there is no standard methodology for marginal costs estimation, and that the methodological approaches available are strongly influenced by data availability issues and by the type of transport mode under examination. The need therefore arises to envisage methods ensuring the transferability of marginal costs estimates, i.e. analysing the conditions whereby values can be adapted to different contexts, in particular for the determination of charges in regions and situations where all the detailed information required does not exist.

GRACE has developed a software tool that allows to derive estimates of the values of marginal external costs (MEC) based on the MEC values calculated within a wide range of bottom-up case studies. The GRACE tool (which corresponds to Deliverable D8 and is made available at www.grace-eu.org), allows to interactively calculate the values of external costs for any given network section (and node) of the EU transport system, for all modes, for all main categories of external costs, i.e. air pollution, global warming, noise, accidents, congestion, wear and tear of infrastructure, and for a wide range of vehicle types. MEC values are presented in €/vehicle.km, which can also be converted into €/passenger.km and €/tonne.km.

Socio-Economic Impacts

Introduction

In order to understand the socio-economic impact of pricing traffic according to the marginal external cost, it is necessary to put the transport market in a broader economic context. Five streams of work, each highlighting another dimension of the socio-economic impact, were undertaken and are summarised in the below table. In each case, pricing scenarios were based on the GRACE estimates of external costs.

Survey of research questions and methodologies used

Research or Policy question	Approach
What is the effect of implementing marginal social cost pricing on the composition of transport flows and on welfare?	Use of GRACE estimates in TREMOVE model for 27+4 EU countries
What is the socio-economic effect of transport pricing in sensitive areas?	Test GRACE estimates with a general equilibrium model for Switzerland that contains a sensitive region (Alps) and a non sensitive region
What are the regional employment effects of marginal social cost pricing?	Use the GRACE estimates in a multi-regional general equilibrium model for the EU to estimate the effects of alternative pricing policies
How to implement marginal social cost pricing when the EU level does not know the marginal external cost at the member country level?	Theoretical analysis using the basic regulation model with asymmetric information
Is a more general equilibrium approach to accident externalities necessary?	Theoretical model with a numerical illustration

- Substituting all existing taxes on transport by a fuel tax equal to the external costs would lead to an unrealistically high fuel tax and would not bring important welfare improvements. One of the important drawbacks of the fuel tax is that it can not strongly be differentiated within countries.

- The introduction of a flat kilometre tax, differentiated by type of vehicle and perhaps by country would generate important revenues and increase welfare significantly.

- Whenever a reform of pricing generates extra revenues, the smart use of the revenues is as important as the design of the pricing reform. From an efficiency point of view, revenue is generally best used to decrease existing distorting taxes. Alternatively, under certain specific circumstances, using the revenues to expand infrastructure may also improve efficiency. There may, however, be instances where concentrating on efficiency improvement is not the over-riding concern.

- The regional differentiation of transport pricing within Switzerland is welfare improving for both regions. The tax on transit traffic constitutes an important transfer to the Swiss population and counts for an important part in the welfare gains of external cost pricing.

- Provided revenue is efficiently recycled, efficient charges will benefit the economies of most or all European countries, but they will tend to benefit countries at the core more than at the periphery. This leads to a possible argument for a mechanism for redistributing revenues between countries, but any such argument should be considered in the context of the EU's existing framework of financial redistribution between regions.

- In looking at such mechanisms, it is also important to take account of the incentives on countries with high levels of transit traffic to overcharge and under invest.

- All member countries with important transit transport flows have an interest to misreport their marginal external costs if their tax and toll cap is a function of their report. The European commission could use three techniques to control this. The first is to use an incentive mechanism for correct reporting but this will not work for congestion costs. The second is that the Commission uses its estimate as toll cap. This can work for all kinds of external costs. The efficiency of this policy depends on the quality of information. The third policy works only for the external congestion costs. It is a toll cap equal to the average road infrastructure cost. In principle this policy can be efficient as it minimizes the amount of monitoring but requires that the transit and local transit flows have the same composition. In practice, there will be incentives to over-charge and under-charge in different parts of Europe.

Further research

Key issues for further research are:-

- Work to understand the reasons for variability in marginal wear and tear costs for road and rail;
- the treatment of renewals in estimating marginal wear and tear costs;

- Additional case-study evidence on the marginal wear and tear costs for under-represented modes, cost-categories and contexts – in particular relating to air and water transport;
- risk elasticities and their implications for the marginal external costs of accidents;
- practical ways of determining congestion and scarcity costs for rail, water and air transport;
- Further estimation of the value of aviation delays, aimed at improving regulations on delays and cancellation compensation;
- Work to explore the implementation and use of transport accounts as a monitoring tool;
- optimal pricing given road users misperception of costs;
- Research to understand people's reactions to pricing complexity within the context of implemented charging schemes;
- Further development and testing of the marginal cost calculation software, and updating as new case study estimates become available;
- Further modelling of incentivisation of countries to set the right charges;
- Further modelling of the socio-economic impacts of more finely differentiated charges.

Table of Contents

1. Introduction and Context

1.1 The GRACE Project

This is the final activity report of the GRACE research project. The focus of this report is to summarise the work of the GRACE project and its key findings.

The GRACE project aims to support policy makers to develop sustainable transport systems by facilitating the implementation of pricing and taxation schemes that reflect the costs of infrastructure use. Five areas of research are covered within the GRACE project:

1. Case study research to address gaps in the existing level of knowledge of marginal social costs for road, rail air and waterborne transport,
2. Development and refinement of methods to enable the use of transport accounts as monitoring instrument for the implementation of transport pricing reform in an enlarged Europe,
3. Innovative research on the appropriate degree of complexity in transport charges,
4. Guidance on the marginal social cost of the different modes of transport in specific circumstances and on simple and transparent methods for determining charges,
5. Modelling the broad socio-economic impacts of pricing reform.

Pursuant to these objectives, GRACE has produced ten deliverables setting out its work and its findings. Nine of these deliverables are reports and are available for download on the project website – www.grace-eu.org. The tenth deliverable is an on-line software tool, also available via the project website – with full access permitted by arrangement with DG TREN. The following table provides an overview of the ten deliverables.

Table 1.1: Deliverables list

Del. no.	Deliverable name	WP no.	Lead participant
D1	Information requirements for monitoring implementation of marginal social cost pricing	3	DIW
D2	Information requirements for examining optimal complexity of transport pricing	4	ITS
D3	Marginal cost case studies for road and rail transport	1	VTI
D4	Marginal cost case studies for air and water transport	2	UA
D5	Monitoring pricing policy using accounts	3	DIW
D6	Optimal complexity of transport pricing	4	ITS
D7	Generalisation of marginal social cost estimates	5	ISIS
D8	Software for above	5	ISIS
D9	The socio-economic impacts of transport pricing reforms	6	KUL
D10	Policy conclusions on marginal social cost pricing	7	ITS

1.2 The Policy Context

Efficient pricing in transport and the internalisation of the external costs of transport have been key aspects of European transport policy for over a decade now. Starting with the Commission's Green Paper 'Towards Fair and Efficient Pricing in Transport' (CEC 1995), and continuing with the White Paper 'Fair Payment for Infrastructure Use' (CEC,1998) and the Common Transport Policy White Paper (CEC,2001), there is a strong emphasis on pricing policy to reflect the full social costs of transport use.

European transport pricing policy has been actively taken forward during the period of the GRACE project. In 2006, 'smart charging' formed a key plank of the Commission's re-statement of its Common Transport Policy which followed their mid-term review of Policy goals and progress. Also in 2006 as part of the revision of the Eurovignette directive, the European Parliament asked the Commission to present by June 2008 "a generally applicable, transparent and comprehensible model for the assessment of all external costs to serve as the basis for future calculations of infrastructure charges". They furthermore asked that "this model shall be accompanied by an impact analysis of the internalisation of external costs for all modes of transport and a strategy for a stepwise implementation of the model for all modes of transport".

As the GRACE project comes to a close, the Commission is working to prepare a Communication on the internalisation of the external costs of transport that responds directly to the European Parliament's request for a model for the assessment of all external costs. This communication is to be adopted in June 2008, with the intention that this will provide a general framework of reference for the internalisation of external costs in the transport sector. More specifically, it may be accompanied by proposals for further legislation, notably in relation to a further revision to the Eurovignette Directive.

The estimation of external costs is absolutely central to the pursuit of the Commission's transport pricing policy and, over the past decade, there has been a considerable body of research in this area. Indeed, GRACE is the most recent in a series of research projects that also includes EXTERNE, RECORD-IT and UNITE, amongst others. To review the best practices in the estimation of external costs emerging from this research and, hence, identify the best methodology to adopt, DG TREN commissioned the IMPACT study. This study has run in parallel with GRACE and is also now coming to a close. A key output from it is a Handbook on the estimation of external costs in the transport sector, which makes extensive use of results from GRACE.

Understanding the potential impacts of different policy options is also vital to the process of taking the policy forward. Modelling to understand the impacts of different pricing policies on the economy, on the environment and on society at large has been a core part of GRACE and of a number of research projects before it; it also forms a key part of the IMPACT study. Drawing on this body of work, the Commission is working on its own impact assessment of the policy.

European transport pricing policy is at an exciting juncture. GRACE finds itself drawing its conclusions at a point where policy-makers are actively taking forward the transport pricing policy agenda. As the Commission prepares its forthcoming communication on the internalisation of external costs, GRACE is able to provide state of the art research on cost estimation and the impacts of particular policy options. Furthermore, in whatever form the policy is taken forward, GRACE's work on transport accounts provides policy-makers with means of monitoring the progress of reforms.

1.3 This Deliverable

This report seeks to summarise the work of the GRACE project and its key findings. Section 2 concentrates on the cost estimation and calculation aspect of the research. It summarises the findings from the set of new marginal cost case studies and outlines the work undertaken to develop a cost calculation software tool. Section 3 then focuses on the research to develop transport accounts as a means of monitoring transport pricing reforms. Section 4 concentrates on the research examining optimal degrees of complexity in pricing, whilst section 5 focuses on the research to model the impacts of adopting more efficient transport pricing strategies. Section 6 then draws out key overall conclusions.

2. Cost Estimation and Charge Calculation

2.1 Introduction

The estimation of external costs is a vital element to the calculation of efficient prices and charges. The nature of most external costs is that they are usually situation-specific. That is, the external cost associated with a particular vehicle, on a particular piece of infrastructure, in a particular place at a particular time are likely to be specific to that set of circumstances. The same vehicle, on the same infrastructure, in the same place but at a different time is likely to give rise to a different level of external cost. Similarly, the same vehicle at the same time, in the same place but on a different piece of infrastructure is again likely to give rise to a different level of external cost. This makes the accurate estimation of external cost a very case-specific task. In theory, a policy to internalize external costs throughout Europe would require cost estimates to be derived for every set of circumstances that exists throughout Europe, but a proposal to undertake such an enormous exercise would almost certainly lead policy-makers to abandon the policy itself. Instead, it is likely to be more fruitful to undertake case-specific cost estimation exercises wherever possible, and then to use those estimates to form an understanding of the ways in which costs vary from one set of circumstances to another. With this understanding, it should become possible to make reasonable approximations of costs in circumstances where detailed cost estimates are not available or where it is not possible, for whatever reason, for them to be undertaken.

GRACE undertook extensive new research on cost estimation across the various modes and cost categories. Furthermore, it sought to understand how costs vary with circumstance and to encapsulate this understanding within a user-friendly software tool that can be used to derive reasonable approximations of external costs. In this way, GRACE has sought to build upon the cost estimation evidence base and to make it generalisable.

The cost estimation work in GRACE was undertaken as a series of case studies, focusing on particular modes and on particular cost categories. For convenience, the case studies were clustered into two broad modal groupings:

- Case studies focusing on road and rail costs – grouped together because, for these modes, there existed some previous research into cost estimation to serve as a starting point and as a reference to compare with; and
- Case studies focusing on port, inland waterways and airports costs – grouped together because, for these modes, there existed very little previous research into cost estimation that might serve as a starting point and as a reference to compare with.

The detail of the numerous case studies undertaken is reported extensively elsewhere (Deliverables 3 and 4). This chapter tries to summarise the main results from the Case studies and the main conclusions for each cost category considered.

The development of the software tool used the GRACE cost estimation results and combined these with similarly robust results from other research. The software tool enables the user to specify a situation they are interested in and the derivation of reasonable approximations of the relevant external costs. This chapter provides a brief overview of the software tool and its development.

Of course, the reason for wishing to estimate or approximate external costs is, usually, in order to consider the introduction of a charge to internalise that cost. The software does not seek to calculate efficient charges itself, as this would also require details of existing charges, taxes and subsidies to be input. However, tests have been undertaken using the software tool to derive external costs, and then, for a limited number of examples, these external costs have been combined with data on existing charges and taxes in order to provide sample charge-calculations. This chapter closes with an overview of these sample calculations.

2.2 Estimation of Road and Rail Costs

2.2.1 Infrastructure cost

Nine different case studies were carried out to examine infrastructure costs, four relating to roads and 5 relating to rail. For road infrastructure costs, 2 case studies were carried out based on panel data over expenditure by road section (one in Germany and one in Poland). A third case study was based on panel data on expenditure in maintenance delivery units (MDU), i.e. organizational units which take care of the road maintenance in a limited geographical area, and a fourth was based on observed lifetime of pavements which results in deterioration elasticities (both in Sweden). For rail infrastructure costs, 3 case studies had similar approaches based on econometrics (those in Britain, Sweden and Switzerland). A second Swedish study is an attempt to use the duration approach in railways, while the fifth case study (based on Hungarian rail cost accounting data) used a much different statistical approach.

There is a well-known and useful relationship between average cost and marginal cost known as the cost elasticity with respect to traffic output. This relationship was utilized within the GRACE case studies as a means of estimating marginal costs.
Cost Elasticity = Marginal Cost / Average Cost; and hence
Marginal Cost = Cost Elasticity *Average Cost

The roads case studies in GRACE found that the elasticity for road infrastructure cost decreases as the measure changes from renewal to maintenance and to operation. The average elasticity for renewal cost is between 0.58 and 0.87, while the elasticity for only maintenance and operation are from 0.12 to zero.

The rail case studies in GRACE found that elasticity for rail infrastructure cost is lower than the elasticity for road and doesn't show the same difference between different measures. The average elasticity is between 0.26 and 0.30 for an aggregate of renewal and maintenance, for maintenance it is between 0.20 and 0.24 and for operation or short term maintenance it is 029 to 0.32.

The majority of the GRACE case studies suggest that the elasticity decreases with increased traffic. Thus highly used infrastructure has a lower elasticity than low volume of traffic infrastructure. This is potentially due to the highly used infrastructure being constructed at the outset to a higher quality (e.g. see below reference to pavement thickness). All elasticities reported above are from the average traffic in the studies. It could also be interesting to examine how the elasticities vary if they are estimated based on traffic levels that deviate around the average.

The operation or short term maintenance is understood to be related to total train km or total vehicle km while the renewal and maintenance are usually related to gross tonne km or HGVkm. Few of the studies have been able to test which type of traffic influences the infrastructure cost. In general, this has been decided a priori based on other information.

The methodology for estimating maintenance costs is more well developed than is the methodology for estimating renewals costs. Most of the studies use an econometric approach with panel data. However, a minority of the studies did use panel data models but use pooled ordinary least squares to estimate the cost function. In two studies a duration model is used where a function of the lifetime of a road pavement or railtrack is estimated. The result can be used to derive a marginal renewal cost. The rail study gave results in line with the econometric study and supported the conclusion drawn from the econometric studies that there indeed exists a marginal cost related to renewal on railways. The result was similar between the two approaches. However, the road study suggested a very low effect of traffic on the observed lifetime of a pavement. A possible explanation with some support is that the authority predicts the higher traffic volume when deciding on the pavement thickness. The marginal cost is thus not found in observed lifetime but in increased cost of the measures taken.

The tables below summarise the average and marginal cost for the road and then rail case studies. Note that, for roads, the mean traffic volume is very different between the studies with the highest traffic volume in the German study and the lowest in the Swedish study.

Table: 2.1 Average and marginal cost in the road sector

	AC	MC	Output variable
	€/Xkm	€/Xkm	Q
Renewal			
Germany R	1.590	1.390	HGV
Poland R	0.210	0.120	All veh
Sweden R paved	0.036	0.032	HGV
Sweden R gravel	0.415	0.236	HGV
Sweden duration model	-	0.0013	HGV
Renewal and Maintenance			
Sweden R+M	0.059	0.040	HGV
Poland R+M	0.270	0.130	All veh
Maintenance/Operation			
Poland M	Na	na	All veh
Sweden O	0.024	(0.002)	All veh
Sweden O winter	0.015	(0.001)	All veh
Sweden O paved	0.003	(0.001)	All veh
Sweden O gravel	0.066	(0.010)	All veh

Table: 1.2 Average and marginal cost in the rail sector

	AC	MC	Output variable
	€/Xkm	€/Xkm	X
Renewal			
Sweden – duration model		0.00028	Gross Tonne (Passenger)
		0.00012	Grosse Tonne (Freight)
Maintenance and Renewal			
Sweden	0.00285	0.00070	Grosse Tonnes
Switzerland (A+B)	0.00364	0.00097	Grosse Tonnes
Maintenance			
Sweden	0.00209	0.00031	Gross Tonne
Switzerland (A)	0.0022	0.00045	Gross Tonne
UK (model V)	*0.00517*	0.001978	Gross Tonne
Switzerland (part of A)	0.00133	0.00038	Gross Tonne
Operation			
Sweden	0.153	0.054	Trains

Hungary			
train movement	3.5	0.22	Train
path allocation	29.8	2.52	No of train
interim passenger train service	13.4	1.09	No pass.train stops
beg/end of line pass train service	17.1	1.85	No of pass train
marshal/shunt for freight wagons	5.03	0.81	No of wagons
consignment of freight wagons	8.22	0.74	No of consigned wagons

2.2.2 Road congestion and rail scarcity

In contrast to other cost categories and modes, there have been a host of studies involving the estimation of marginal road congestion cost. The difficulty is that the available estimates vary considerably between different studies, and not always in the ways one might anticipate. In GRACE the range of previous road congestion cost studies were comprehensively reviewed and modelling work was undertaken – using the SATURN software - to investigate the reasons for the unexpected differences in the results reported for different cities in previous studies. In order to retain experimental control, the modelling is based on a carefully specified series of "city scenarios" rather than on a set of real cities which differ from each other in a myriad of ways.

It was found that these differences can be variously attributed to:

- differences in the definition of "optimal" tolls – the term is often quite loosely applied, e.g. in modelling studies. For example; the term sometimes relates only to congestion tolls (rather than covering other externalities), sometimes allows for the cost of implementation of the tolls (and sometimes not), and sometimes relates only to simple tolls - such as cordons (rather than tolls which vary in space and time).
- differences in the way that optimal tolls (however defined) are calculated. For example, do they fully reflect the behaviour of travellers at the margin or are they derived from a theoretical representation of the marginal impacts?

- differences in the nature of the cities being studied. Factors which are particularly likely to influences the result include the degree of congestion, the availability and attractiveness of alternative modes, the drivers' tolerance of congestion, and the capacity of the network to absorb additional demand.
- differences in the valuation of different externalities – perhaps reflecting different values of time and resource costs.
- differences in the models used to estimate system performance.

For rail scarcity, work was undertaken to calculate directly the costs involved in depriving another operator of a particular slot – one of a number of possible means of addressing the issue. The case study concerns a highly-utilized stretch of the British East Coast Main Line from London to Doncaster. The basis of the approach taken here is that operators should be charged for the capacity they use in accordance with the social opportunity cost of that capacity. In order to implement this approach it is necessary first to measure the amount of capacity used by each train run, and then to estimate its opportunity cost.

We find that a substantial peak scarcity charge per slot is justified. In contrast, the off-peak charge would only be 10% of this level. The results seem to confirm the view that existing variable charges for the use of infrastructure on key main lines where capacity is scarce are too low as a result of the neglect of scarcity in the charges set.

Furthermore, the private value of a slot is different from the social value of a slot, indicating problems with a simple market based solution. This result is an effect of high congestion cost on the road network that is not internalized in a road pricing regime.

The institutional arrangements behind franchising suggest that where the dominant operator is a franchisee, data may be available for the rail regulator to perform a scarcity estimate along the lines of the GRACE case study. This is certainly true in Britain.

2.2.3 Accidents

Work on accident costs in GRACE was confined to an overview and state-of-the-art survey. It seems that there is a growing consensus on the method to estimate the value of statistical life (VSL). The HEATCO project suggests specific values for each Member State. Nevertheless, the research on VSL continues with the aim to explore the numerous biases that have been found to potentially affect the estimates.

On the question of the proportion of internal and external cost and especially the perception of road users risk no new conclusions can be drawn. This is still an area of large uncertainty. However, by assuming something on the perceived cost, actual databases can be used to estimate the proportion of internal versus external cost.

There is still no consensus on the risk elasticity. Surprisingly, many studies find decreasing risk with increasing traffic volume. This could be a problem associated either with the studies or behaviour effects. If we do not control for infrastructure quality, we may find that roads with higher expected traffic volume are designed with a higher traffic safety standard. In addition, road users may react to a perceived increased risk by driving more carefully and slower. This is an unobserved cost component that would increase the cost.

2.2.4 Air pollution and Greenhouse gases

Four case studies for road transport within densely built areas have been conducted. They are expected to complete the picture on air pollution from existing studies and to analyse the variations of environmental costs and the driving parameters. Assessing data availability and due to the fact that a broad range of European countries and local meteorological conditions should be considered, the cities selected for this purpose were Berlin, Prague, Copenhagen and Athens.

The results show that for all vehicle types the higher marginal costs due to airborne emissions correspond to the city of Athens, followed by Berlin, Copenhagen and Prague in that order. The factors that seem to be more relevant for these results are the wind speed and the population density. The high share of low wind speeds for the

Athenian area together with a population density close to 20 000 hab/km^2 in some zones, leads to a pollutant exposure of the population which is about a factor of two higher compared to the other cities. In addition, petrol cars cause lower cost per vehicle kilometre compared to diesel cars as they emit much less fine particles, leading to lower health impacts.

A European abatement cost of €20 per tonne of CO_2 represents a central estimate of the range of values for meeting the Kyoto targets in 2010 in the EU based on estimates by Capros and Mantzos (2000). They report a value of €5 per tonne of CO_2 avoided for reaching the Kyoto targets for the EU, assuming a full trade flexibility scheme involving all regions of the world. For the case that no trading of CO_2 emissions with countries outside the EU is permitted, they calculate a value of €38 per tonne of CO_2 avoided. It is assumed that measures for a reduction in CO_2 emissions are taken in a cost effective way. This implies that reduction targets are not set per sector, but that the cheapest measures are implemented, no matter in which sector. Recent work has confirmed the assumption that emissions in future years will have greater total impacts than emissions today.

Hence, for application in GRACE we used a range of €14 to €51 (with a central value of €22 per tonne of CO_2- equivalent emission in the period 2000 to 2009). These shadow prices were derived from Watkiss et al. (2005b), converting from £2000/t C to €2002 (factor prices).

2.2.5 Noise

Based on a state-of-the-art review, it is observed that existing estimates show considerable non-linearities of marginal noise cost with background noise levels. Population density along the route and average distance of traffic from buildings are also found to be key determinants of cost. For example, in Berlin the average number of persons per road kilometre affected by noise is slightly higher than in Stuttgart. However, the costs are more than a factor of three lower due to the much higher number of vehicles and higher speeds leading to a higher background noise level. In Helsinki, on the other hand, the population density along the route considered is lower than in Berlin and Stuttgart, furthermore the average distance from buildings is higher – leading to lower noise costs.

2.2.6 Sensitive areas

The impact pathway approach has been used to estimate a factor that relates the cost in Alpine regions to the cost in 'flat' regions. The biggest effect is found to be related to the topographical and meteorological conditions.

The results indicate that local air pollution costs, noise costs, accident costs and infrastructure costs are all somewhat greater in Alpine regions as compared with flat regions. Local air pollution costs from road transport in an alpine region would be 5 times higher than in a flat area, with a slightly higher factor for cars than for HGVs. The corresponding factor for rail is around 3.5. The noise cost is also estimated to be about 5 times higher in road transport and 4 times for rail transport. The number of accidents is higher per kilometre in Alpine regions suggesting a factor of 1.2 for road transport. The infrastructure maintenance cost is for the road sector about 4.5 times higher and for rail transport 1.4 times. In addition, a factor for visual intrusion is suggested to be around 10 due to the specific alpine conditions. This has however, no corresponding marginal cost.

2.3 Cost Estimation for Ports

2.3.1 Introduction

The aim of the port case studies was to construct a model and a methodology to get an insight into the marginal costs of maritime transportation. Marginal costs in this setting are defined as those costs corresponding to an extra vessel calling at a port or leaving a port. An overview is given of costs, whereby it is indicated whether those costs should be considered as marginal or not.

Once the theoretical setting about marginal costs in ports has been concluded, a simulation tool was built in order to calculate the marginal cost in case of a vessel calling at and leaving a port. Marginal costs taken into account are:

- infrastructure costs as a consequence of using locks in the port;
- crew cost on the vessel;
- operating and maintenance cost of the vessel, tugboats and pilotage boat (or helicopter);
- accident costs (cargo as well as injuries of persons);
- noise costs and air pollution costs.

It is illustrated that the simulation tool can be used for all types of ports and for several effects. Five ports for the case-studies have been selected: Port of Antwerp (Belgium), Port of Bordeaux (France), Port of Genova (Italy), Port of Felixstowe (UK) and the Port of Gdynia (Poland). It is clear that the simulation tool can be used for the selected ports.

First provisional estimations have been achieved. They show that marginal costs per vessel call usually increase in vessel size. A 200 TEU container vessel in Antwerp for instance incurs a marginal cost of €12,150, whereas a 3000 TEU vessel incurs a marginal cost of €28,842. The effect is mainly, but not always, due to higher vessel crew and operating costs.

Marginal infrastructure costs are only a small fraction of overall marginal costs (€706 per vessel in Antwerp for instance), and fully depend on lock use: if no locks are used, no marginal infrastructure costs occur. Marginal costs are usually comparable in level over vessel and corresponding commodity types. A comparison between the ports of Antwerp and Bordeaux, where the port-approach as well as the in-port timing is known, learns that marginal costs of call in Bordeaux are not always lower than corresponding costs in Antwerp, although Bordeaux' approach is a lot shorter in distance. For Genova as well as for Felixstowe, no approach timing is known. A comparison of the at-terminal costs learns that for container vessels, Felixstowe usually incurs higher marginal costs than Genova, the main reason for which may be port efficiency.

For the port case study, the simulation tool can be used to deal with congestion and scarcity costs. However, in the case of the ports that were investigated, congestion and/or scarcity seems not to be relevant nowadays, e.g. due to existing overcapacity. However, port economists start to take into account potential future capacity problems. Therefore, it is necessary to provide a simulation tool able to calculate the consequences of possible congestion.

The environmental costs of maritime transport are assessed for air pollution, global warming and oil spills. Environmental costs of air pollution are estimated for 15 types of marine vessels using fuel consumption, emission factors and damage factors.

Up to date scientific research has not tackled the problem of environmental costs of oil spills. In this research a first approach is presented to estimate the environmental costs, expressed in Euro per tonne of spilled oil. Given a volume of worldwide oil spills of 570,000 tonnes stemming from marine transportation, and assuming environmental cost of 15,000 Euro per tonne of oil spilled, the total worldwide cost of transport related oil spills amounts to 8.55 billion Euros annually.

Using the above specific cost figures of air pollution and the global figures on oil spills, the environmental costs of six maritime trajectories in Europe are computed.

Using these examples the outcomes quantify the monetary impacts maritime shipping has on the environment in Europe.

2.4 Cost Estimation for Airports

An empirical model is proposed to evaluate economies of scale, economic inefficiency and marginal costs. It consists of estimating a translog model, formed by a cost function and two input cost share equations that allows to estimate the airport parameters under study. A stochastic frontier model has been estimated, which analyses economic inefficiency in the structure of the error term.

Three case-studies are distinguished: AENA (Aeropuertos Españoles y Navegación Aérea) Spanish airports case-study, an international airports case-study and Chicago O'Hare airport case-study.

An empirical application of the translog model to the study of important industry parameters in Spanish airport sector is provided, based on a balanced panel consisting of 37 commercial airports observed over the period 1991-97. These airports are controlled, owned and managed by AENA and are characterised by a lack of incentives on the part of the agents who manage commercial airports to adopt the criterion of cost minimisation.

The results confirm that the resource use is statistically not economic efficient. Most of the airports operate in the area of increasing returns to scale. We also find very limited possibilities for input substitution, and elastic production factor demands. The marginal cost of Spanish airports were estimated and the average figure of € 8.14 of the year 1991 is obtained.

Additionally (in the second case-study) important economies of scale are presented which are not exhausted at any output level, as well as very significant technological progress. Two different specifications (mono-production and multi-production cost functions) are estimated showing that elasticities of scale are overestimated in the case of the mono-production estimation. Regarding long-run marginal cost estimations, some reasonable values are obtained for Air Transport Movements (ATMs) and Work Load Units (WLUs; 1 passenger or 100 kg of cargo) in the average airport, which are about € 406.03 and € 5.97 (for the year 2005), respectively. A short-run cost function is also estimated using the total surface of terminal building as a fixed production factor. It can be seen that the marginal costs of one additional ATM and WLU for the average airport are € 119.02 and € 4.89, respectively.

The delays at Chicago O'Hare (third case-study) airport were statistically analyzed with help of 3 different indicators: DAS (Delay Against Schedule), MSD (Mayer-Sinai Delay) and MVD (Martín-Voltes Delay) for 52 different routes. Each indicator presents some advantages and disadvantages. However, we are inclined to measure delays with MVD because it is a sort of hybrid between the other two and for some specific reasons. Firstly, it is an indicator that is measured against the departure schedule of the flight. Secondly, it corrects somehow the schedule padding behaviour that airlines may introduce in order to optimize their performance with respect to the number of delayed flights.

This issue will have a special relevance when policy regulations require airlines to compensate passengers who experience many types of delays and flight cancellations. Nowadays, there is no unique regulation that applies to all the airlines no matter where passengers fly, and it is really difficult to become familiar with what an airline is legally required to provide as a compensation, what its policies are on compensating passengers, and how passengers may be able to negotiate for additional compensation.

However, delays are not an easy topic to study and are is subject to much debate over the potential strategic behaviour of airlines with respect to their schedule padding time (i.e. adding time to allow for possible delays). This last issue has been shown to exist analyzing the performance of 52 routes at Chicago O'Hare airport.

The extra over-padding time of each airline at some selected airports and routes is also calculated. In many cases the over-padding time exceeds 30 min. These figures will depend on the past performance and the expected results from distinct changes in the subsystems that affect flight times (Air Traffic Control centres, airports and airlines) and even the weather conditions. We could expect some extra-padding time due to some value of the components, especially the one that refers to weather conditions. We could have expected to observe a similar pattern of extra-padding time applied to the schedules of airlines, but it has been shown that there is no such a figure (common extra-padding time).

Costs caused by emission of airborne pollutants, greenhouse gases and noise (for aircraft) were assessed, based on the Impact Pathway Approach. Quantifiable costs due to taking-off and landing at Frankfurt airport – the biggest airport in Germany – were calculated for a number of aircraft. Costs due to air pollution amount to – depending on aircraft type –between 10 and 235 € per Landing and Take-Off (LTO) cycle, greenhouse gas emissions add another 20 to 220 € per LTO cycle. Noise costs were quantified for different times of day: day time, evening and night time with the latter showing the highest cost. Quantified night time noise – depending on flight route – ranges from 4 – 16 € per take-off to 200 – 900 € per take-off. Costs for landing tend to be lower, but are in the same order of magnitude.

2.5 Cost Estimation for Inland navigation

Computing infrastructure costs of inland waterways is complicated by the fact that the waterways serve multiple purposes. In order to compute the infrastructure costs it has to be clear what part of the total costs is related to the transportation function. In a second step, the infrastructure costs are divided into fixed costs and marginal costs. In a next step, the mathematical relation is determined between total infrastructure costs and the marginal costs.

It is reported that the average marginal infrastructure cost for inland navigation in the Netherlands in 2002 is on average € 0.53 per vessel-kilometre.

The significance of congestion costs is very much dependent on the specifics of the situation. In general there is not much congestion on the inland waterways. However, for particular locks and bridges there are significant waiting times and these times can increase rapidly when traffic intensity increases.

The methodology for estimating congestion and scarcity on inland waterways was divided into three parts:

- congestion at locks;
- congestion at bridges;
- scarcity on waterways.

The methodology for estimating congestion at locks was tested on several case studies and is proven to be easily implemented and generating promising results. The methodology has been applied to 5 locks in the Netherlands. The increase in costs per ship when the intensity increases with 1 million ton per year varies between € 0.08 (Volkerak locks) and € 379.55 (Lock Eefde). The increase in costs per ship when the intensity increases with 1% is in the range € 0.15 (Locks at IJmuiden) to € 49.52. When a lock is already strongly congested, marginal costs are very high.

The methodology for estimating congestion at bridges is considered an interesting suggestion, however, for now it can not yet be implemented. Including all possible crossing modalities is beyond the scope of the GRACE project and will therefore not be included in the methodology. Besides this argument there is also the lack of information that will complicate estimation of costs.

The methodology for estimating the costs of scarcity was illustrated using the Low Water Surcharge that is currently imposed on the Rhine when the water level drops below a certain value. On the Rhine a surcharge is already paid by the shipper to the shipping-agent, when the water level drops below a fixed value, in order to compensate the shipping-agent for the increase in transportation costs. The increase in cost per TEU when the water level drops with 1 cm varies from € 0.38 to € 2.50 at Kaub and from € 0.65 to € 1.25 at Duisburg-Ruhrort.

Air pollution costs for inland water transport are calculated for two selected trajectories on the Rhine and the Danube. The approach uses a regionally differentiated method including the newest findings of European research on emission factors and damage costs. Emissions costs were computed and relative figures in terms of costs per tonne kilometre were calculated, as shown in Figure 1. Environmental costs range between 0.17 and 0.41 cent per tkm. These costs are well within the range given by UNITE (2001)[2]. The graph shows clearly, that the Vienna-Bratislava voyage is cheaper due to the lower population densities along the trajectory. The figure illustrates as well the decreasing environmental costs for larger vessels[3].

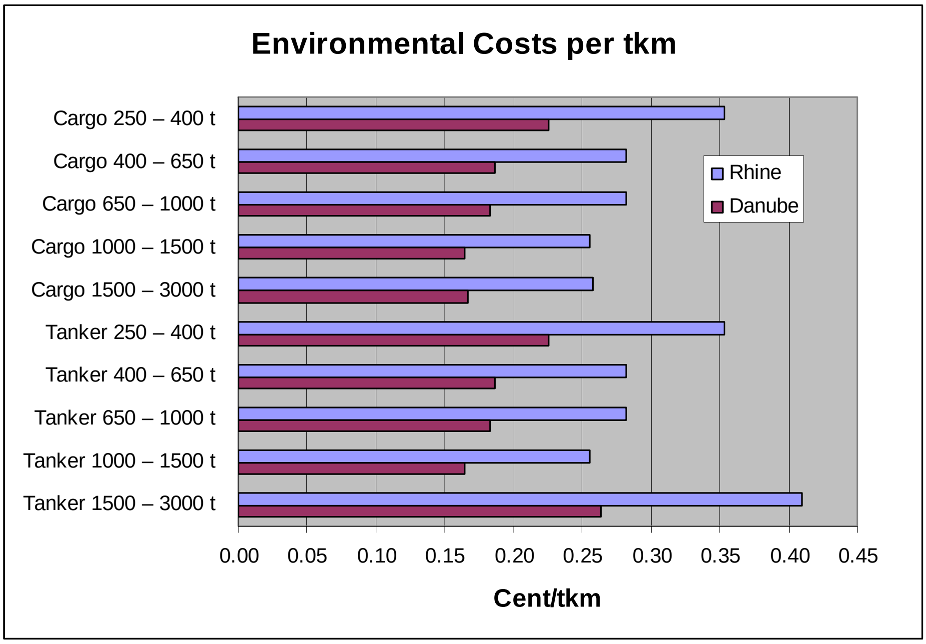

Figure 1: Air pollution costs per tonne-kilometre

2.6 Generalisation of Research on Cost Estimation

GRACE has developed a software tool in order to assist the user in the estimation of marginal costs for any section/node of the TEN-T for which all the detailed information required for a full fledged, bottom-up calculation does not exist. Drawing

[2] UNITE (2001) WP5/8/9, Version 2, p.33
[3] However, some implausibilities occur, e.g. for large tankers, which are due to problematic input data on the emission side.

heavily on previous RTD projects that have addressed the calculation of marginal costs (e.g. UNITE, RECORDIT), in addition to the new insights coming from the GRACE case studies, the GRACE tool incorporates methods ensuring the transferability of marginal costs estimates and their generalization, i.e. identifying the variables (cost drivers) and parameters whereby existing marginal costs can be adapted to different contexts and/or new estimations can be carried out.

Marginal costs estimates for the use of transport infrastructure have been produced for a wide range of situations, and using a variety of different approaches. One thing that these case studies have in general shown is that there is no standard methodology for marginal costs estimation, and that the methodological approaches available are strongly influenced by data availability issues and by the type of transport mode under examination.

However, it is important to stress that transferability methods cannot be implemented with the same degree of confidence across the several cost categories. Although much of the effective implementation depends on sheer data availability, the level of difficulty varies with the cost categories.

The following table provides an overview of the two basic approaches adopted in the GRACE tool. i.e. the cost functions (CF) and the reference costs (RC), across transport modes and external cost categories. Empty cells in the table correspond to modes and cost categories for which the absolute value of external costs is known to be very small, and to all intents and purposes is therefore considered negligible.

Cost functions have been devised when causal functional relationships have been identified between variations in the drivers (the independent variables in the function) and the values of marginal costs (the dependent variable). This is clearly the preferred option, allowing the user to carry out sensitivity analysis through the modification of values and parameters of the function.

On the other hand, reference costs have been proposed, as a second best solution, when the current state of research does not allow for the identification of a usable (i.e.

simple and reliable) cost function, and only reference marginal external costs are available for typical situations, e.g. urban and non urban context, without allowing sensitivity analysis. In fact, this fallback option is only adopted in the case of wear and tear marginal external costs, for which the current methods of assessment state of the art do not allow for the determination of a cost function, so that reference costs available from literature have been proposed for road and rail transport modes.

Table 2.3

Cost Category	ROAD		RAIL	IWW	AIR	SSS
	Urban	Interurban				
Air Pollution	CF	CF	CF	CF	CF Airport	CF (Port)
Noise	CF	CF	CF	-	CF Airport	-
Accidents	CF	CF	-	-	-	-
Congestion /scarcity	CF*	CF	N.A.	CF	CF Airport	
Global Warming	CF	CF	CF	CF	CF Airport	CF (Port)
Wear and tear	RC*	RC*	RC	CF	CF Airport	CF (Port)

The asterisks on the cost function and reference cost approaches in road urban congestion and wear and tear costs indicate the presence of hybrid approaches.

The software tool has undergone several rounds of testing to refine both its underlying estimation capabilities and its outward appearance and usability. It is being made available on a controlled basis via the web, and the intention is that it will continue to be developed and updated as the research evidence grows.

Whilst the tool itself estimates marginal cost and does not then go on to calculate marginal cost-based charges, it is clearly acknowledged that the calculation of charges is of keen interest. In order to translate marginal cost estimates into marginal cost-based charges, one needs to offset the existing set of transport-related charges and taxes. However, inclusion in the software tool of the detail of the myriad different such charges and taxes that exist throughout Europe would have been an enormous undertaking and has not been attempted. Instead, tests have been undertaken to use the outputs of the tool, in combination with specific details of the relevant existing transport-related charges and taxes, to calculate efficient, marginal cost-based charges. These are reported in detail in Deliverable 7, but a summary of one of the calculations follows.

Table 2.4 Central London – Costs vs Charges – Private Motorist

	GRACE Calculated Cost (euros per vkm)			**Total Charges (toll plus taxes – in euros vkm)**			**Grace Cost minus Actual Charge (euros vkm)**		
Engine Category:	**Time Period**			**Time Period**			**Time Period**		
	Peak	Off-Peak	Night	Peak	Off-Peak	Night	Peak	Off-Peak	Night
Euro2 Petrol	2.963	0.209	0.223	2.32162	0.08162	0.08162	0.64138	0.12738	0.14138
Euro4 Petrol	2.961	0.208	0.222	2.32162	0.08162	0.08162	0.63938	0.12638	0.14038
Euro5 Petrol	2.961	0.208	0.222	2.32162	0.08162	0.08162	0.63938	0.12638	0.14038
Euro2 Diesel	2.977	0.224	0.238	2.30426	0.06426	0.06426	0.67274	0.15974	0.17374
Euro4 Diesel	2.965	0.212	0.226	2.30426	0.06426	0.06426	0.66074	0.14774	0.16174
Euro5 Diesel	2.960	0.207	0.221	2.30426	0.06426	0.06426	0.65574	0.14274	0.15674

The table presents the GRACE charges which have been calculated using the GRACE software tool and represent the marginal social cost (MSC) per vehicle kilometre for a private motorist travelling within London. These are compared with the average charge per vehicle kilometre paid by a private motorist travelling through central London.

The key components of this are:

- The central London congestion charge - £8 (www.tfl.gov.uk) or 11.2 euros[4] per day – which assuming an average trip length of 5 kms[5] per day within central London gives an average charge per vkm of 2.24 euros
- Vehicle Excise Duty – 0.78 pence or 0.01092 euros per vkm for petrol cars and 0.57 pence or 0.00798 euros per vkm for diesel cars
- Fuel Duty – 5.05 pence or 0.0707 euros per vkm (petrol) and 4.02 pence or 0.05628 euros per vkm (diesel)

The final three columns of the table compare the two sets of costs. It can be seen from the table that currently the charges associated with driving through central London are less than the MSCs as calculated by the GRACE tool. However, in percentage terms different patterns can be observed. In peak hour conditions they are around about 78% of the GRACE costs. For off-peak petrol the actual charges are around 39% of the calculated MSCs, whilst for the diesel categories the charges range from 28% to 31% depending upon the engine type. With regards to night time costs the charges are equal to about 37% of the calculated costs for the petrol categories and range from 27% to 29% for the diesel categories.

[4] Assuming an exchange rate of 1.4 euros per £1
[5] See Santos and Bhakar (2006)

3. Transport Accounts and the Monitoring of Pricing Reforms

3.1 Introduction

Transport accounts, developed in the UNITE projects for all EU 15 countries and for Switzerland and Hungary, provide information about the total social costs (infrastructure costs, supplier operating costs, delay costs due to congestion, accident costs, environmental costs) and revenues of transport for road, rail, other public transport, air, inland waterway and maritime transport, disaggregated by network types, differentiation, transport means and user groups. Since transport accounts show the total or average social costs rather than marginal costs they should not be viewed as an instrument for determining charge levels or charge structures. The major purpose of transport accounts is rather to serve as a monitoring tool.

However, the conclusion from the UNITE project and from the early GRACE work was, that both methodological and data improvements are required in order to enable the use of transport accounts for monitoring pricing policy. Hence, this chapter discusses potential methodological advancements and derives conclusions on the necessary data collection procedures. It has suggested a range of methodological improvements of transport accounts with the aim to enable their use as monitoring tool for transport pricing reform.

Furthermore, we have analysed the situation in the new member states and have developed recommendations and guidelines to produce transport accounts for these countries. Conceptual issues for elaborating regionalised accounts were explored and tested for the urban areas of Rome and Amsterdam and for the Swiss Alpine region. Finally, for making the accounts capable to fulfil their envisaged monitoring function, simplified updating procedures were developed.

3.2 Recommendations for splitting up total infrastructure costs into fixed and variable components

Quantitative ranges of variable infrastructure costs have been derived which can – in absence of genuine marginal cost information – be used as a proxy for marginal cost. For road maintenance our analysis suggests a cost variability of between 50% and 60%, for road renewals between 50% and 70%. Road operation costs do not seem to vary much with road use, e.g. seem to be a fixed cost. For rail we suggest to use an average of the computed scaled elasticities to derive variable cost shares, amounting to 0.16 for maintenance and to 0.22 for combined maintenance and renewals.

3.3 Recommendations for splitting up total accident costs into internal and external components

Based on various new data sources such as HEATCO, safety net, and country surveys on third party liability insurance premiums a more refined methodology to estimate internal parts of accidents could be derived. For applying this methodology, we have suggested generalised values on the value of statistical life and on the proportion of internal costs, but the methodology requires on the other hand country-specific information on third party liability insurance premiums and on the share of medical costs borne by the user. Furthermore, we have suggested correction factors for taking into account the problem of underreporting.

3.4 Improvements of air and waterborne accounts

New studies on the WTP for reducing annoyance from noise and new exposure data for German airports have enabled to demonstrate an improved methodology to estimate noise costs from air transport. For maritime transport we have analysed available categorisation approaches for port infrastructure, port services and charges paid within ports. Furthermore, new emission inventories for maritime air pollutants have allowed us to improve estimates of air pollution costs for maritime shipping and to allocate these costs to countries.

3.5 Accounts for new member states

The major conclusion from this part of research is that the most important implementation barriers result from policy maker's unfamiliarity with the accounts methodology or originate from a lack of resources and problem perception, organisational opposition against change, fear of undesirable results coming from the accounts, and lack of an organisation responsible for making national transport accounts. The most important recommendations for overcoming the implementation barriers are:

- dissemination and marketing targeted at policy makers,
- explaining more clearly the use and policy implications of transport accounts,
- appointing organisations responsible for creating these transport accounts,
- providing funds, and coupling with applications for (regional) funding.

3.6 Regional accounts

For the Swiss Alpine region different types of regional accounts were successfully developed, each of them depending on the perspective taken and on the way how transboundary effects are considered. For the urban area of Amsterdam a conceptual approach for an urban account was developed including an analysis of data requirements and availability. The same is true for the Rome case study where conceptual issues and the methodology have been developed, but future work is needed to fill in the framework with data and cost estimates. Our major conclusion is that the elaboration of regional accounts can provide useful insights into relevant policy questions, but data support from regional authorities is the major prerequisite.

3.7 Improvements and Updating

Our major and overall conclusion from the research reported in this deliverable is that it is well possible to improve the methodology of accounts if new and improved data is available. The emergence of such new data, but also of new country case studies stimulated the development and testing of methods as demonstrated in this deliverable. It is worthwhile to analyse periodically the availability and quality of new data and studies to develop methods further, and to produce in a next step “new” UNITE accounts based on these improvements.

4. Price-Complexity

4.1 Introduction

This area of GRACE sought to investigate the optimal degree of complexity in pricing. It was, first, necessary to explore some definitions of optimal complexity and to introduce the trade-off between the theoretical advantages of highly differentiated charges and the practical problems that such differentiation might bring. It then addresses four modal sectors and, for each one, explores four issues:

- the existing degree of charge differentiation,
- the differentiation implied to achieve marginal social cost pricing,
- the level of differentiation that is likely to may become possible in the medium term, and
- the information required to define or identify optimal complexity of charges.

Subsequent work concentrated on the passenger market in the road sector. Hence, this chapter goes on to discuss the results of surveys which used a specially designed questionnaire to explore user response to complexity in road user charges and modelling work to identify optimal levels of complexity in road user charges.

4.2 Review of Current and Projected Use of Complex Charges in the Road, Rail, Airport and Port Sectors

In the road sector, a review of 36 case studies provides evidence on the current extent of price differentiation and reveals the existence of differentiation by vehicle characteristics (number of axels, weight, height, length, country of registration, type of fuel, emissions standard, size of engine….), site characteristics (location, level of service, congestion sensitivity….), method and date of payment (manual, electronic, bulk purchase, season ticket…), and time (peak/off-peak, based on current congestion). The review also identifies the technologies currently used to support road user charging.

A brief enumeration of the external costs of road travel leads to the conclusion that, the external costs of road traffic include congestion, pavement damage, gaseous and particulate emissions, safety hazard, noise, and visual intrusion, and that the key drivers are: the vehicle characteristics, the way it is being driven and whether the engine is warmed up, the design and current condition of the road, the other traffic currently using the road, the current meteorological conditions, and the riparian topology, land use and activity.

The costs of implementing road user charges with different degrees of complexity are identified and the medium term prospects for the technological developments needed to support a greater degree of price differentiation are explored. It is concluded that, pending improvement in the accuracy of vehicle location systems, real-time monitoring of noise and emissions, more accurate weather forecasts, more knowledge of different environmental impacts of different vehicle types in specified conditions, more accurate data on individual choice and purchasing behaviour and further development of web-based tools to assist drivers to choose cost-minimizing routes, effective differentiation is unlikely to go much beyond the dimensions already being used in existing applications (vehicle type, site characteristics, expected meteorological conditions, expected congestion and type/method of payment).

Analysis of optimal complexity in the road sector is seen to require information on costs (of delays, of environmental emissions including noise, of accident costs, of pavement damage and of alternative payment channels), on user responses to charges and on user responses to complexity per se. The sources of this information are variously identified as: an equilibrated network assignment model, the resource value of travel time, data on noise and emissions profiles for different types of vehicle per unit distance travelled in different conditions, valuations of noise and of key emissions according to population density and time of day, data on the involvement of different types of vehicle in accidents of differing severity, data on the cost of accidents of different severities, data on the costs of pavement damage associated with the use of different types of vehicle on different types of road, data on the relative costs of operating different payment options, and a survey designed to ascertain users responses to different degrees of complexity.

In the context of rail track charges, a review of the situation in 7 countries shows that differentiation is currently employed on the basis of: vehicle type (usually the weight or the axle-load of trains, the train dimensions, the speed, and whether freight or passenger), the infrastructure characteristics (typically type and quality of track), whether the train is full or empty, time period, and, in some cases, length of contract. It is concluded that SMC pricing would require differentiation on the basis of the marginal costs of maintaining, renewing and operating track infrastructure, of air pollution, of noise and other environmental damages, and of accidents, and should allow for delay and scarcity costs. However, it was noted that departures from SMC pricing might be required to deal with operator deficits, and that solutions for allocating scarce capacity need to be established. The relevant cost drivers are identified as including the type and characteristics of vehicles (train operating requirements, speed, weight, number and type of wagons, type of traction, and noise emissions), the type and quality of tracks (track equipment and condition, electrification, economic importance of relations such main, minor and feeder lines, etc.), track utilisation levels and the nature of riparian land use. It was not thought that there were any major technological constraints on the introduction of this degree of differentiation. It is concluded that the information required to determine the optimal degree of complexity would include: the marginal costs to the infrastructure manager, the marginal cost of noise and emissions, marginal costs of accident hazard, the costs of operating a given charging regime, the costs (to train operators) of responding to a given charging regime, the opportunity cost and the scarcity costs.

Although the GRACE project is concerned with infrastructure charges, we recognise that a proportion of such charges are likely to be passed on to end users and so thought it would be useful to investigate how such users are already affected by price differentiation. Due to resource constraints this investigation was limited to one sector - rail passenger fares. A review of 11 case studies reveals that rail fares are commonly differentiated according to class (first /second), length of journey, time or season (peak/off-peak), train type (stopping / express), and level of comfort (e.g. on night trains, seat / couchette). Prices also differ according to the flexibility of the ticket, the degree of advance booking, purchase medium, and whether bought with a return ticket, and there are often special discounts for particular types of people (e.g. groups, families, seniors, tourists). The overall picture is thought to be rather complicated and certainly confuses some potential passengers. From the theoretical point of view, efficient prices in rail passenger transport should be based on marginal social cost and should allow for the Mohring effect. It is thought that, in the medium term, competition from low cost airlines and other modes would result in more niche products and inventive discounts and that commercial pressures would cause operators to experiment with yield management pricing. Although strictly beyond the scope of the GRACE project, conclusions are drawn on the information required to establish optimal levels of complexity; namely: the cost of servicing an additional passenger on a particular route in a particular class at a particular time (given current loadings), the extent of the Mohring effect, the cost of the additional crowding or delay, the cost of collecting the revenue from an additional passenger who purchases a ticket of a given type at a given time through a given channel, and, crucially, rail passengers' behavioural response to a tariff of a given degree of complexity.

In the context of airport charges it is noted that deregulation, competition and privatisation have radically changed the environment in which charges are set and that, in the context of ICAO and IATA guidelines on transparency and non-discrimination, airlines are charged fees in each of a number of defined categories: (e.g. landing charges, passenger charges, handling charges, and aircraft parking charges) and that this system is overlaid by an array of rebates and incentives. The charges reflect aircraft characteristics (weight, size, noise and emissions, manoeuvrability) and the services utilised (landing and taxiing facilities, air bridges, security, customs, baggage handling, etc). A separate charging regime is applied to no-aeronautical commercial activities (e.g. shops, car hire services) on airport premises and is generally based on the value of the space utilised. From a theoretical perspective it is noted that efficient prices should be based on the marginal cost of maintaining, renewing and operating the airport infrastructure, of the externalities involved in air transport, and of security, congestion and slot scarcity. It is expected that, in the medium term, more emphasis will be placed on the noise and emissions created by aircraft and that there will be increased pressure to make more efficient use of slots (e.g. via a slot auctioning process rather than allowing grandfather rights to prevail). No major technological constraints are envisaged in this process but efficient slot allocation presupposes the existence and use of sophisticated modelling and market intelligence by airlines participating in a slot auction.

For port charges we note that prices currently differentiate according to vessel type (eg tonnage, draught, length), use of services (pilotage, towage, berth facilities, loading/unloading facilities, passenger facilities), location of operations within the port, duration of service use (processing time), season, and although only rarely, environmental impacts. This differentiation does not generally reflect the actual costs incurred by the port operations, does not recover costs and creates severe inefficiencies such as congestion as well significant financial loss. The application of discounts on the basic prices does not overcome these basic problems. From a theoretical perspective, the pricing principle should be based on the short-run marginal cost and should take into account the costs imposed on port operators, shippers and the wider community. Identifiable external costs, which are scarcely considered at present, include the costs of accidents, noise, emissions and congestion. The costs of delay caused by congestion and inefficient slot allocation are a particularly serious source of inefficiency. It is anticipated that the issues of operational efficiency, transparency, and wider impacts on the economy and environment will become more important over time. In order to determine optimal charges for a port call it is first necessary to identify all the involved parties and their competences and the extent of the total logistic chain which is to be considered. Only then can the costs of servicing an additional vessel of a particular type requiring a particular service at a particular time (i.e. the infrastructure costs, the transport user costs, the costs of supplying port services and the external costs) be established.

4.3 Determining the Optimal Degree of Complexity in Road Charging

Work reported in Deliverable 2 concluded that the questionnaire should be designed to provide information on the particular aspects of price differentiation which users perceive as contributing to complexity, on the behavioural responses to perceived complexity, and on whether behavioural response to a given degree of complexity of charges can be represented by appropriate adjustment of the (true) charges. Deliverable 2 similarly concluded that the modelling work should allow for a wide range of behavioural responses and should explore the performance of a transport system characterised by charges with different degrees of complexity.

The design and content of the questionnaire emerged after consideration of the overall objectives and was influenced by that of a questionnaire with similar objectives being developed by ITS for the UK Department for Transport. The basic concept was that the questionnaire would ask respondents to indicate their understanding of, and likely response to, a complex charging scheme which they had had time to study. It was therefore designed to be conducted in two stages. The first stage questionnaire was used to screen suitable respondents, to gain an insight into the type and characteristics of a regular journey they were making, to obtain data on some personal characteristics and attitudes, and to see whether they would take part in a further telephone interview. The stage two questionnaire was conducted by telephone after the respondents had had an opportunity to study a charge scenario and consider their possible responses to it. The second set of questions sought more detail about the respondent's regular journey and, most importantly, asked them to estimate the charge that they would incur and to indicate their likely response to it. Additional questions probed the reasons for any reluctance to consider alternative travel arrangements and covered a wide range of related issues including: the confidence they had in their ability to estimate both existing costs and the proposed charges, the reasons for any difficulty they had had in estimating the charge and their attitude to uncertainty.

Surveys using this questionnaire were implemented in Newcastle, Cologne and Thessaloniki in the second half of 2006. Analysis of the data collected with this questionnaire provided some very interesting insights and allowed quantification of several aspects of response to complex charges that had not previously been studied in such detail. Among other findings the following are perhaps particularly relevant to the current investigation:

- respondents were not able to produce accurate estimates of their current motoring costs or trip distances and were themselves aware that this was the case;
- substantial proportions of the sample claimed that they didn't always seek the "best" deal when dealing with everyday household bills and that they did not normally think about the costs of alternative travel routes;
- although most respondents claimed that they found the charge scenarios easy to understand, many were unable to estimate the charge that they would incur on their regular journeys and most of them recognised that this was the case;
- charges that were a function of distance travelled seemed to be particularly difficult for people to predict;
- respondents who said that they had found the charges difficult to predict were likely to be less certain about their likely behavioural response;
- many respondents (30%) said that, even if charges were introduced, they would not bother to think seriously about alternatives to their current transport arrangements because they felt they had no choice;
- many respondents (45% in Newcastle, 23% in Cologne and 70% in Thessaloniki) said that they would not think seriously about alternative travel arrangements unless the charge represented a significant monthly sum (>37 euros per month) and that, at lower levels, the effort required to think about it was not worth it;
- most of the respondents who said they were very likely to continue with their existing travel arrangements had said the charge was too low to warrant serious consideration of alternatives; and.
- most of our respondents showed an aversion to uncertain charges – though a minority seemed actively to be risk-seeking.

The questionnaire data was used to specify and calibrate models of response to charges for use in the next stage of the work. Although there was some support for a model which explicitly recognised the process of disengagement, whereby people elect not to make a serious effort to consider the implications of a new charge, that model did not perform well enough to justify such a radical departure from conventional practice in the next stage of the work. A fairly conventional logit model was therefore used to capture the likelihood of each of a series of behavioural responses to complex charges. These models suggested that the responses were influenced by the size of the charge (although to a lesser extent than is implied in a conventional elasticity model), by the age, gender and income of the trip maker, and by the purpose of the trip – with mandatory trips being less affected than discretionary trips.

The next stage of the work involved the construction of a network modelling package to test the performance of charge regimes with different degrees of complexity. The package was built around the SATURN assignment model, a charge estimation module, and a demand response module which, between them predicted an equilibrium level of network conditions, charges and demand. The demand response module differed depending on the complexity of the charges being studied; responses to complex charges were predicted using the logit models calibrated on the questionnaire results while responses to simple charges were predicted using a conventional elasticity model. The most complex charge regime had link-specific charges based on the environmental externalities associated with traffic using that link plus a charge based on the increment to congestion caused by an additional vehicle using that link at the current demand level. A range of simpler charging regimes were derived from this fully complex specification.

A number of different charging regimes were tested using this network modelling package and several very interesting results emerged, of which the following are particularly relevant to the question of optimal levels of complexity:

- The complex charging regime produced larger revenues and greater reductions in externalities than any of the simpler regimes but produced lower benefits[6] even before allowing for the less precise response to the pricing signal and the higher costs of scheme operation.
- The underperformance of the complex regime was even greater when allowance was made for the less precise response to the pricing signal and the higher costs of scheme operation.

[6] This is defined as the reduced environmental externalities, plus reduced vehicle operating costs (excluding tax) and time for continued travellers, minus tax revenue formerly coming from trips which are now discontinued, minus consumer surplus foregone by discontinued trips.

- The basic underperformance of the complex regime seems to be related to the fact that it was based on link-specific charges which, while reducing congestion, encouraged the use of longer routes and so led to an increase in vehicle operating costs.
- We note in this context that, because users do not perceive their current operating costs correctly, their response to supposedly optimal charges will not be efficient.

Deliverable 6 includes detailed discussion of a number of issues related to our methodology, most notably the limitations of our network modelling package and the difficulty of predicting longer term responses using our questionnaire method. The implications of our findings for other modes and sectors are also discussed.

4.4 Conclusions

The most appropriate degree of complexity was found to depend on 3 key factors: the policy objective used to define optimum; the type of simplification envisaged; and the level of fuel taxes assumed to co-exist with the new charges. That is, if the objective was to maximise net benefits, the complexity associated with some link-specific "marginal cost" charges is likely to be counterproductive and a much simpler charging regime is likely to perform much better. If the objective was to maximise net revenue, the optimal degree of complexity may be beyond that which is justified, even in theory, by marginal social cost pricing. If the objective was to minimise externalities, it would be important to maximise users' ability to understand the pricing signal and so the most appropriate degree of complexity is likely to fall some way short of the full extent of complexity implied by social marginal cost pricing. A charging regime that requires people to deal with more than one dimension of complexity is particularly likely to result in an imprecise adjustment of behaviour to the pricing signal. Furthermore, a close match between costs and behaviour cannot be expected in the short term, so there is little reason to introduce highly differentiated charges unless they are likely to remain stable for a considerable period of time.

If people can be assisted to estimate distances (for example, via in car navigation aids), distance-based charges appear to offer the prospect of high benefits at relatively low costs. One implication of this result is that, to the extent that fuel consumption is a proxy for distance travelled and environmental externalities, overall benefits might be increased more simply and cost- effectively by increasing fuel taxes than by introducing a wholly new form of road user charging.

An important conclusion from our network modelling work was that tolls designed to optimise levels of congestion can not perform well unless they recognise the fact that users do not base their decisions on an accurate assessment of vehicle operating costs (net of tax). There is clearly a need for some further theoretical work to define a toll which recognises this kind and to operationalise the calculation of such a toll within the context of a network model such as SATURN.

It would clearly be desirable, when the opportunity arises, to study “real” estimates and responses. However, it is also suggested that further efforts should be made to develop a network based representation of the performance of time varying tolls but note that this is a non-trivial problem because of the possibility that such a regime would cause queues to migrate forward in time and that there might be no convergent solution. More research is also required to explore the factors that make one price signal more “complex” than another (some work already underway in the DIFFERENT project should address this) but further investigation of behavioural responses to uncertainty is also required.

Our work concentrated on the performance of urban networks dominated by peak hour passenger traffic. Further work is obviously required in other transport sectors where the behaviour of actors, the nature of externalities and the costs of scheme implementation are quite different. Some interesting insights for the transport sector may be found in the utilities sector where the market solution appears to be provision of a range of levels of complexity to suit the needs of a range of customers.

5. Socio-Economic Impacts

Introduction

In order to understand the socio-economic impact of pricing traffic according to the marginal external cost we need to put the transport market in a broader economic context. In GRACE we take five different approaches that each highlight another dimension of the socio-economic impact. Table 5.1 gives an overview of the research questions and methodologies used. All approaches have in common that pricing scenarios based on the GRACE estimates of external costs are used.

Table 5.1: Survey of research questions and methodologies used in this deliverable

Sections	Research or Policy question	Approach
2.	What is the effect of implementing marginal social cost pricing on the composition of transport flows and on welfare?	Use of GRACE estimates in TREMOVE model for 27+4 EU countries
3.	What is the socio-economic effect of transport pricing in sensitive areas?	Test GRACE estimates with a general equilibrium model for Switzerland that contains a sensitive region (Alps) and a non sensitive region
4.	What are the regional employment effects of marginal social cost pricing?	Use the GRACE estimates in a multi-regional general equilibrium model for the EU to estimate the effects of alternative pricing policies
5.	How to implement marginal social cost pricing when the EU level does not know the marginal external cost at the member country level?	Theoretical analysis using the basic regulation model with asymmetric information
6.	Is a more general equilibrium	Theoretical model with a numerical

	approach to accident externalities necessary?	illustration

5.2 What is the effect of implementing marginal social cost pricing on the composition of transport flows and on welfare?

General impacts of pricing reform

TREMOVE was used to analyse three possible pricing reform scenarios. The three pricing reform scenarios vary in the complexity of the pricing reform that is simulated. The pricing reforms are principally based on marginal external cost information generated in the GRACE project. A model is required to analyse the impacts for three reasons: first some external costs (congestion) are a function of the volume of transport, second the ultimate effect of the pricing policy depends on the demand reactions and modal shifts, and third the ultimate welfare effects will depend on the way the transport revenues are used.

The TREMOVE model represents the transport markets by country modules for 27 EU countries + Croatia, Norway, Switzerland and Turkey. In each country module, all passenger and freight modes are represented and a distinction is made between metropolitan, urban and non urban zones. Every transport mode has a simplified representation of all externalities. Road congestion is endogenous and is represented via aggregate area speed flow functions, air pollution is represented more finely via a vehicle stock module, and other external costs are linked to activity by mode and type of vehicle. The model estimates the changes in transport demand, the modal split, the vehicle fleets, the external costs and the welfare level in reaction to changes in taxation, pricing and regulation policies.

The three pricing scenarios are summarized in Table 5.2. All scenarios have in common that all existing taxes, charges and subsidies on transport are abolished and that the non road modes cover their variable costs and marginal external environmental and noise cost. This implies for some countries and non road modes important price increases. Finally all policy scenarios are supposed to be implemented from 2010 onwards but only results for 2020 are reported.

Table 5.2: Pricing reform scenarios for TREMOVE II model

	Cars	Trucks
Scenario 1	use only fuel tax to cover total marginal external cost –	use fuel tax for climate change externalities and a flat km tax for all other externalities
Scenario 2	Use fuel tax only for climate change externalities and country and vehicle specific flat km tax for all other externalities	Use fuel tax only for climate change externalities and country and vehicle specific flat km tax for all other externalities
Scenario 3	Idem as scenario 2 but km tax is differentiated with respect to time and place	Idem as scenario 2 but km tax is differentiated with respect to time and place

In the average marginal external cost for 2020 in the basecase equilibrium (before any reform) is reported. These values are based largely on GRACE results.

For each of the 3 scenarios two variants are defined that help to understand the role of the use of the net change in transport revenues that result from the policy change. In most partial equilibrium models, the net change in tax revenues is added as a benefit to the changes in consumer surplus and producer surplus with a weight of 1. In TREMOVE, the value of extra tax revenue collected will depend on two factors: where it is taken away and how it is used. For the use of the tax revenues two variants are defined. In the first variant "general tax decrease", all net changes in transport tax revenues are used to decrease general taxes outside the transport sector. 1 € of extra tax revenues collected from non commuting transport and used to decrease general taxes is given a value slightly higher than 1 for most countries. This means that this general tax decrease generates a small extra beneficial welfare effect. In the second variant "labour tax decrease", the change in transport tax revenues is used to decrease existing labour taxes. There is now a much stronger beneficial effect on the labour market, the value of the extra € ranges between 1.26 and 2.52 depending on the national about taxes[7]. The reason is that taxes are shifted away from labour, alleviating directly the labour market distortion. The labour market distortion exists because income and social security contributions create a large gap between the private return to the supply of labour (net wage) and the social return to the supply of labour (gross labour cost to the employer). Not only the use of the extra tax revenue but also the type of transport where extra tax revenue is raised matters: ceteris paribus it is better to tax leisure trips than commuting transport because a tax on commuting transport is almost like a labour tax and therefore adding to the distortion on the labour market. Whenever tax revenues are weighed differently than consumer and producer surplus, marginal social cost pricing is no longer maximising welfare and this will show up in the results: there will be a bias in favour of scenarios generating more tax revenues. Finally, it is obvious; that if one knows that the extra transport tax revenues are used in bad transport infrastructure projects rather than for decreases in other taxes as assumed here, the value of the collected tax revenues is closer to 0 than to 1 and increasing taxes to reduce external effects in the transport sector loses its appeal.

The aggregate results (EU-27+4) are summarized in Table 5.3: revenues, welfare changes and volume changes for the year 2020 are reported. The first column reports absolute tax revenues (net of subsidies) in the transport sector. The second column reports welfare changes when the revenues are recycled in the economy via a decrease of general taxes. The third column gives welfare changes when the revenues are used to decrease existing labour taxes. The two last columns report changes in volumes of tonkm and passengerkm. The results per country are given in Appendix I.

[7] See “The marginal cost of public funds in OECD countries: hours of work versus labour force participation” H.J. Kleven and C.T. Kremer, CESifo Working Paper Series, April 2003.

Table 5.3: Aggregate revenue, welfare and volume effects of the pricing reforms for EU-27+4 for year 2020

In % of GDP	total revenues	Welfare change when general taxes are decreased	Welfare change when labour taxes are decreased	change in tonkm in % of reference	change in passkm in % of reference
Reference	2.298	0	0	0	0
scenario 1	6.224	0.034	1.706	-10.7	-17.4
scenario 2	5.402	1.191	2.725	-11.0	-11.5
scenario 3	5.391	1.181	2.702	-10.8	-11.2

We draw 7 lessons from these scenario results:

a) it is clearly very difficult to use the fuel tax as the only instrument to address all the externalities of cars and motorcycles. Scenario 1 shows that this requires enormous increases in fuel taxes, large increases in tax revenues (factor 3) but only a tiny efficiency gain if we rule out the pure recycling effect of tax revenues to alleviate labour market distortions;
b) when a km charge for cars and trucks takes over as main pricing instrument (scenario 2), revenues are double those in the reference scenario and welfare improves strongly – overall transport volumes decrease by some 11%;
c) the benefits of finer spatial and temporal differentiation (scenario 3 compared to scenario 2[8]) give indeed higher congestion relief benefits but generate less revenues – because of the large weight given to the increase in tax revenues, the result is that scenario 3 generates a smaller welfare gain than scenario 2 if taxes are equal to marginal external costs – if taxes could be optimised in both scenarios scenario 3 would produce clearly better results than scenario 2;
d) it is well known that the introduction of a more refined (area and time based) charging and taxing regime increases the transaction costs (billing, enforcement etc.); this is not yet taken into

[8] The total tkm and vkm are not lower in scenario 3 but the reduction is more targeted in the congested areas.

account in the welfare computation and this needs to be checked region by region as a more refined pricing regime may only make sense in heavily congested areas;
e) the way the extra tax revenues are used is as important as the selection of the pricing reform scenario;
f) the welfare gains come mainly from a reduction of external accident costs, a reduction of external congestion costs and from a good use of the extra tax revenues;
g) the pricing reform policies suggested here is not yet a complete mix to address the different externalities; some externalities like accident externalities need more refined instruments like fines for speeding or alcohol in order to signal the social costs of drivers' behaviour.

5.3 What is the socio-economic effect of transport pricing in sensitive areas in Switzerland?

In this analysis, we evaluate the relative economic impacts on the Swiss economy of regionally differentiated transport pricing strategies reflecting the especially high costs of transport in a sensitive area like the Alps. We also look at cost recovery considerations within each transport mode, which is still a major concern for policy makers. In addition, the importance of the recycling of transport tax revenues to reduce existing distortionary taxes is examined.

Transport policy scenarios are simulated applying SwissTRANS, a multi-sectoral general equilibrium model of Switzerland introducing both, the Alpine region and the rest of Switzerland, and calibrated to an initial economic equilibrium in 2001. The model combines inter-sectoral linkages within regions together with linkages among regions. Transport per mode is represented in an aggregate way using aggregate congestion functions for road transport.

Simulation of different transport pricing scenarios in an economy-wide perspective suggests the following policy recommendations:

a) A change from the current pricing regime towards a marginal social cost pricing scheme that is regionally differentiated is beneficial for both the Alpine region and the rest of Switzerland.

Though the impact is rather limited in terms of welfare, the policy debate should be oriented in this direction.

b) Regional transport and redistribution policies should not be considered separately as the latter may change the welfare analysis considerably.

c) Cost recovery objectives should not be an objective per se of pricing - average cost pricing as objective for rail and road can lead to inefficient policies in the rail and road sector; when compared to current pricing, average cost pricing results in welfare losses.

d) Additional transport revenues should be used to reduce existing distortionary taxes

e) Appropriate pricing of transit transport[9] is important as it plays a crucial role in the determination of the net welfare effect for Switzerland.

5.4 What are the regional employment effects of marginal social cost pricing?

The regional economic impacts of 3 policy scenarios of European-wide transport pricing on the regional welfare and (un)employment in Europe are computed. The scenarios are identical to the scenarios defined for the TREMOVE model: fuel taxes as the only instrument, a CO2 tax under the form of a (much smaller) fuel tax supplemented by a km charge differentiated by country and finally a CO2 tax under the form of a small fuel tax supplemented by a time and place differentiated km charge (cfr. Table 5.2 above).

The spatial computable general equilibrium model CGEurope represents Europe by more than 1200 regions. In every region there are immobile households that supply labour and mobile capital. They consume a local good and tradable goods produced by the other regions. They

[9] Throughout the deliverable, the word “transit” is used to denote traffic passing through a territory and does not stand for public transport..

consume more of a good when its price decreases but they love variety and end up consuming a bundle of goods produced by the different regions. Every region produces one variant of the tradable good. Transport costs are one component of the costs of trading goods between regions. As there is imperfect competition for tradable goods, they are sold at decreasing average cost rather than at marginal cost. Labour markets are imperfect: wages do not equilibrate the market and there is unemployment. The unemployment is seen as the result of the efficiency wage hypothesis: higher unemployment reduces the real wages. The tax revenues are redistributed lump sum and are split equally between the origin and the destination region. . Compared to the TREMOVE and the Swiss general equilibrium model, this model introduces two new market distortions: imperfect competition on the tradable goods markets (prices above marginal costs) and unemployment.

The proposed EU-wide pricing reform scenarios have overall small negative effects on real income and on employment. The overall impact on real income equals -0.11% of GDP but this is before counting the benefits of lower environmental, accident and congestion relief that are of the order of 2 % or more of GDP according to TREMOVE results for the same scenario. The reason for the negative effects is as follows. In the CGEurope model, the presence of imperfect competition makes that prices of tradable goods are already larger than the marginal production costs, so adding the external costs tends to make the tradable goods even more expensive. The spatial pattern of the GDP and unemployment effects of the pricing reform is characterized by a concentration of losing regions in the EU-27 periphery. The regions suffering the strongest losses of welfare and unemployment are located in the new member states. The precise mechanisms at work are complex as trade effects and returns to scale tend to balance each other. On the other hand it is logical that reforms that raise the price of transport affects most those regions that rely more intensively on international trade for their trade.

5.5 How to implement marginal social cost pricing when the EU level does not know the marginal external cost at the member country level?

This research focuses on one particular problem: the asymmetric information problem in the implementation of marginal social cost pricing. While the upper level (EU, or country) is in principle concerned with the welfare of all the EU citizens and wants social marginal cost based pricing, a lower level government (a member state or region) may prefer much higher transport charges to extract revenue from through traffic (called transit here) . This issue is present in the European policy debate: there are the high transit taxes of Switzerland and there is the fear of peripheral countries that road charges for trucks contain a monopoly margin. One of the solutions proposed by the European Commission is to cap the road toll to the average infrastructure costs.

A simple theoretical model is used to explore the asymmetric information problem. One transport link crossing a single country is used by transit and local traffic. The local government knows the external costs but the federal government does not. We consider two stylized cases of external costs. First constant marginal external costs that is independent of the volume of traffic but affect the local population only (some forms of air pollution or accident externalities on locals). Second, we consider external congestion costs that are a function of the volume of traffic and affect the local users and the transit users.

For external costs that do not affect the volume of traffic (air pollution etc), the federal government (here EU) can use two policy instruments to control the potential misuse of marginal external cost pricing by the member states. The first is an incentive mechanism (financial reward) that makes the member countries reveal the information correctly. This scheme is theoretically appealing but may be difficult to implement politically. The second is to impose a toll cap based on the federal government estimate of the marginal external cost. This can not result in perfect pricing but improves welfare compared to the case where the regions set the tolls they want.

For external costs that affect traffic volumes (congestion costs) there are three instruments available for internalization. The first instrument, rewarding truthful revelation, does not always work for external costs that affect the volume of traffic. The second policy, a cap based on the external cost estimate of the federal government can also work for congestion; it improves welfare but is not perfect. The third policy is a cap based on the average infrastructure expenditures for road. This requires a minimum of information to monitor for the federal level. If transit and local traffic are homogeneous and average infrastructure costs are constant (constant returns to scale in road capacity), this generates in principle optimal pricing and even optimal investment policies because it is in the region's interest to do so. This could be the theoretical justification of Eurovignette type of directives. When the composition of transit and local traffic differs (say more trucks in transit or in off peak), the scheme may not work as well. Then there exists the risk that trucks are overcharged as this is a way to make transit pay a disproportionate share of the infrastructure costs.

Overall we find that there is a need for federal control of regional tolling. This requires investment in knowledge of the possible range of external costs. For air pollution, accident and noise, the federal government could implement toll caps based on the estimated marginal external cost. For the external congestion cost, a cap equal to the average infrastructure cost could be an interesting instrument.

5.6 Is a general equilibrium approach to accident externalities necessary?

Accident costs are considered as an important negative externality. In the traditional partial equilibrium approach one tend to overlook the effects on other markets that are distorted: labour markets (heavily taxes), markets of medical services (subsidized). It is not clear à priori if this calls for a strong correction in the estimation of the marginal external accident cost.

The marginal external accident cost that needs to be charged in a richer general equilibrium model has the following structure:

General equilibrium marginal external accident cost =
(1) Partial equilibrium external accident cost + (2) Correction for labour tax revenues + (3) Correction for change in mitigation activity + (4) Correction for the induced labour supply effects

Where

(1) the Partial equilibrium external accident cost represents the effect of one more carkm on general accident risk times [productivity value of sick days lost due to a change in the general accident risk + congestion time loss of an increase in accident risk + discomfort of subjective accident risk that remains after mitigation].

(2) the Correction for labour tax revenues equals the labour tax losses of the driver associated to the extra sick days of the driver in case of accidents (positive term)

(3) the Correction for a change in mitigation activity: the increased taxation of trips may reduce accident risks and thus the mitigation efforts by the households, as these efforts are often heavily subsidized, reducing these mitigation activities is in itself a gain (positive or negative term)

(4) the Correction for the induced labour supply effects represents the fact that increased taxation of commuter trips may decrease the supply of labour, as labour is already heavily taxed; this is itself a loss and calls for a downward correction of the externality tax (negative term)

If we distinguish between safe and dangerous driving we find that the marginal external accident cost of a kilometre driven is higher for dangerous driving because the general accident risk effect of dangerous driving is higher than for safe driving and also the correction for labour tax revenues is higher as dangerous driving also generates more sick days for the dangerous driver himself.

A numerical illustration of the partial equilibrium approach used in GRACE and the general equilibrium approach proposed shows that the differences are very small (<1%).

6. Overall Conclusions and Recommendations

6.1 Introduction

European transport pricing policy is at an exciting juncture and GRACE finds itself drawing its conclusions at a point where policy-makers are actively taking forward the transport pricing policy agenda. The conclusions emerging from GRACE encompass the estimation of the marginal social costs of transport, the monitoring of pricing reforms, the degree of price complexity to be implemented and the likely impacts of implementing pricing reforms based on marginal social cost.

6.2 Overall Conclusions

There is a well-known and useful relationship between average cost and marginal cost known as the cost elasticity with respect to traffic output, and this may be effectively utilized for the estimation of marginal road and rail infrastructure costs. The elasticity for road infrastructure cost decreases as the measure changes from renewal to maintenance and to operation. Elasticity for rail infrastructure cost is lower than the elasticity for road and doesn't show the same difference between different measures. The evidence suggests that the elasticity decreases with increased traffic.

The marginal cost follows from the elasticities and the average costs. The average cost is less homogenous than might be expected and, hence, the marginal cost – in particular on roads - has a huge variability depending on the huge variability in average cost.

Estimates of road congestion costs in previous studies exhibit a wide degree of variability. The reasons for this variability are now better-understood, and involve not only variations in actual congestion levels in different studies but also identifiable differences in the analytical approaches of different studies. Further research to estimate road congestion costs should benefit from these insights.

For rail transport we find that capacity constraints at particular times and locations across the network give rise to significant scarcity costs. Hence, it is found that a substantial peak scarcity charge per rail slot is justified.

In relation to the estimation of accident costs, there is a growing consensus on the method to estimate the value of statistical life (VSL) and the HEATCO project suggests specific values for each Member State. However, the question of the proportion of internal versus external accident cost, and especially the perception of road users risk, is still an area of large uncertainty, and there is still no consensus on risk elasticity.

In relation to environmental costs, air pollution costs within densely built areas appear to be inversely related to the wind speed and positively related to the population density. Meanwhile, petrol cars cause lower cost per vehicle kilometre compared to diesel cars. For noise costs, population density along the route, average distance of traffic from buildings and existing background noise levels are found to be key determinants of cost

The impact pathway approach has been used to estimate a factor that relates the cost in Alpine regions to the cost in 'flat' regions. The biggest effect is found to be related to the topographical and meteorological conditions. The results indicate that local air pollution costs, noise costs, accident costs and infrastructure costs are all somewhat higher in Alpine regions – by factors ranging between 1.2 and 5 – than in flat regions.

The port case studies provided an insight into the marginal costs of maritime transportation. In order to calculate the marginal cost of a vessel calling at and leaving a port, a simulation tool that takes into account the typology of the ports and the vessels was built. First provisional estimations show that marginal costs per vessel call usually increase in vessel size. Marginal infrastructure costs are only a small fraction of overall marginal costs (€706 per vessel in Antwerp for instance), and fully depend on lock use. The simulation tool can be used to deal with congestion and scarcity costs but congestion and/or scarcity seem not to be relevant for the ports investigated at present, due to existing overcapacity.

The environmental costs of maritime transport are assessed for air pollution, global warming and oil spills. Using specific cost figures of air pollution and the global figures on oil spills, the environmental costs of six maritime trajectories in Europe are computed.

Marginal costs at airports were explored through three case-studies: AENA (Aeropuertos Españoles y Navegación Aérea) Spanish airports case-study, an international airports case-study and Chicago O'Hare airport case-study. The first and second of these generated estimates of marginal cost, whilst the third focused specifically on the investigation of the cost of delays.

Costs caused by emission of airborne pollutants, greenhouse gases and noise (for aircraft) were assessed, based on the Impact Pathway Approach. Quantifiable costs due to taking-off and landing at Frankfurt airport – the biggest airport in Germany – were calculated for a number of aircraft. Costs due to air pollution amount to – depending on aircraft type –between 10 and 235 € per Landing and Take-Off (LTO) cycle, greenhouse gas emissions add another 20 to 220 € per LTO cycle. Noise costs were quantified for different times of day: day time, evening and night time with the latter showing the highest cost. Quantified night time noise – depending on flight route – ranges from 4 – 16 € per take-off to 200 – 900 € per take-off. Costs for landing tend to be lower, but are in the same order of magnitude.

Computing infrastructure costs of inland waterways is complicated by the fact that the waterways serve multiple purposes. Nevertheless, it is reported that the average marginal infrastructure cost for inland navigation in the Netherlands in 2002 is on average € 0.53 per vessel-kilometre. The significance of congestion costs on inland waterways is very much dependent on the specifics of the situation. In general there is not much congestion on the inland waterways. However, for particular locks and bridges there are significant waiting times and these times can increase rapidly when traffic intensity increases. The methodology for estimating congestion at locks was tested on several case studies and is proven to be easily implemented and generating promising results. The methodology for estimating the costs of scarcity on inland waterways was illustrated using the Low Water Surcharge that is currently imposed on the Rhine when the water level drops below a certain value. Air pollution cost for inland water transport is calculated for two selected trajectories on the Rhine and the Danube.

Given the (un)availability of data on ports, airports and inland navigation the several case-studies had to opt for different methods. Therefore it was not possible to present one general methodology in order to determine marginal costs for air and water transport. Within each of these case-studies, the calculation of marginal costs depends on the typology used. In the port sector, a distinction can be made between ports without and with locks. In the inland navigation case-study, marginal costs depend on the level of the already used capacity of the locks. In the airport case study, variances between airports are reported.

Hence for ports, airports and inland navigation, the inserted numerical results should only be used in their own specific context. The figures cannot be used for general statements about marginal costs. Every figure is linked with a specific typology, with a specific time-frame and with specific assumptions. The framework developed in the project should be further confronted with experts' opinion to further validate the data. A general framework has been outlined and a first attempt of numerical calculations have been made. It should be stated here that port authorities are rather reluctant to give detailed data about port arrivals and departures, if they dispose of vessel call data at all.

Drawing on the growing evidence base of marginal cost estimates, GRACE has developed a software tool in order to assist the user in the estimation of marginal costs for any section/node of the TEN-T for which all the detailed information required for a full fledged, bottom-up calculation does not exist. One thing that the wide ranging set of marginal cost case studies has shown is that there is no standard methodology for marginal costs estimation, and that the methodological approaches available are strongly influenced by data availability issues and by the type of transport mode under examination. In addition, it is important to stress that transferability methods cannot be implemented with the same degree of confidence across the several cost categories. Two basic approaches have been adopted in the GRACE tool. i.e. the cost functions (CF) and the reference costs (RC). Cost functions have been devised when causal functional relationships have been identified between variations in the cost-drivers and the values of marginal costs. On the other hand, reference costs for typical situations have been proposed, as a second best solution, when the current state of research does not allow for the identification of a simple and reliable cost function. Whilst the software does not itself calculate charges, it has been demonstrated that the outputs of the tool, in combination with details of the relevant existing transport-related charges and taxes, can be used to calculate approximate efficient, marginal cost-based charges.

Transport accounts, developed in the UNITE projects for all EU 15 countries and for Switzerland and Hungary, provide information about the total social costs and revenues of transport disaggregated by network types, differentiation, transport means and user groups. However, the conclusion from the UNITE project and from the early GRACE work was, that both methodological and data improvements are required in order to enable the use of transport accounts for monitoring pricing policy. Furthermore, we have analysed the situation in the new member states and have developed recommendations and guidelines to produce transport accounts for these countries.

Quantitative ranges of variable infrastructure costs have been derived which can – in absence of genuine marginal cost information – be used as a proxy for marginal cost. In addition, based on various new data sources such as HEATCO, safetynet, and country surveys on third party liability insurance premiums a more refined methodology to estimate internal parts of accident costs could be derived.

Data shortages exist in New Member States, but perhaps the most important implementation barriers result from policy maker's unfamiliarity with the accounts methodology, a lack of resources and problem perception, organisational opposition against change, fear of undesirable results, and lack of an organisation responsible for making national transport accounts.

The elaboration of regional accounts can provide useful insights into relevant policy questions. However, data support from regional authorities is the major prerequisite.

The emergence of new data and of new country case studies stimulated the development and testing of methods to enhance the transport accounts within GRACE. It would be worthwhile, as a next step, to produce "new" UNITE accounts based on these improvements.

A further area of GRACE sought to investigate the optimal degree of complexity in pricing. This concluded that a close match between costs and behaviour cannot be expected in the short term and thus there is little reason to introduce highly differentiated charges unless they are likely to remain stable for a considerable period of time. Furthermore, the "optimum" degree of complexity depends crucially on the policy objective used to define optimum. If the objective was to maximise net benefits, the complexity associated with some link-specific "marginal cost" charges is likely to be counterproductive and a much simpler charging regime is likely to perform much better. If the objective was to maximise net revenue, the optimal degree of complexity may be beyond that which is justified, even in theory, by marginal social cost pricing. If the objective was to minimise externalities, it would be important to maximise users' ability to understand the pricing signal and so the optimal degree of complexity is likely to fall some way short of the full extent of complexity implied by social marginal cost pricing. The optimal degree of complexity will also depend on the type of simplification envisaged and a charging regime that requires people to deal with more than one dimension of complexity is particularly likely to result in an imprecise adjustment of behaviour to the pricing signal. The use of a complex pricing regime with high average charges could yield significant revenues. This is because the sensitivity to the actual charge is reduced when the charge structure is complex. If people can be assisted to estimate distances, distance-based charges appear to offer the prospect of high benefits at relatively low costs. The implication of this result is that, to the extent that fuel consumption is a proxy for distance travelled and environmental externalities, overall benefits might be increased more simply and cost- effectively by increasing fuel taxes than by introducing a wholly new form of road user charging. Finally, the optimal degree of complexity may depend on the level of fuel taxes assumed to co-exist with the new charges.

Work to investigate the socio-economic effects of implementing marginal social cost pricing in the EU has arrived at several key findings. Best welfare results are obtained by using more refined pricing instruments than higher fuel taxes. Substitution of present fuel taxes by a combination of a lower fuel tax (equal to the CO2 damage) and a km charge differentiated by type of vehicle and country could already bring important welfare gains.

The benefits of going beyond the km charge differentiated by type of vehicle and country in the direction of regional and time variation have to be judged region by region. When the characteristics of the regions are very different in terms of external costs it is worthwhile differentiating their pricing.

Pricing transport according to the marginal social cost affects more the peripheral countries as they rely more on interregional and international transport services for their trade relations. In a labour market characterised by unemployment, unemployment in the peripheral regions could slightly increase, unless some arrangement is made for revenue use to compensate for this.

Full marginal social cost pricing could generate suboptimal welfare and unemployment effects because there can be negative interactions with existing distortions on the labour market (commuting traffic and unemployment) and on the product markets. One of the ways to limit these negative side effects is to use the net additional tax revenues raised in the transport sector to reduce existing tax distortions on the labour market

The way the extra tax revenues are used is as important for the overall welfare effect as the selection of the pricing reform scenario itself. If the net revenues are allocated to inferior transport infrastructure projects, it is better not to raise extra tax revenues in the transport sector.

There is a need for the federal level (EU or lower) to control the implementation of external cost pricing to avoid misuse of monopoly positions. Caps on chargeable air pollution, noise and accident external costs and a cap on average congestion charges equal to average infrastructure costs need to be considered.

6.3 Recommendations for Policy

The following are the key recommendations from the project:

Road and Rail

- Optimal charges for the use of transport infrastructure will be below average maintenance and renewal costs for road, and a long way below for rail, wherever there is spare capacity and little environmental impact.

- Most of the evidence suggests that charges should be higher for low quality, less heavily used infrastructure, as the low quality nature of the infrastructure makes it more susceptible to damage.

- Where capacity is scarce there is a strong case for a charge to cover marginal congestion costs for roads and scarcity costs for rail. These charges will be very variable in time and space. The effects of such charges on traffic levels on inefficiently priced competing modes need to be taken into account.

- Environmental charges for noise and air pollution should vary with the characteristics of the vehicle; for air pollution, population density and windspeed are the other key cost drivers; for noise, population density and background noise levels.

- The sensitivity of an area in relation to transport has a major effect on the appropriate pricing levels – for example, appropriate charges in Alpine areas may be several times those in flat areas.

Ports, Inland Waterways and Airports

- Efficient charges for ports and inland waterways will comprise a wear and tear charge for the use of locks, plus congestion, scarcity and environmental charges. Methodologies for estimating all of these are put forward. Given current levels of congestion, this approach will result in very low charges relative to average cost.

- Efficient charges for airports will also comprise a base charge well below average cost plus congestion, scarcity and environmental charges.

- Airports produce substantial environmental costs which are not usually internalised in charges.

- If capacity is expanded in line with demand, and operators reserve blocks of capacity on long run contracts (e.g. in ports) long run marginal cost pricing (incorporating a charge for incremental capacity, perhaps as a fixed element in a two part tariff but excluding congestion and scarcity charges) may be more appropriate.

Generalisation

The generalisation exercise confirms that there are major differences in marginal social cost in time, space and vehicle type that have not internalised in existing charges.

- An appropriate methodology for estimating external accident costs has been set out but there remain major uncertainties concerning risk elasticities and users' perception of risks.

Accounts and Monitoring

- To be useful in connection with pricing policy, transport accounts need to:-

    - Split infrastructure costs into fixed and variable – detailed estimates have been derived for the variability of road and rail costs;

    - Split accident costs into internal and external - a more refined methodology to estimate internal parts of accident costs has been established;

    - Be based on detailed databases showing capacity utilisation ratios for individual sections of the network, and to categorise these by population density

- It is possible for countries to prepare comparable transport accounts using guidelines tested within the project.

- Data shortages exist in some Member States, but perhaps the most important implementation barriers result from policy maker's unfamiliarity with the accounts methodology, a lack of resources and problem perception, organisational opposition against change, fear of undesirable results, and lack of an organisation responsible for making national transport accounts. Overcoming these requires more effort on institutional reform and dissemination of best practice.

- The elaboration of regional accounts can provide useful insights into relevant policy questions, but data support from regional authorities is the major prerequisite.

- It is worthwhile periodically analysing the availability and quality of new data and studies to develop methods further, and to produce in a next step "new" UNITE accounts based on these improvements.

Complexity

- It was not thought that there were any major technological constraints on the introduction of highly differentiated charges in the rail, water or air sectors.

- The costs of implementing the most complex charging regimes for roads appear likely to outweigh the benefits and a simpler scheme is likely to yield higher net benefits.

- A close match between costs and individuals' behaviour cannot be expected in the short term and there is thus little reason to introduce highly differentiated charges unless they are likely to remain stable for a considerable period of time.

- Given that, faced with "difficult" charge structures or unpredictable charges, individuals generally seek to avoid them but are not very sensitive to the precise level of the charges, complex charges (particularly those which vary in more than one dimension) are very unlikely to result in a complete adjustment of behaviour to the pricing signal.

- If individuals can be assisted to estimate distances, distance-based charges appear to offer the prospect of high benefits at relatively low costs.

- Because individuals do not perceive their vehicle operating costs accurately or net of tax, an additional charge based simply on the valuation of externalities can not lead to social-welfare-maximising behaviour; the optimal charge must take this misperception into account.

- Road freight operators are likely to invest time into understanding the cost implications of any charging regime, however complex it might be, and so are likely to be much less affected by problems of misperception and/or lack of understanding.

Socio-Economic Impacts

- Substituting all existing taxes on transport by a fuel tax equal to the external costs would lead to an unrealistically high fuel tax and would not bring welfare improvements. One of the important drawbacks of the fuel tax is that it can not strongly be differentiated between countries.

- The introduction of a flat kilometre tax, differentiated by type of vehicle and perhaps by country would generate substantial revenues and increase welfare significantly.

- Whenever a reform of pricing generates extra revenues, the smart use of the revenues is as important as the design of the pricing reform. Revenue is best used to decrease existing distorting taxes.

- The regional differentiation of transport pricing within Switzerland, where marginal social cost differs substantially between the regions, is welfare improving for both regions, showing that differentiation even of inter-urban charges within a country may be important.

- Provided revenue is efficiently recycled, efficient charges will benefit the economies of most or all European countries, but they will tend to benefit countries at the core more than at the periphery. This leads to a possible argument for a mechanism for redistributing revenues between countries, but any such argument should be considered in the context of the EU's existing framework of financial redistribution between regions.

- In looking at such mechanisms, it is also important to take account of the incentives on countries with high levels of transit traffic to overcharge and under invest.

- All member countries with important transit transport flows have an interest to misreport their marginal external costs if their tax and toll cap is a function of their report. The European Commission could use three techniques to control this. The first is to use an incentive mechanism for correct reporting but this will not work for congestion costs. The second is that the Commission uses its estimate as toll cap. This can work for all kinds of external costs. The efficiency of this policy depends on the quality of information. The third policy works only for the external congestion costs and assuming constant returns to scale. It is a toll cap equal to the average road infrastructure cost. In principle this policy can be efficient as it minimizes the amount of monitoring but requires that the transit and local transit flows have the same composition. In practice, there will be incentives to over-charge and under-charge in different parts of Europe.

6.4 Recommendations for Further research

Key issues for further research are:-

- Work to understand the reasons for variability in marginal wear and tear costs for road and rail;
- the treatment of renewals in estimating marginal wear and tear costs;
- Additional case-study evidence on the marginal wear and tear costs for under-represented modes, cost-categories and contexts – in particular relating to air and water transport;
- risk elasticities and their implications for the marginal external costs of accidents;
- practical ways of determining congestion and scarcity costs for rail, water and air transport;
- Further estimation of the value of aviation delays, aimed at improving regulations on delays and cancellation compensation;
- Work to explore the implementation and use of transport accounts as a monitoring tool;
- optimal pricing given road users misperception of costs;
- Research to understand people's reactions to pricing complexity within the context of implemented charging schemes;

- Further development and testing of the marginal cost calculation software, and updating as new case study estimates become available;
- Further modelling of incentivisation of countries to set the right charges;
- Further modelling of the socio-economic impacts of more finely differentiated charges.

7. Dissemination and Use

7.1 Exploitable Results

The exploitable results generated by the GRACE project are summarized in the previous chapters of this report and are set out in more detail in each of the ten deliverables. In particular, the exploitable results equate with:

- New case study evidence on the marginal social cost of the use of road, rail, air and water transport (Deliverables 3 and 4);
- Guidelines on the enhancement and updating of transport accounts (Deliverable 5);
- New evidence on the optimal degree of price complexity (Deliverable 6);
- A software tool to assist with the estimation of the marginal social costs of transport use (Deliverables 7 and 8);
- New evidence on the socio-economic impacts of more efficient transport prices (Deliverable 9); and
- Conclusions for the implementation of transport pricing policy based on the marginal social cost of transport use (Deliverable 10).

We are already aware that the results and knowledge arising out of GRACE are being used and that they will continue to be used amongst the research and policy communities. Perhaps the outputs of the project with the greatest potential for exploitation are the new estimates of the marginal social cost of transport use, and the Software Tool. The table below is completed for this aspect of the work.

Table 7.1 Overview table

Exploitable Knowledge (description)	**Exploitable product(s) or measure(s)**	**Sector(s) of** application	Timetable for commercial use	Patents or other IPR protection	**Owner &** Other Partner(s) involved
New estimates of the marginal social costs of transport	Transport models and the GRACE Software Tool	Transport	NA	NA	VTI; UA; AUTH; BUTE; DIW; ECOPLAN; IER; ISIS; ITS; TNO; UG; ULP

7.2 Dissemination of knowledge

GRACE has undertaken a range of dissemination-related activities during the lifetime of the project. The key dissemination activities are described below.

- In July 2005, an initial press release, announcing the start of the project was Drawn up and issued. This was circulated to various media sources in several partner countries including Britain and Poland.

- In July 2005 a project website (www.grace-eu.org) was established. It has been maintained and added to throughout the project. The website provides a summary of the project, deta1ils of the partners, links to related projects and, now, all of the ten GRACE deliverables.

- In autumn 2005 an Advisory Board for the project was set up. This comprised key contacts within DG TREN as well as highly esteemed international academic experts from Australia, Chile and the USA. Liaison with the Board has continued through the project and a number of members have attended the GRACE dissemination seminar and conference, including our academic expert from Chile (Prof Juan de Dios Ortuzar). In addition, our academic expert from the USA (Prof Small) was a visitor in Leeds in the run up to the final conference, during which time there were active discussions regarding the GRACE findings and policy conclusions.

- In summer 2006 we liaised with European Parliament magazine – the official magazine for Members of the European Parliament - for the inclusion of a page on GRACE within their summer 2006 special issue on transport. This had a wide and high profile circulation. Furthermore, the page was also included within the brochure for the MEP awards ceremony in autumn 2006, again reaching a wide and high profile audience.

In October 2006 GRACE organised an international seminar, held in Brussels, to disseminate the findings from the first phase of the project. Approximately 50 experts from transport policy and research attended, there was a good deal of discussion and debate and the day was felt to have been a good success. Feedback and reflection on the seminar helped to inform the deliverables which reported on the first phase of the work, submitted in the weeks following the event.

In December 2007 GRACE organised a 1.5 -day international conference, held in Brussels, to disseminate key findings from the project and the project's overall conclusions. Over 50 experts from transport policy and research attended, there was a good deal of discussion and debate and the day was felt to have been a good success. Feedback and reflection on the conference helped, in particular, to shape the finalization of the GRACE software tool and the overall policy conclusions, deliverables that were then submitted subsequent to the event.

GRACE has maintained close links with the IMPRINT-NET coordinated action on transport pricing. Specifically, GRACE has contributed a number of presentations to the IMPRINT-NET Expert Groups, which were workshops held between February 2006 and April 2007. GRACE also contributed presentations to the first IMPRINT-NET annual conference, held in November 2006. These presentations are available via the IMPRINT-NET website.

GRACE has also established and maintained links with the IMPACT project, a consultancy study funded by DG TREN to assist with preparations for a Communication on the internalisation of the external costs of transport that responds directly to the European Parliament's request for a model for the assessment of all external costs. Partners from the consultancy team attended both of GRACE'S dissemination events and partners from GRACE attended both of the IMPACT project's workshop events. This relationship has allowed for GRACE results to be fed directly into and used by the IMPACT project, and for the IMPACT results to feed into aspects of GRACE'S work.

Finally, GRACE has given rise to several research papers and publications. A selection of these includes:

Bąk M., Borkowski P., 2006. „Calculation of road infrastructure costs in Poland" (in Polish, original title: Kalkulacja kosztów użytkowania infrastruktury transportu drogowego w Polsce). Systemy Transportowe – teoria i praktyka (Transport systems – theory and practice), Zeszyty Naukowe Politechniki Śląskiej Transport nr 62, ISSN 0209-3324, Gliwice

Bak M., Pawlowska B., Borkowski P., 2007. „Transport accounts in European countries" (in Polish, original title: Rachunek kosztów i przychodów w transporcie w krajach europejskich). Problemy ekonomiki transportu (Problems of transport economics), nr 1/2007 ISSN-0239-0493, Warsaw

Bąk M., Borkowski P., 2006. The evaluation of road transport infrastructure costs in Poland (in Polish, original title: Ocena kosztów wykorzystania infrastruktury transportu drogowego w Polsce). *IV Konferencja naukowo – techniczna „Systemy transportowe",* Politechnika Śląska, 6 September 2006, Katowice

Bąk M., Borkowski P., 2007. Road infrastructure cost calculation in post-socialist economies. The example of Poland. *11 World Conference on Transportation Research*, University of California, June 24-28, 2007, Berkeley

Bonsall, P., Shires, J., Link, H., Becker, A., Papaioannou, P., and Xanthopoulos, P. (2007) COMPLEX CONGESTION CHARGING – AS ASSESSMENT OF MOTORISTS' COMPREHENSION AND THE IMPACT ON THEIR DRIVING BEHAVIOUR, paper presented at the European Transport Conference, Amsterdam, October 2007.

Burnewicz J., Bak M. (eds.), 2008. Costs and charges in transport sector. University of Gdansk Publishing House, Gdansk (in Polish, original title: Koszty i opłaty w transporcie). To be published in 2008

Johnson, D.H.; Nash, C.A. (2008) Charging for Scarce Rail Capacity in Britain: A Case Study . Review of Network Economics, 7(1).

Link, H. (2006): An econometric analysis of motorway renewal costs in Germany. Transportation Research, Part A, 40(1).

Matthews B and Nash C A (2007) Rail Infrastructure Charges in Europe – current practices and the latest research, paper presented at the 39th University Transport Studies Group (UTSG) conference, Leeds.

Nash, C.A. (2006) European Rail policy on Infrastructure Charges, paper presented at the Public Private Partnership Convention, Indian Rail, 2006

Nash, C.A. (2006) Rail infrastructure charges in Europe - principles and practice, paper presented at Networks for Mobility, 2006, Stuttgart

Nash, C.A. (2006) Examining Efficient Pricing Of Rail Infrastructure, paper presented at Transfin 2006, Nice.

Nash, C.A. (2007) Infrastructure charging – theory and practice. In: Elke Schaenzler and Johannes Ludewig at CER (eds.) Community of European Railway and Infrastructure Companies: Competition in Europe's rail freight market, Eurail Press, Brussels, pp.37-49.

Nash, C.A. (2008) Transport infrastructure pricing: a European perspective. In: E Verhoef, M Bliemer, L Steg and B van Wee (eds.) Pricing in Road Transport. A multidisciplinary perspective, Edward Elgar, Cheltenham, pp.293-311.

TANCZOS K, MESZAROS F, and TOROK A (2007) "Rail Infrastructure Costs in Hungary", paper presented at the 6th Conference on Applied Infrastructure Research, October 5-6, 2007, TU Berlin.

Wheat, P.E.; Smith, A.S.J. (2006) Assessing the marginal infrastructure wear and tear costs for Britain's railway network, paper presented at the European Transport Conference September 2006, Strasbourg

Wheat, P.E.; Smith, A.S.J. (2008) Assessing the Marginal Infrastructure Maintenance Wear and Tear Costs for Britain's Railway Network. Journal of Transport Economics and Policy, pp.1.