**CE Delft**
**Solutions for environment, economy and technology**

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

# Internalisation measures and policy for the external cost of transport

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Author(s): H.P. van Essen, B.H. Boon, A. Schroten, M. Otten (CE Delft)
M. Maibach and C. Schreyer (INFRAS)
C. Doll (Fraunhofer Gesellschaft - ISI)
P. Jochem (IWW)
M. Bak and B. Pawlowska (University of Gdansk)

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# Summary


**Internalisation of transport external costs: policy background**

Transport activities give rise to environmental impacts, accidents and congestion. In contrast to the benefits, the costs of these effects of transport are generally not borne by the transport users. Without policy intervention, these so called external costs are not taken into account by the transport users when they make a transport decision. Transport users are thus faced with incorrect incentives, leading to welfare losses.

The internalisation of external costs means making such effects part of the decision making process of transport users. According to the welfare theory approach, internalisation of external costs by market based instruments lead to a more efficient use of infrastructure, reduce the negative side effects of transport activity and improve the fairness between transport users.

Internalisation of external costs of transport has been an important issue for transport research and policy development for many years in Europe and worldwide. A substantial amount of research projects, including several with support of the European Commission, suggest that implementing market-based instruments inspired by the economic theoretical concept of marginal social cost pricing could yield considerable benefits. Fair and efficient transport pricing has also been advocated in a number of policy document issued by the European Commission, notably the 2006 midterm review of the White paper on the European Transport Policy.

**The IMPACT study**

When amending Directive 1999/62/EC on charging heavy duty vehicles for the use of certain Infrastructure, the EU legislator requested the European Commission to present a model for the assessment of all external costs. The model must be accompanied by an impact analysis on the internalisation of external costs for all modes of transport, a strategy for stepwise implementation and where appropriate a legislative proposal to further review the Eurovignette Directive.

In the light of this mandate from the EU legislator, the European Commission has commissioned the IMPACT study in order to summarise the existing scientific and practitioner's knowledge. The central aim of the study is to provide a comprehensive overview of approaches for estimation of external costs (presented in a Handbook) and an analysis of internalisation approaches, including an assessment of the impacts of various approaches (presented in the report at hand).

**Internalisation approaches**
The analysis of internalisation approaches falls apart into two parts: a qualitative assessment of internalisation approaches based on literature and a quantitative assessment of the impact of various internalisation scenarios based on modelling work. Based on these assessments, it is concluded that current tax and charge structures are generally poorly related to the marginal social cost approach, i.e. to the cost drivers for both external and infrastructure costs.

Especially for road transport, differentiated kilometre based charges are recommended for internalisation of air pollution, noise and congestion costs. Preferably these charges should be differentiated to vehicle characteristics (including Euro standard and particulate filters), location and time of the day. A special focus should be given to traffic in urban areas and sensitive areas such as Transalpine freight traffic, since marginal costs are higher in these areas. External accident costs can be internalised either by a kilometre based charge (differentiated to relevant parameters like location, vehicle type and driver characteristics) or via charging insurance companies for these external costs based on accident rates. The latter option is to be preferred but requires further study. For congestion costs local road pricing schemes can be a good alternative to differentiated kilometre based charges. For aviation and maritime shipping, the number of visits to (air)ports could be taken as charge base.

The main recommended internalisation approaches for climate change costs are carbon content based fuel taxes. Also emission trading is a good option, particularly for maritime shipping and aviation.

**Impacts of internalisation by market based instruments**
TREMOVE and TRANS-TOOLS model runs have been carried out for various internalisation scenarios. Their results show that fuel consumption, emissions and the number of fatalities decrease in all scenarios. Overall the reduction of fatalities and emissions are highest in the scenarios that are closest to the above recommended internalisation approaches. The results of the network model TRANS-TOOLS indicate that both for freight and passenger transport particularly for long distance modal shift effects are likely to occur. The experience with existing pricing schemes shows that the impacts of charges differentiated to parameters like emission standard and location would result in higher reductions of social costs than with flat charges. Existing congestion charging schemes have proven to be effective in reducing congestion levels and the associated social costs with up to 50% or even more. National studies for the UK and the Netherlands show that nationwide road charging can half the total congestion costs.

Cost benefit analyses from various studies show that in most cases the overall benefits of internalisation by market-based instruments exceed the costs. The main benefits that can be expected are from congestion reduction. Earlier studies showed welfare gains from efficient pricing for all modes of inland transport would amount to over € 30 billion per year[1], for Germany, France and the UK alone (ECMT, 2003).

**Policy recommendations**

It is recommended to start with more stringent legislation for those situations where externalities or the gap between costs and taxes/charges is largest, where travel alternatives exist or can be improved and, consequently, where public acceptability for price changes will be highest. Typical cases are roads in urban and sensitive areas, congestion charging and heavy goods vehicles (HGV) charging.

A more explicit enabling for Member States to charge HGV for external air pollution, noise and accidents costs on top of infrastructure costs would be an important first step towards more efficient pricing. An alternative could be to leave accident costs out and opt for internalisation of accident cost via insurance companies.

In addition enabling much stronger differentiation of charges and taxes is recommended, including differentiation the charges for recovering infrastructure costs for the various vehicle categories as due to their proximity to marginal infrastructure costs would lead to efficiency gains. A further differentiation over the time of day could internalise a part of the external costs of congestion.

Finally, it is recommended to make more explicit that the already allowed regulatory charges by Directive 2006/38/EC include additional urban congestion charges in urban areas and environmental charges in mountainous areas on top of the charges at average infrastructure cost and air pollution, noise and accidents costs.

Internalisation of the external climate change costs of transport should be embedded in an overall climate policy approach. For each transport mode a strategy towards either emission trading or a clearly labelled $CO_2$ tax is recommended.

It is recommended to leave decisions on earmarking to Member States. For public support, the revenues collected for external effects should be decoupled from budgetary constraints. E.g. charge levels should not be increased for budgetary reasons when fleet renewal results in lower revenues from the related charges.

[1] The gain in welfare recorded is a net gain compared to the current situation: it is what remains after subtracting the welfare losses at various points - in particular, the reduction in the consumer surplus currently enjoyed by motorists who are under-charged - from the sum of the various elements of welfare gain, including the increase in revenues, the reduction in travel time in the newly decongested roads, the reduction in the real cost to society represented by pollution and accidents, and so on.

# 1 Introduction

## 1.1 Background of the IMPACT project

The benefits from transport are enormous. It contributes significantly to economic growth and enables a global market. Unfortunately, most forms of transport do not only affect society in a positive way but also give rise to side effects. Ships for example contribute to air pollution, trains and aircraft to noise and road vehicles to congestion. In contrast to the benefits, the costs of these effects of transport are generally not borne by the transport users and hence not taken into account when they make a transport decision. Therefore these effects are generally labelled external effects. Important examples of external effects of transport are noise, air pollution, accidents, congestion and impacts on climate change. The costs associated to these effects are called the external costs.

The internalisation of these effects means making such effects part of the decision making process of transport users. This can be done directly through regulation, i.e. command and control measures, or indirectly through providing better incentives to transport users, namely with market based instruments (e.g. taxes, charges, emission trading). Combinations of these basic types are possible: for example, existing taxes and charges may be differentiated, e.g. to Euro standards.

In some cases existing instruments do not give proper incentives to limit the external effects. Then there may good reasons to change the system of the various transport taxes, through a change in rates, tax base or through the introduction of additional taxes or charges. Because of considerations of fairness and economic efficiency, changes to the pricing system may also include lowering or abolishment of existing taxes or charges, in order to avoid overpricing and to limit the total tax burden of transport users. General fiscal policy considerations which might be completely unrelated to transport policy also need to be taken into account.

Transport pricing is a sensitive subject. There is a lot of public and political resistance to the subject particularly when it comes to the increase of overall tax and charge levels. At the other hand, some examples show that public and political support is gained when a new pricing scheme has proven to be effective (e.g. the London and Stockholm congestion charges).

Some transport users already pay a large variety of taxes and charges. A major aim behind these existing taxes and charges is to cover infrastructure costs or to generate revenues for the general budget. In most cases, internalisation of external costs has not been a major aim when current taxes and charges were introduced. An important question therefore is when and under which conditions existing taxes and charges may be regarded as already internalising external costs.

Internalisation of external costs can be an efficient way to reduce the negative side effects of transport. It may:
- Improve economic and in particular transport efficiency (e.g. efficient use of energy and of scarce infrastructure and rolling stock of all transport modes).
- Guarantee a level playing field between transport modes.
- Improve safety and reduce environmental impacts of the transport sector.

Over the last decade, issues related to external effects and internalisation have been extensively studied under a number of European Framework Program projects (e.g. UNITE, PETS, ExternE, IMPRINT, REVENUE, MC-ICAM, TRENEN, GRACE). The European Commission has raised this issue of internalisation of external costs of transport in several strategy papers, such as the Green Book on fair and efficient pricing (1995), the White Paper on efficient use of infrastructure, the European Transport Policy 2010 (2001) and it's midterm review of 2006.

With the amendment of Directive 1999/62/EC on the charging for infrastructure use of heavy duty vehicles the subject has come to the forefront of attention. Article 1(9) of the Eurovignette Directive 2006/38/EC (amending Article 11 of the old Directive 1999/62/EC) requires the Commission to present a general applicable, transparent and comprehensible model for the assessment of all external costs (including those caused by non-road modes of transport). This model is to serve as a basis for future calculations of infrastructure charges. The model must be accompanied by an impact analysis on the internalisation of external costs for all modes of transport and a strategy for stepwise implementation. Recital (18) of the Eurovignette Directive further specifies the intention of the lawmakers, namely that 'uniform calculation methods', 'based on scientifically recognized data' should further contribute to the application of the 'polluters pays' principle for all transport modes in the future.

## 1.2 Aim and scope of the IMPACT project

In the light of this mandate from the EU legislator, the European Commission has commissioned the IMPACT study in order to summarise the existing scientific and practitioner's knowledge. The central aim of IMPACT is to provide a comprehensive overview of approaches for estimation of external costs, and an analysis of internalisation approaches, including an assessment of the impacts of various approaches.

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

The first Deliverable, the Handbook on external costs (CE Delft, 2008), presents the best practice methodologies and figures for the different external cost components in the transport sector. It covers all environmental, accidents and congestion costs. Infrastructure costs have not been included in this Handbook, as the issues of infrastructure financing are considered to be of a different nature. This Handbook is meant to provide to the Commission input as regards the generally applicable model for the assessment of external costs, as mandated by the Eurovignette Directive.

Nevertheless, the issue of internalisation of external environmental, accidents and congestion costs is strongly related to charging for infrastructure costs. Within the framework of the IMPACT project, the Commission therefore requested also an analysis of infrastructure costs. The results of this work are reported in Deliverable 2 (D2). Contrary to the other work within IMPACT, the scope of this piece of work is limited to road transport. IMPACT D2 presents an overview of road infrastructure costs and all road transport related taxes and charges and provides a preliminary assessment on whether road users are charged for the (variable) costs of road infrastructure.

The report at hand is the third Deliverable of IMPACT. It presents approaches for the internalisation of external costs, the results of the impact assessment which has been carried out for selected scenarios and policy strategies for internalization of external costs in the various modes of transport. It builds on the quantitative results of the other two deliverables. This report includes the following:

- Internalisation approaches: state of the art, including a theoretical framework and an overview of good practices.
- Results of the impact assessment on selected internalisation scenarios[2].
- Recommended internalisation approaches for the various external costs and how this can be reflected in policy and legal strategies.

The impact assessment in this Deliverable has been based on the external cost estimates presented in Deliverable 1. The scope of this study is the European Union (EU-27) plus Norway and Switzerland.

## 1.3 Reader

Chapter 2 gives an overview of the state of the art of internalisation, a theoretical framework, the legal background and an overview of existing taxes and charges. In chapter 3 we discuss various approaches for internalising external costs. This chapter ends with an overview of the scenarios that have been subject to the impact assessment.
Chapter 4 gives an overview of the results of the impact assessment. Based on these results and on the assessments made in the other chapters, we present policy and legal strategies in chapter 5. Finally, chapter 6 lists the main conclusions and recommendations.

[2] The impact assessment has been carried out by the authors of this report for a set of scenarios that was selected by the Commission services. The authors have made use of model runs with TREMOVE (run by LAT Thessaloniki) and TRANS-TOOLS (run by the Joint Research Centre of the European Commission in Seville) obtained through the Commission services.

# 2 Internalisation of external costs: the state of the art

## 2.1 Introduction

Transport gives rise to various types of external effects which pose costs to society. External effects of transport are by definition the consequences not taken into account by those making decisions on transport. The fundamental reason for this is that there is no well functioning market, where the originators of eternal effects can buy the right to do so directly from those affected by the external effects. Therefore the market clearing process does not lead to an efficient outcome, from a societal point of view.

The external effects of pollution, noise and climate change may be labelled inter-sectoral externalities when transport users inflict these to a large extent on others outside of the transport sector. In contrast, the externalities of congestion and accidents are (for accident costs partly) intra-sectoral externalities, imposed by transport users upon one another[3].

The notion of external costs originates in the economics literature with Pigou (1912) who also formulated the first internalisation strategy: namely a regulatory levy on the price of the activity creating the externality set on a level equal to the corresponding marginal external costs. This levy is known as the Pigovian tax. To explain the basic idea in the context of transport, transport users will then take account of the additional external effects of their transport decisions in just the same way as they would do with private costs and hence the transport market can do its proper work in achieving social efficiency. In other words, the proper incentives are given to ensure that the costs of transport do not exceed the benefits to society.

Coase (1960) noted that in the (full) absence of transaction costs, the allocation of property rights would also ensure the efficient internalisation of externalities, irrespective of the initial distribution of the property rights. This means that in such circumstances, it would not matter for social efficiency whether the ‘victims’ pay off the originators of the externality or the latter compensate the first. This ‘Coase theorem’ is a useful reminder that an internalisation strategy does not necessarily consist of a Pigovian tax. However, the Coase reasoning also points to the conditions where a Pigovian tax seems the proper internalisation strategy. Firstly, the source or originator of the externality is known whereas those affected by it are not identifiable (hence the catch phrase ‘costs on society’). Secondly, the transaction costs of providing an initial allocation of property rights on externalities and the subsequent trade in them are relatively high.

[3] We will refer to this distinction in the next section.

As already acknowledged by Pigou, the translation from theoretical Pigovian taxes (often referred to as Marginal Social Cost Pricing, Marginal Social Cost Pricing) to practice is not a simple one, as the nature of the externality renders it difficult to get the information required for imposing the charge at the source of the externality and subsequently for setting the tax at the right level. The informational challenges concern both the identification of how the externality is related with the transport activity (i.e. what is the source of the externality) and what the related (marginal) external costs are.

There are limits to both the level of detail of the estimation of external costs and the way users can take account of differentiated charges. As an example: external congestion cost levels may vary from minute to minute[4], transport users may not fully understand such differentiated charges or not be able to take full account of such varying taxes and charges and even then, technological solutions to charge such rapidly varying taxes and charges are not straightforward either. Still, Marginal Social Cost Pricing is more efficient when the charge structures better reflect the actual marginal costs.

In this chapter we give an overview of the state of the art of internalisation, both from a theoretical and practical point of view. First, we provide an overview of the main aims of internalisation and pricing policies (section 2.2). This includes a discussion of the formulated aims in Directive 2006/38/EC. Next, we give a theoretical framework of the methods for internalisation external costs of transport (section 2.3). In section 2.4 we give a brief overview of legal state of the art with respect to internalisation and pricing policy. A more detailed overview is provided in Annex 0. Section 2.5 gives an overview of existing taxes and charges in various EU Member States for each of the modes. Annex A gives a more detailed overview of these ‘good practices’.

## 2.2 Aims of internalisation and pricing policies

To design pricing policies for internalisation of external costs one should start with a clear picture of the aims they might serve. The purpose of internalisation of external costs is to make sure that the polluter and not the society pays. In other words, where market fails to ensure that the market price reflects the entire costs or benefits of certain activity, internalisation of such external costs/benefits serves to remedy the market. Apart from that policy makers might have additional objectives when they decide to internalise external costs or more in general when they interfere in the market price.

In this section we first discuss the various aims and motives that can be distinguished and then we focus on the aims of internalisation as described in Directive 2006/38/EC.

[4] There are examples in the US, where certain lanes are tolled and others not, with charges levels being adapted according to traffic levels every six minutes. Clearly, drivers can only take account of such varying charges when they have the option of using the tolled lane or the non-tolled lane (US FHA, 2006).

### 2.2.1 Potential aims of internalisation and pricing

The motives for internalisation and/or the introduction of pricing policies can be various. Related to these motives may be specific policy aims. As background to the discussions, we distinguish in this section different motifs and aims of pricing policies for the transport sector (based on Verhoef, 2004).

Three motives for pricing policies can be distinguished (each with various possible policy aims):

- Influencing behaviour, to improve the efficiency of the transport system by:
  - Reducing environmental impacts of traffic.
  - Allowing a freer flow of traffic (i.e. reducing congestion).
- Generating revenues, to:
  - Finance new, extended or modernised infrastructure (which may in turn be related to the aim of improving freer flow of traffic).
  - Cover costs of infrastructure management, operation and maintenance.
  - Finance mitigation measures.
  - Finance the general budget.
- Increasing fairness, to:
  - Make the polluter/user pay (polluter pays principle).
  - Level out the income distribution or avoid overburdening of socially vulnerable groups.
  - Prevent changes in income distribution.
  - Level the playing field between transport modes.

Clearly, when implementing pricing policies, a multitude of effects will occur, contributing to more than one potential aim. Motives and aims of policy interventions will differ between economic sectors, transport modes or types of region, according to the level of externalities, market structures or financial conditions. Financially viable industries with much private capital involvement, such as the electricity or telecommunication markets, will aim at covering total costs and, even more, increase profits. As in these markets external effects practically do not exist the role of the state here concentrates on equity issues. Within transport, the ‘weaker but cleaner’ mass transport modes are not so much subject to pricing discussions as the road mode, with the policy aim of improving the environmental performance of the transport sector in total.

### 2.2.2 Motives and aims in directive 2006/38/EC

Although in theory the various motifs and aims can be distinguished neatly, in practice things are more complicated. As mentioned above, implementation of pricing policies will generally contribute to more than one potential aim. The motifs and aims underlying directive 2006/38/EC also appear to be multiple.

From the first two recitals of the Directive 2006/38/EC, the motives of the lawmakers become clear. At the one hand, the amendment is aimed at eliminating distortions of competition and bolstering competition; at the other hand, it is about encouragement of sustainable transport, which is to influence behaviour, but without undue burdens. A fairer charging scheme is explicitly mentioned as means for the sustainability aim and not an aim in itself. The internalisation is meant to serve all these aims and to render operational the 'user pays' and 'polluter pays' principles. At the same time, the Directive also involves the recovery of infrastructure costs and the generation of funds to provide new infrastructure. By requiring to set the weighted average tolls so as to recover the infrastructure costs (article 7(9) of the amended Directive) the Directive also serves a fiscal goal, trying to decouple investments from fluctuations in public budgets and thus to foster optimal investment decisions.

### 2.2.3 Primary aim of internalisation used in this project

According to welfare theory, the primary motif for internalisation is a more efficient economy by ensuring that private costs equal marginal social costs. This is particularly related to influencing behaviour by providing optimal incentives. In this project providing optimal incentives is taken as the primary aim of internalisation. The other motives may be politically relevant and will be taken into account, but less central.

## 2.3 Theoretical framework

Internalisation of external costs can be done by a wide variety of methods and instruments. The traditional way to internalisation has been regulation through command and control measures. The focus of this report is on internalisation through market-based instruments, and pricing instruments and emissions trading in specific, as such is in line with the primary aim mentioned in section 2.2.3 above. Consumers receive a direct financial incentive to adapt behaviour and at the same time keep the freedom for making their own choices. There are however many different ways of implementing pricing policies, for example with regard to price structures and price levels.

The impact assessment in chapter 4 is limited to market-based instruments. In chapter 3 and chapter 5, market based instruments are also put in perspective to other instruments, in particular regulation.

### 2.3.1 Optimal internalisation methods depend on the aims

The optimal internalisation strategy depends on the underlying aims and motifs behind pricing. If internalisation takes mainly place out of equity considerations, inter-sectoral externalities are especially relevant, because these make up the 'unpaid bill' that the transport sector imposes upon society. Charging for external congestion costs may be of lower priority then. In contrast, if the improvement of economic efficiency is the goal, both intra- and intersectoral externalities should be internalised in all cases[5].

If the main aim of pricing is generating revenues then minimizing transaction costs is particularly important. The most efficient way of revenue raising is often to increase existing taxes or charges, especially those where elasticity is low, but this does usually not give the right incentives to increase efficiency.

As stated before (section 2.2.3) the central aim of the internalisation scenarios to be developed in the current study is influencing behaviour to improve economic efficiency and reduce external effects. This implies that in order to design internalisation strategies, one needs to have a close look at the impacts on welfare. These impacts are discussed in the next sections.

### 2.3.2 Marginal Social Cost Pricing

In theory, Pigovian taxes are an appropriate way to overcome externalities and so to achieve economic efficiency (welfare). This is often related with the principle of Marginal Social Cost Pricing. *Margina*l costs in this context means the *additional* costs of an additional transport activity (e.g. an extra kilometre driven).

Under the REVENUE research program, 'pure Marginal Social Cost Pricing' has been defined as a situation where prices in transport are set equal to the marginal costs[6], consisting of:
- The marginal producer costs (e.g. reconstruction, wear & tear, maintenance costs).
- The marginal user costs (congestion, scarcity costs).
- The marginal external costs (environmental costs, external accident costs, external congestion costs).

Marginal Social Cost Pricing would, under some conditions, lead to an optimal allocation, i.e. efficiency in a static perspective. As further discussed below, these conditions are not fully met in reality, which means that instead of achieving an 'optimum', the introduction of Marginal Social Cost Pricing would result in a suboptimal situation, though in most cases still bringing an improvement in efficiency.

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5 See Lakshmanan (2001).

6 In REVENUE the term 'price relevant cost' is used.

### 2.3.3 Deviations from Marginal Social Cost Pricing

The theoretical 'first best' solution, regulatory Pigovian charges based on marginal external cost levels, may not be appropriate or feasible when first-best conditions are not achievable or not known, or when a multitude of motifs and aims are at stake, and thus prices need to be set conditional to constraints of imperfections. Hence, deviations from Marginal Social Cost Pricing may be needed.

As listed in section 2.1, there may be many reasons for deviating from Marginal Social Cost Pricing. We elaborate here on three of the most important reasons:

1 *Limited scope of a pricing scheme* - First-best pricing is not applied throughout the whole network considered or for all competing modes[7].
2 *System requirements & costs* - Pure Marginal Social Cost Pricing requires a technological system which may be too complex or expensive to implement. This is related to transaction and administrative costs.
3 *Insufficient revenues* - Revenues from pure Marginal Social Cost Pricing may be insufficient to cover total infrastructure costs.

Below we elaborate on these main reasons to deviate from Marginal Social Cost Pricing.

**Limited scope of a pricing scheme**

As said above, Pigovian taxes are optimal under certain theoretical assumptions that may not always be fully satisfied in practice. For example, their optimality is based on the assumption that Marginal Social Cost Pricing is applied throughout the whole network considered, the whole transport sector and even throughout the economy. In addition, it is based on the assumption that governments use lump sum taxes to pursue any redistribution targets they may wish to meet. See also MC-ICAM (2001) and Lindsey and Verhoef (2001).

Internalisation measures often have a limited scope, with some exceptions. In most cases they are limited to a single mode of transport or even only a part of a network. This may give rise to boundary effects, in particular a shift from the priced modes or parts of the network to the other parts or modes. From a welfare point of view this could lead to much less positive welfare effects.

The shift away from priced modes or parts of infrastructure will only be significant in cases where there is true competition. An example is the German kilometre charge for heavy duty vehicles on motorways only. After the introduction there was an increased use by heavy duty vehicles of regional roads. However, after a few months this temporarily shift did not hold and now just three sections of the federal road network are included in the charging system to prevent from traffic shifts (Deutscher Bundestag, 2005). Apparently, in this case the secondary network or the single carriageway roads are not a valid alternative for the motorways.

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7 This is called the 'Lancaster-Lipsey theory of second best': in case of existing distortions in related markets, deviations from 'first best' solutions may achieve more welfare gains.

To avoid undesired side effects caused by the limited scope of a system, the scope needs to be chosen in such a way that there is only limited competition between the priced and the non-priced parts. The first-best choice, however, is to extend the scope of the pricing system as far as possible. In the impact assessment, scenarios have been selected with internalisation measures in all transport modes.

**System requirements & costs**

In addition, exact Marginal Social Cost Pricing may not be practical because a tax or charge varying by all relevant cost drivers, including time, place and all relevant vehicle characteristics may be impossible, or at least, very expensive to implement. The theoretical proof of the optimality of Marginal Social Cost Pricing abstracts from such implementation and transaction costs, including the costs for setting up and running the charging system and the costs of users to get fully informed.

Pure Marginal Social Cost Pricing requires a system that can differentiate price levels according to all cost drivers for the various external costs, e.g. the actual congestion level, the actual vehicle emissions factors for pollutants and noise, the actual fuel consumption and maybe even the actual blood alcohol level of the driver. Such an ideal system would be too complicated from a technological point of view and the price incentives would be far too complicated for users to comprehend and to respond to. It should also be noted, however, that technological progress (such as the Global Positiong System, GPS) allows for imposing charges which were not deemed feasible a decade ago.

Therefore, any feasible pricing system will use a limited number of easy measurable parameters as a proxy for the actual cost drivers. Examples of such proxies are the Euro standard as a proxy for the actual emission factor or the distinction between peak and off peak hours as a proxy for the actual congestion level. As long as the proxies are well chosen and close enough related to the cost drivers, these types of deviations from a pure Marginal Social Cost Pricing will not give rise to large negative impacts on the potential welfare gains. The same holds for implementation and transaction costs. As long as these costs are relatively small compared to the price incentives, their impacts on welfare will be limited.

We conclude that welfare gains require internalisation measures that are:

- Built on good proxies for cost drivers, in other words close to the source of the externality.
- Not too complex so as to limit implementation and transaction costs.

**Insufficient revenues**

Finally, in Marginal Social Cost Pricing, no consideration is given to the financial implications of the pricing scheme in terms of surpluses or deficits for each mode. This implies that there is no guarantee that the total revenues from Marginal Social Cost Pricing are sufficient to cover all infrastructure costs. This issue is related to the various options for charging for infrastructure costs, which is discussed in the next section. Note that for road transport, the revenues of Marginal Social Cost Pricing exceed the average infrastructure costs, while for rail transport this is will be the other way around (see also UNITE, 2003 and GRACE, 2007).

**Conclusions on deviations from Marginal Social Cost Pricing**
The limitations of Marginal Social Cost Pricing make clear that the orientation of price structures to marginal cost characteristics is the most important, rather than meeting the exact level of marginal costs. Also the provision of sufficient and understandable information to the users and the consistent application of Marginal Social Cost Pricing at least across all transport modes are key constraints in the implementation of Marginal Social Cost Pricing.

### 2.3.4 Internalisation strategies and charging infrastructure costs

This report is about internalisation of external environmental, congestion and accident costs. It is not its primary aim to discuss and recommend an efficient way of charging for infrastructure costs. The two issues are strongly related though. Therefore in this section, we discuss options for efficient ways of charging infrastructure costs and the relation with internalisation approaches.

Improving transport efficiency and covering infrastructure costs are two different aims and their optimal pricing schemes are different as well. Still, in most cases there is a need to combine both aims. Pricing measures that are aimed at infrastructure cost recovery will also have an impact on the optimal design of measures for improving efficiency. Therefore, there is a wish for an integrated pricing strategy that meets both cost recovery and improving transport efficiency.

**Marginal Social Cost Pricing and marginal infrastructure costs**
From the perspective of Marginal Social Cost Pricing, it is important to distinguish fixed and variable infrastructure costs. Variable means changing with the amount of traffic (not the size of the network). Only the variable costs of infrastructure use lead to marginal infrastructure costs. Marginal infrastructure costs can be estimated as the variable part of total infrastructure costs (see also IMPACT D2). The variable costs are a share of the maintenance, operation and management costs, but not of the costs related to building new or enlarging existing infrastructure capacity. The fixed part of the maintenance, operation and management costs relate to costs that do not depend on the usage of the infrastructure but for example on erosion of surfaces caused by climate influences and maintenance of signalling systems. However, in the long run parts of these get variable as the usage of infrastructures impact the duration of reinvestment cycles.

From economic welfare theory it is most efficient to charge infrastructure by the marginal damage and reinvestment costs caused by its users (vehicles, trains, aircraft or vessels). The main cost drivers of road, rail and aviation infrastructure cost are kilometres driven or the number of movements and the respective vehicle, train or aircraft weight. For railways train speeds constitute an important additional driver for investment and maintenance costs. For road the axle weight is important, which depends on both vehicle weight and number of axles. Therefore, the optimal charges for marginal infrastructure cost are charges per kilometre differentiated to vehicle weight for airports, by weight and number of axles on roads and by weight and speeds on rail tracks. Since the cost of a road or rail stretch also depends on the characteristics and location of that very part of the network, also these should be taken into account. This means that marginal cost based charges for an expensive mountain road will be much higher than for a regular road.

**Infrastructure cost recovery**
For infrastructure cost recovery, there may be a need to charge a mark-up on the marginal infrastructure costs. Covering full infrastructure costs may particularly be important when revenues are needed for new infrastructure investment. For this reason, some economists claim that infrastructure cost charging should not be based on marginal infrastructure costs but rather on average costs.

Rothengatter (2003) remarks that Marginal Social Cost Pricing is typically orientated to optimize the use of an existing facility of which the fixed costs are sunk[8] costs. Infrastructure providers may not be able to recover the investments in new infrastructure and thus have no incentive for such investments. When pricing is based on full cost recovery, charge levels are different from marginal social cost levels. This primarily holds for infrastructure and not so much for the here relevant external costs.

In a Marginal Social Cost Pricing based scheme, total revenues, including those from charges for internalization of environmental, accidents and congestion costs may or may not be sufficient to cover the total infrastructure costs. There are studies (e.g. Roy, 2000) which show that revenues of social marginal cost pricing for road and rail together might lead to sufficient revenues for the maintenance costs if congestion is priced. In this study the revenues exceed the financial costs in urban areas but are below financial costs in rural areas.

In general, whether or not marginal cost based pricing suffices, may be mode dependent. In that case, one might want to use the revenues of external cost pricing of one mode to cover the fixed infrastructure costs of other modes. This could be done by introducing intermodal funds. However, it should be noted that intermodal and interregional distribution of revenues may lead to strong political resistance and thus make such a scheme impossible or at best cause high implementation and transaction costs.

8 Sunk costs are unrecoverable past expenditures.

Another option for recovering the total infrastructure maintenance costs and even also the infrastructure investment costs, is to adjust marginal costs within one transport mode, or on a well defined transport network segment (as foreseen in the Eurovignette Directive). This can be done in various ways:

- Mark-ups. These can be added to the marginal costs levels in order to achieve cost coverage. One particular form of a mark-up is Ramsey pricing, which requires that charges are increased and that the increase is inversely proportional to the price elasticity of demand. It maximizes social welfare subject to budget constraints. Under such a scheme, the mark-ups above marginal social costs may differ between transport services (e.g. peak versus off peak, passengers versus freight) because price elasticities may differ.
- Multipart tariffs. These consist of fixed, blockwise[9] variable and variable parts. They can be flexibly adjusted to the costs and demand characteristics and can be superior to linear tariffs.
- Fully distributed cost schemes. These take short run marginal costs as a starting point and allocate the remaining costs according to selected parameters. It can involve high differentiation and additional incentive elements.

Apart from these so called second-best solutions, two more pricing policies can be distinguished. These are average cost pricing and monopoly pricing. In contrast to second-best pricing, which aims to achieve efficiency under second-best solutions, average cost pricing and monopoly pricing are basically target orientated pricing policies. These policies have as target cost recovery (average cost pricing) or profit maximization (monopoly pricing), hence *not* internalisation of external effects and in general (social) efficiency of transport. As formulated in REVENUE, 2006 (page 50):

> *'The constraints in the case of second-best pricing and the objective of the target oriented pricing approach may try to achieve the same issue.*
> *The remaining difference is that second best pricing approaches intend to meet the constraint in a most efficient or optimal way which is not the explicit goal of target oriented pricing approaches[10]'.*

So, whereas Ramsey pricing and multipart tariffs may be apt to secure efficient financing, this does not hold for average cost pricing or monopoly pricing.

The issue of use of revenues and how to take account of existing taxes and charges will be discussed later in section 2.3.8.

**Infrastructure charging in the Eurovignette Directive**

According to the existing Eurovignette Directive for road freight transport infrastructure costs (both fixed such as construction and variable such as maintenance and operation) can be recovered through user charges, tolls or

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9 An example of block wise variable costs are the use of electricity supply in railways, that diesel train operators do not use and thus do not pay for.

10 It is interesting to note the relationship with the 'user pays' principle. This principle can be interpreted in different ways. The most straightforward interpretation is that each user fully pays for the cost that he imposes. Alternatively, it can be interpreted as that all users together should pay for the costs they collectively impose (see also MC-ICAM, deliverable 2). The first interpretation is closer to marginal cost pricing.

vehicle taxes. (see also section 2.4). This seems more in line with the principle of cost recovery than marginal cost pricing (though there are ways for combining the two, see above).
In order to compare total infrastructure costs and related charges, usually average infrastructure costs are computed. Most common is the separation of (financially relevant) infrastructure costs and taxes and charges and comparison of total infrastructure costs (e.g. wear and tear, capital costs) and total taxes and charges within an infrastructure cost account. In most Member States existing transport taxes and charges contribute to infrastructure costs, but the cost coverage shares vary widely. In some countries, total revenues from transport taxes and charges exceed total infrastructure costs; in other countries the contribution is well below 20% (see IMPACT D2).

If internalisation of external costs would be enabled by an amendment to this Directive, also charging for environmental, accidents and congestion costs could be possible. A key question is whether this should be on top of the charges for total infrastructure costs or that the charges for the fixed infrastructure costs should be regarded as already internalising some of the external environmental, accident or congestion costs, in order to avoid overpricing. In section 5.3.3 we discuss this issue on how to avoid overpricing in this specific case of the Eurovignette Directive.

As stated before, this project is not about the optimal way to charge for infrastructure costs, but rather at internalisation of external environmental, congestion and accident costs. Therefore we do not attempt to conclude here on the optimal way of charging the fixed infrastructure costs.

### 2.3.5 Differentiation of existing taxes or charges

If the aim of internalisation is influencing behaviour in order to reduce external costs, there is an alternative for the introduction of mark-ups or new taxes or charges based on external cost levels. This alternative is differentiation of existing taxes or charges, giving incentives on a revenue neutral basis.

In the air transport sector such differentiation has been introduced at several airports. Existing infrastructure charges are differentiated with respect to the noise emissions of aircraft. The idea is that aircraft operators are thus motivated to operate less noisy aircraft. This can either reduce the noise exposure of the population or free up capacity for other aircraft. Because the overall charge levels are not increased, the demand for transport may not go down.

Such a revenue neutral differentiation cannot generally be seen as internalizing external costs without hurting the efficiency of infrastructure use. Although, given the correct level of differentiation, the externalities will be taken into account, the change in charges may lead to inadequate incentives for an efficient infrastructure use. Consider the important example of tolls that account for the variable costs of road infrastructure. If these tolls are differentiated by increasing them at peak times and reducing them during off peak hours, users may have paid according to their marginal (external) costs of congestion, but rather likely this has been done at the expense of the remaining charge being no longer conform the marginal costs of infrastructure use[11].

In the specific situation where the existing tax or charge was introduced to cover fixed costs (e.g. fixed infrastructure costs), differentiation may be an improvement from the perspective of economic efficiency. The total costs will still be financed, and users of infrastructure receive incentives to adapt their behaviour to account for e.g. congestion or emissions of pollutants.

A practical advantage of differentiating existing taxes or charges which were introduced to cover fixed infrastructure costs is that there will be no need to discuss the use of revenues (see section 2.3.8). There are however some other practical aspects that need to be taken account of. First of all, because differentiation gives incentives for changing behaviour, periodic adjustment may be required to ensure the financing requirements. This is similar to any charge and should not be a problem.

Second, there is the question to what extent public bodies can make private concessionaries differentiate their tariffs. Some current concessions allow for differentiations but do not require them. In particular when different concessionaries compete with each other, such as some ports and airports may do, there may be resistance to differentiating existing taxes or charges.

### 2.3.6 Emission trading

Emission trading for transport is relevant as a means for limit the greenhouse gas emissions from transport, particularly $CO_2$. Although emission trading effects the prices transport users pay, it is not a pure pricing instrument, because it does not set transport price levels. However, in the case of a cap & trade system and when the allowances are auctioned, emission trading may be regarded as an internalisation measure.

There are various options for a trading scheme for climate emissions from transport. The main design options have been discussed in CE, 2006b:
- Geographical scope (national, EU, global).
- Sector scope (subsector like passenger cars, transport mode or a combination of some or even all transport modes).
- Trading entity (the party that is required to hand in emission allowances, e.g. vehicle drivers, filling stations or oil refineries.
- Emission control, i.e. either a cap & trade or baseline & credit scheme (see explanation below).
- Closed scheme (no linkage to the EU ETS) open schemes (inclusion in the EU ETS) or a semi open scheme (linkage to the EU ETS).
- Use of Kyoto project mechanisms.
- Allocation of allowances (grandfathering or auctioning).

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[11] Nonetheless, allowing for such differentiations is likely to increase welfare (abstracting from implementation/ transaction costs), because it relaxes one restriction on the charge levels.

**Cap & Trade versus Baseline & Credit**
The main feature of a *Cap & Trade* (C&T) emission trading scheme is that a fixed ceiling (cap) is set to a certain type of emission ($CO_2$, $NO_x$) in combination with tradable emission rights. The permits are initially allocated in some way (grandfathering or auctioning), typically among existing sources. Each source covered by the program must hold permits to cover its emissions, with sources free to buy and sell permits from each other. The current EU Greenhouse Gas Emission Trading Scheme (EU ETS) is an example of a C&T scheme. During the first trading period from 2005 to 2007, the ETS covers only $CO_2$ emissions from large emitters in the power and heat generation industry and in selected energy intensive industrial sectors.

*Baseline & Credit* (B&C) schemes have a different angle, providing tradable credits to facilities that reduce emissions more than required by some pre-existing regulation (baseline) and allow those credits to be counted towards compliance by other facilities that would face high costs or other difficulties in meeting the regulatory requirements. In this type of scheme no absolute $CO_2$ emissions can be capped, but only the relative emissions, such as for example the $CO_2$ emissions per vehicle kilometre. An example of a B&C system is the recent Californian proposal that is aimed at car manufacturers. In the Californian system, car manufacturers have to achieve a reduction of average $CO_2$ emissions of new cars over the coming years. Manufacturers that achieve lower average emissions than the norm can sell credits to manufacturers that do not achieve the norm.

Source: CE Delft, 2006b.

### 2.3.7 Policy packaging

It may be more effective to combine different policies in a policy package than to introduce pricing instruments in isolation. As formulated in MC-ICAM, 2004 (Deliverable 2, p48-49): ‘It was found in the AFFORD project that packages designed to match policy instruments to externalities sometimes performed much better than analysis of the effects of the isolated instruments suggested, and even approach first-best efficiency gains[12]’. Optimal policy packages are likely to combine or supplement marginal cost based usage charges such as vehicle taxes, standards, or other regulations. For example, if a $CO_2$ fuel charge provides insufficient incentive to develop and buy fuel efficient vehicles, then a differentiated vehicle tax related to $CO_2$ emissions might be adopted too[13]. While countries currently rely heavily on fuel taxes, several factors limit how much they should, and indeed can, be used either to raise revenue or as Pigovian tax instruments. For this reason, fuel taxes need to be used in combination with other instruments, including (of course) road pricing as well as differentiated vehicle taxes’.

In the final report it was formulated as follows (MC-ICAM, 2004; final report, p20). ‘Second best policies[14] almost by definition require policy packaging. The failure to achieve the ideal result with one policy instrument forces us to look at ways of

[12] These are the gains of Marginal Social Cost Pricing assuming that all conditions are met.
[13] Indeed there is evidence that fuel charges do not provide sufficient incentives. In general, when purchasing a car, consumers only take account of the first three years of potential fuel savings of a fuel efficient vehicle (NRC, 2002; Annema, 2001). Hence, there is reason not to internalise only by marginal cost pricing, but to design more complete policy packages.
[14] Second best means here optimal pricing from a welfare point of view, under real world conditions.

improving the situation by the use of other policy instruments'. This includes the use of other pricing and non-pricing measures.

The choice between transport instruments, or packages of instruments, depends not only on their relative efficiency but also on their equity impacts, since in general the overall objective of society concerns not only a maximization of total efficiency, but also to achieve an equitable distribution of welfare. Moreover, any major transport policy reform will be acceptable only if it is welfare increasing or welfare neutral for a sufficiently large majority of the voters. A necessary condition for voters to accept the reform is that their utility is not reduced (SPECTRUM, 2003).

Verhoef (2002, p. 13) also notes that 'the possible weaknesses that can arise from second-best taxes when applied in isolation can often be reduced when constructing a policy package of second-best measures, that is designed to cover the most important externalities and dimensions of behaviour relevant for the particular case considered. What is of importance here, of course, would be that the various charge levels employed for the individual instruments in the package are carefully chosen, simultaneously, so as to maximize the package's eventual efficiency'.

Some non-pricing measures have proven to be very effective in the past. However, also when applying these non-pricing measures it makes sense to internalise the remaining external costs.

### 2.3.8 Use of revenues and earmarking

The introduction of mark-ups or new taxes or charges to internalise external costs, leads to revenues. The use of the revenues is an integral part of the internalisation policy, but it is well understood that the aim of internalisation in this particular context is not revenue raising but holding users to account for the externalities they create. Under the Pigovian tax framework the revenues are not supposed to go to those affected by the externality as such would lower their incentive to avoid the externality below efficient level. For the same reason it should not be used to directly reimburse those responsible for the externality.

Mayeres and Proost (2001) have given an extreme example that it is possible to increase societal welfare by using the revenues of a congestion charge for financing new road infrastructure or reducing income taxes, but that by applying the revenues for public transport subsidies, welfare might go down[15]. In general this might not be the case.

From a fairness point of view, the revenue from congestion charges could be used to finance new infrastructure. In CE Delft (2002) a road pricing system was developed in which investments in new road infrastructure aimed at relieving

[15] The impact of the use of revenues on economic welfare is case specific, so this example may not be generalised. The availability of public transport generally offers mobility alternatives and helps giving a greater elasticity to the demand curve, thus making pricing policies more effective.

congestion are governed by the willingness to pay of users. The investment rule developed prescribes that the time to expand road capacity at a particular location is when the revenues from an optimised congestion charge levied on the new, additional capacity are precisely sufficient to fund the capital costs of that capacity. In general also environmental impacts and network effects should be considered in this type of decisions.

More generally, in the REVENUE project extensive research has been carried out into the issue of how to use the revenues from transport pricing. REVENUE (p. 38) concludes that ‘the arguments in favour or against earmarking are more or less balanced’. This conclusion was reached after studying the relation of earmarking with efficiency, equity and acceptability objectives (REVENUE, 2006; Deliverable 6, p. 37-38). Below the considerations are repeated.

**Efficiency**
As there is no guarantee that transport projects will be the most efficient proposals, standard theory informs us that earmarking (sometimes also referred to as ‘hypothecation’) of funds to transport budgets may result in a loss of efficiency, in that it may require that a set of projects be undertaken which does not maximize social welfare. However, this simple theory takes no account of institutional arrangements and social acceptance. Governments at the lower levels may take no account of the effects of their decisions on the rest of the system outside their area. For instance, governments may select projects that favour local rather than transit traffic. To the extent that detailed investment decisions are sensibly left to national or regional government earmarking funds to be invested in the Trans European Network may offset this inefficiency.

**Equity**
Equity considerations giving individuals with lower incomes higher weights when balancing utilities will lead to deviations from Marginal Social Cost Pricing which reduce efficiency but improve equity. There is no reason to suppose in general that earmarking will improve equity in this sense, although there may be specific cases where it would. Equity arguments for earmarking more often take the form of saying that those who pay should get corresponding benefits for their money. This would only be fair in general if the existing distribution of income were fair. Even so, it would not be the most efficient way of using the revenue, which would be to undertake the most beneficial set of projects across all sectors subject to the requirement that the existing distribution of income was not changed.

**Acceptability**
The prospect of a pricing reform being implemented will be enhanced if it enjoys public acceptability. It may be thought that this is most likely if a majority of the population benefits from it. If surplus revenue is used to minimize the number of individuals that will experience a reduction in utility from the transport pricing reform, the acceptability of that reform will increase. Earmarking of surplus revenues to the transport budget is one method for ameliorating the harmful impacts of pricing reform that raises prices for certain users.

As remarked above, in the end arguments for or against earmarking were judged to be more or less balanced.

**Some practical guidelines for the use of revenues**

Deciding on the use of revenues for the various cost items, the following considerations could be taken into account:

- Applying revenues from congestion charges for providing alternatives, e.g. investment within the modes or for intermodal funds, helps in gaining public support.
- Using taxes and charges related to other external effects for investments to reduce these external effects is both fair an efficient. Examples are noise screens and insulation, research into new technologies and rewarding the best in class[16].
- Other options for using revenues are redistribution per capita or allocation to the general budget. Lowering of labour taxes comes out as most efficient according to many studies and models. Allocation to the general budget, in contrast, is sometimes worst in respect of welfare gains.

## 2.4 Legal background

In this section, a brief overview is provided of the legal background for internalisation in the various modes. It focuses on prevailing EU directives, but attention is also given to current proposals from the European Commission, and to other current international arrangements that may either enable or restrict internalisation of external effects. Specific national laws are not addressed. A more detailed overview of legal background is provided in Annex 0.

The purpose of this overview is to provide a general background on the legal possibilities for internalisation. This current state of affairs serves as a point of departure for the internalisation scenarios to be developed in this project. However, it is not the intention that all internalisation scenarios put forward adhere to current legislation. Some adaptations may be proposed.

Directive 2003/96/EC requires Member States to respect minimum tax levels for energy products, including motor fuels. However, there are a few important exemptions. Regarding aviation, fuel is to be exempted from the minimum tax levels as set in the Directive, except when it is used for private pleasure flying. Similarly, fuel for navigation is to be exempted, except when it is used for private pleasure craft. Member States may limit these exemptions to international and intra-Community transport. In addition, in case of bilateral agreements, exemptions may also be waved. In such cases, a level of taxation below the minimum level set out in the Directive may be applied.
Energy products and electricity used for the carriage of goods and passengers by rail, metro, tram and trolley bus may also be exempted. Also, energy products used as fuel for inland navigation may be exempted. Finally, the Directive makes

[16] There is some recent scientific literature on greening taxes and use of revenues that addresses this issue. Some model results indicate that from an economic efficiency perspective, rewarding the best companies may be superior to lowering labor taxes.

it also possible for Member States to grant tax reductions/exemptions in favour of bio fuels, under certain conditions.

The rail directive 2001/14/EC allows for rail infrastructure charges to be differentiated with respect to environmental characteristics. Mark-ups that lead to additional revenues are however not allowed in the absence of comparable charges for competing modes. If this is the case, it is up to Member States to decide on how to use the revenues. In case mark-ups are permitted they may, due to the high fixed costs associated with the provision of rail networks, be 10 to 20 times higher than the marginal infrastructure costs, which makes the remaining welfare effect questionable. Further, the directive constitutes of a long list of exception rules allowing for a broad range of pricing systems.

Directive 2006/38/EC (the 'Eurovignette Directive') allows for tolls and user charges for road vehicles over 3.5 tonnes to recover infrastructure costs only. The weighted average toll should be related to the construction costs, and the costs of operating, maintaining and developing the infrastructure network. These costs may include expenditures related to the infrastructure designed to reduce noise nuisance, congestion, accidents or related to particular environmental elements. Mark-ups up to 25% (15%) above infrastructure costs are allowed for regions with acute congestion or environmental problems, under the condition that these are invested in cross-border (domestic) priority TEN projects. Member States are free to determine the use to be made of the revenue of the general charge, though they are recommended to be used benefiting the transport sector. Differentiations of charge levels are allowed (according to Euro classes, time of day and type of day or season) in charge levels of 100%, i.e. that the cheapest charge should be at least 50% of the highest charge[17]. In addition, from 2010 on Member States are required to differentiate tolls to Euro standards. The Directive explicitly does not restrict Member States to introduce regulatory charges to combat time and place related traffic congestion or to combat environmental impacts, including poor air quality. The Directive includes minimum levels for annual vehicle taxes.

The nature of the two directives diverge; while 2006/38/EC follows the objective of total cost recovery, its pendant in the railway sector (2001/14/EC) starts from the idea of Marginal Social Cost Pricing. In addition charging infrastructure costs for road is enabled by 2006/38/EC, while for rail charges are compulsory according to 2001/14/EC. The theoretical requirement of equal pricing of all modes is thus not fully assured in the core directives.

In addition, there are Directives that provide standards for emissions of pollutants applicable to road vehicles, vessels, aircraft and locomotives.

[17] Where the cheapest period is zero-rated, the penalty for the most expensive time of day, type of day or season is no more than 50% of the level of toll that would otherwise be applicable to the vehicle in question.

Finally, Directive 2004/52/EC provides a framework for the interoperability of toll collection systems within the EU. The Directive sets a target date of July 2006 for an agreement on the definition of the European Electronic Toll Service (EETS). Early 2007 the European Commission released the key information on the definition of this EETS. It is expected to enter into service in 2009 for HGV and 2011 for other vehicles (Ertico, 2007).

Next to these Directives, there are several proposals for Directives that are of relevance. First of all, there is a proposal relating to passenger car related taxes (COM(2005) 261). According to the proposal, by 2008 at least 25% of the total revenue from annual circulation taxes and registration taxes shall come from a carbon dioxide based element in the tax structure. This share should be 50% for 2012. By 2016, it is proposed, all registration taxes should be abolished.
Second, there is a proposal for the inclusion of aviation in the EU emissions trading scheme. Starting from 2011 airlines would have to purchase allowances for all $CO_2$ emissions of aircraft above the historic emission levels of 2004-2006.

Third, there is also a proposal concerning special tax arrangements for commercial gas oil, aiming at narrowing excessive differences in tax levels between Member States, in order to reduce distortions of competition and environmental damage in the transport haulage by reducing 'fuel tourism' (COM (2007) 52).

For aviation, maritime and inland shipping, there exist various international treaties that limit the possibilities for charging these modes, including the introduction of fairway dues and fuel taxes. The most important are the Chicago Convention on international aviation and the Mannheim and Danube conventions for inland shipping.

## 2.5 Existing taxes and charges in EU Member States

In the current situation, transport users pay various taxes and charges. This raises the question to what extent external costs may be regarded as being internalised by the already price instruments. In this section we give an overview of the main taxes and charges that are present in the various Member States. We also include various examples of attempts Member States make to internalise external costs by implementing new or adjusting existing taxes or charges. A more detailed description of these 'good practices' is given in the fact sheets of Annex A, one for each good practice. These fact sheets address the issue of costs and effects of particular policy measures. Annex D lists the main differentiations of existing taxes and charges to environmental parameters.

Non-pricing measures that may also be said to reduce (partly) external costs such as traffic management systems to limit congestion, safety measures to reduce the number of accidents, environmental prescriptions (e.g. Euro standards) and existing environmental charges that apply more general such as energy taxes are not included in this overview. The reason is that the focus of the study is on pricing measures for the transport sector.

In section 3.2.4 we come to the subject of how to assess the existing taxes and charges in the light of internalisation policy. There we will also address the question to what extent external costs may be regarded as being internalised by the already existing taxes and charges. In the analysis of the baseline scenario (section 3.4), we compare for road transport existing tax and charge levels with infrastructure and external costs for various situations.

Existing taxes and charges have been implemented for various reasons. The main reasons behind most taxes and charges are generating revenues for the government for either filling the general budget or to cover specific expenses related to transport, in particular of building or maintaining infrastructure. Some pricing instruments also have other aims. Circulation taxes are often differentiated to parameters like fuel type and/or vehicle weight in order to influence the fleet mix. Also social considerations play a role in the design of taxes and charges.

So far, very few measures have been introduced directly aimed at internalisation. The most important exception is the Swiss toll for heavy goods vehicles (HGV), which was aimed at internalisation of external costs. Many other pricing measures, however, have been introduced or modified to reach specific aims related to external effects of transport. Examples are charges that have been differentiated to environmental parameters (like circulation taxes differentiated to Euro standard, tax exceptions for hybrid cars, LTO charges differentiated to night and day time or to aircraft noise emission level). Also the congestion charges in London and Stockholm are rather aimed at the reduction of external effects (congestion) than that they are part of an explicit *internalisation* strategy. Though not directly aimed at internalisation, these types of measures may result in prices that are closer to internalisation of external costs than flat taxes or charges.

**Swiss HGV toll**

Since 2001 a distance-, weight- and emission based *heavy goods vehicles toll* (HGV toll) is applicable on the entire Swiss road network. The aim of the scheme is to internalize the external costs of road transport, limit the growth of heavy goods vehicles traffic, and finance new railway infrastructure. Simultaneously to the introduction of the HGV toll, the weight limit of vehicles was increased.

Due to these measures, vehicle kilometres decreased by 23%, while the transport volume by road (in ton kilometres) remained the same (both compared to the business as usual scenario). The number of tonne kilometres by rail in 2005 was about 8% higher than the business as usual scenario. Together this resulted in a small increase in the overall transport volume. So, the advantage for the road sector caused by the higher weight limit was counterbalanced by the kilometre charge. Overall the effect of the charge was thus a considerable modal shift.

The other main effect of the scheme was its incentive for fully exploiting the logistic potential to optimise utilisation of the vehicle fleet and especially avoiding empty runs. Also the replacement of old vehicles was accelerated. As a consequence, emissions decreased by 6 to 14% in the four years after the introduction, compared to the business as usual scenario.

Source: ARE, 2007.

An overview of the main taxes and charges for the various modes are listed in Table 1.

Table 1 Overview of existing taxes and charges

| Mode | Existing taxes and charges |
|---|---|
| *Road-HGV* | Infrastructure charge:<br>– User charge (fixed).<br>– Toll on specific parts of the network (e.g. bridges and tunnels).<br>– Toll on motorways.<br>– Toll on all roads. |
| | Fuel excise duty |
| | Circulation tax |
| | Congestion charge |
| | Insurance tax |
| | VAT |
| *Road-cars* | Fuel excise duty |
| | Circulation tax |
| | Vehicle purchase tax |
| | Toll |
| | Parking fees |
| | Congestion charge |
| | Insurance tax |
| | VAT |
| *Rail* | Infrastructure charge |
| | Diesel excise duty |
| | Electricity tax |
| | VAT |
| *Water* | Harbour due |
| | Dues for locks and bridges |
| | Fuel excise duty (in a few specific cases) |
| *Aviation* | LTO charge (often differentiated wrt noise emissions) |
| | En-route charge (for air traffic control services) |
| | Noise surcharge (in several Member States) |
| | Emission charge (at a few specific airports) |
| | Fuel excise duty (in a few specific cases) |
| | VAT (domestic flights) |

Note: The nature of the various taxes and charges is very different. VAT is not a transport specific tax, but a general consumption tax. It has been included here to give a complete picture of the differences between the various modes.

### 2.5.1 Road transport

For road transport, fuel taxes are the most important taxes in Europe. They are present in all countries and their level is a relative large share of the total taxes and charges road users pay (about 70%, see section 3.4.3). In some countries, road users pay also tolls for using the infrastructure. This may be limited to very specific parts of infrastructure (like bridges and tunnels), in or extend to most motorways. Also the vehicles that are subject to toll differ. Sometimes all road users need to pay the toll (e.g. motorways in France and Italy) while in other cases only HGV are charged (e.g. the German, Swiss and Austrian HGV tolling systems).

On several tolled motorways in France, toll levels are differentiated in order to spread returning holiday traffic more evenly over the day. Tariffs in peak hours are increased, whereas in shoulder hours a reduction applies. Experiences from the US indicate that such differentiation may reduce congestion considerably, also when targeting commuter traffic. There, a differentiation of 50% in bridge toll levels diverted 20% of the traffic from peak to shoulder periods.

**German HGV Toll**
Heavy goods vehicles are subject to a compulsory toll (*Maut)* on German motorways since 2005. Similar to the Swiss scheme, the charge level is based on the distance travelled, the emission class and the number of axles of the vehicle. The aims of the scheme are to finance infrastructure expenditures, to charge the real costs, to promote efficient use of HGV's and innovative techniques, and to stimulate a shift of road freight transport to other modes. There is not yet much information available on the impacts of the charge. One effects is that the number of containers carried by rail increased by about 7%.

Source: Schulz, 2006.

In addition to these usage dependent charges, road transport users pay also annual circulation tax and/or vehicle purchase tax. The level of the latter differs significantly over Europe: in many countries such a tax is absent while in countries like the Netherlands, Greece and in particular Denmark the vehicle purchase tax is a large share in the costs of passenger cars.

Many countries apply differentiations in registration or circulation taxes for passenger vehicles, to give incentives for purchasing fuel efficient cars. In some countries the differentiation is very rough, whereas other countries have a more sophisticated differentiation. In the Netherlands, the registration taxes are dependent on the vehicles relative efficiency compared to cars that have more or less the same size. Providing an incentive on purchase may be effective because at that time, consumers make a choice that will partly determine their long time emissions of $CO_2$.

Two more specific charges for road transport are parking fees and congestion charges. Parking fees are levied in many cities. Sometimes they are introduced to cover the costs of parking facilities, in other cases they are introduced to give incentives, in particular aimed at reducing the number of vehicles in crowded areas. Congestion charges serve a similar aim. Examples are the congestion schemes in London and Stockholm.

All over the world, more and more cities have plans for the introduction of a congestion charging scheme. The Commission for Integrated Transport of the UK has made an extensive overview of the various examples (CfIT, 2006). Besides the cordon type schemes of cities London and Stockholm, a different type of scheme applies to various motorways in the US, the so called High Occupancy Tolls (HOT). These tolls apply to single occupant vehicles who wish to use so called High Occupancy Vehicle lanes or roads. These are lanes or roads that are dedicated for the use of high occupancy vehicles (so vehicles with at least two or three passengers). High Occupancy Tolls allow more vehicles to use High

Occupancy Vehicle lanes while maintaining an incentive for mode shifting, and raises revenue.

| **London Congestion Charge** |
| --- |
| In 2003, a *congestion charge* of 5 pounds per day for road passenger vehicles was introduced in London City, which increased to 8 pounds per day since 2007. The aim of the charge is to reduce congestion in the inner city. At the time of introduction, substantial investments were made in the public transport system, to offer people an alternative. The congestion charge has decreased traffic volumes by 15%, reducing congestion by up to 30%. In addition, emissions of pollutants and $CO_2$ have gone down by about 20%.<br><br>Source: Transport for London (2006). |

A specific type of taxation related to road transport is the taxation of company cars. In the UK, the company car taxation scheme for passenger cars has been adapted to incentivise the purchase of fuel efficient cars. The additional income tax that company car users pay, is differentiated to the fuel efficiency of the car. Due to the revenue neutral scheme, the average fuel efficiency of company cars has improved by 15 g/km[18].

In some countries insurance taxes exist. They are usually based on a share of the insurance premium.

### 2.5.2 Rail transport

In all EU countries, rail transport companies pay an infrastructure charge. In most countries this covers the marginal infrastructure costs, while in a few countries it covers total infrastructure costs. In various countries the infrastructure charges are differentiated.

Several infrastructure managers apply scarcity charges, in order to reflect capacity constraints at the level of time table planning. In addition, in some countries performance schemes exist, charging for traffic disturbances caused by train operators. Revenues of these performance schemes are used to compensate other operators that had to suffer from the disturbance.

Italy has a congestion and scarcity charge for rail infrastructure. The infrastructure charge depends both on the time of the day and the speed profile of the train, so as to optimize the capacity of the track. For each route standard speed profiles are designed to optimize the line. Higher prices are charged on trains the speed of which diverges from the norm for the route in question because this will stall other traffic and reduce capacity. In addition, there is a charge per node that varies with the implicit amount of congestion at the node by categorizing nodes according to traffic levels. In line with the privatisation process and public tendering of train services many German federal states have introduced penalty charges on delays varying by type of track and train class.

[18] The issue of company car taxation is a complex issue that is not further covered in this study.

These are not part of the national track access charges. In Switzerland, the rail infrastructure charges are differentiated to the noise emission class of the train.

In addition to the infrastructure charges, some countries levy excise duties on train diesel and/or on electricity. Note that electricity production is also part of the European Emission trading system. This does, however, not internalise the costs of air pollution caused by power plants for rail electricity; this may happen by charging or regulating the power plants in general.

### 2.5.3 Aviation

Air companies pay various taxes and charges. The most important are the landing and takeoff charges (LTO charges). At many airports worldwide, the general LTO charges are differentiated with respect to the noise emissions of the aircraft and the time of day. The purpose is to incentivise the use of quieter aircraft and to reduce night noise. The type of differentiation is sometimes relatively simple, while in other cases they are more sophisticated. Frankfurt Airport has a very sophisticated differentiation scheme and also an additional noise surcharge the revenues of which are earmarked for the financing of a noise abatement program. A few other airports have similar surcharges or governmental taxes for the financing of mitigation measures such as insulation.

At some airports, the LTO charges are also differentiated to emission of pollutants (see text box below for an example). At the London airports of Heathrow and Gatwick, at three Swiss airports (Zurich, Bern and Geneva), at the Euro-Airport Basle-Mulhouse and since January 1st 2008 in Frankfurt and Munich (to be followed by Cologne) a revenue neutral differentiation scheme based on emissions of pollutants is in place.

**Emission based landing fees in Sweden**
At 19 Swedish airports *emission based landing fees* are levied. The emission charge is based on the engines' actual emission of $NO_x$ and HC during the Landing and Take Off cycle (LTO cycle). The charge level per kg of emission is based on an estimate of the external costs. Nonetheless the scheme is revenue neutral, because simultaneously infrastructure charges have been reduced. The charge is to stimulate airlines to purchase and operate aircraft with lower engine emissions. LTO emissions per trip decreased in the first years after the introduction of the charge. However, since 2004 LTO emissions per trip are rising again.

Most aircraft fuel is free of excise duty. There are few exceptions for fuel used for domestic aviation such as exist in Norway, Germany and the Netherlands. The absence of fuel taxation is often explained by the alleged possibility of 'fuel shopping' by airline companies, exploiting differences in tax levels. En route charges are levied for the provision of air traffic control services.

Congestion charges at airports are commonly discussed, but according to European law can not be established in the EU. While attempts are made for Heathrow and Dublin airports, the three New York airports have introduced scarcity charges since January 1st 2008.

### 2.5.4 Waterborne transport

It is important to distinguish inland shipping and maritime shipping. Fuel used for both inland shipping and maritime shipping is free of excise duty. As for aviation, the absence of fuel taxation may be explained by the risk of 'fuel shopping', this risk seems real for shipping as they seem capable of storing extra fuel on board, particularly for maritime shipping. Both inland navigation and maritime shipping pay charges for using harbours, docks and bridges. These charges are often related to the operating costs.

Fairway dues for inland shipping exist in only a few cases. German experiences reveal, that channel charges cover only 15% of maintenance costs. On the Rhine, one of the most important European shipping routes, the Mannheim Convention of 1868 prevents the levying of shipping charges at all. Note that besides inland shipping, inland waterways also serve other aims, in particular water management.

Fairway charges for maritime shipping are prevented by UN Law of the Sea Convention.

**Differentiated port dues in Sweden**
In 1998 20 to 25 Swedish ports have introduced a *differentiated port due* with respect to $SO_x$ and $NO_x$ emissions of the ships. The aim of this charge is to provide ship owners/operators an incentive to reduce emissions of sulphur and nitrogen oxides. Simultaneously to the introduction of the differentiated port dues also differentiated fairway dues were introduced. Together these measures reduced $NO_x$ emissions by a little less than 10%, while $SO_x$ emissions were reduced by about 30%.

### 2.5.5 Subsidies and tax exemptions

So far, we gave a brief overview of taxes and charges in the various modes. Transport users also receive subsidies and get tax exemptions. Little expertise exists on the level and effects of transport subsidies. Public expenditures on investments and running expenditures for the maintenance, improvement and enlargement of infrastructure are a major source of fiscal support for transport. In many cases infrastructure charges exist to (partly) cover these costs. This subject is covered in Deliverable 2 of IMPACT (for road transport) and also discussed in section 3.2.4 of this report.

In 2006 the EEA has commissioned a study to get an overview of the level of transport subsidies (EEA, 2007). This study estimated direct grants from governments to the transport sector (on budget subsidies) that are not related to infrastructure, at roughly 70 billion Euro per year for the whole EU. In addition to these on-budget subsidies, transport gets VAT tax exemptions, which are estimated at roughly 30 billion Euro per year (EEA, 2007).

# 3 Internalisation scenarios

## 3.1 Introduction

In this chapter various approaches for internalising the external costs are discussed. This is done in three steps. First some important cross cutting issues are elaborated in section 3.2. Second, the internalisation approaches for the various cost categories are discussed in section 3.3. Section 3.4 shows a comparison of existing taxes and charges that road transport users currently pay and the level of taxes and charges at marginal external cost level. Finally, section 3.5 presents internalisation scenarios that have been subject to the impact assessment of IMPACT.

## 3.2 Smart pricing measures for internalisation - cross cutting issues

The previous chapter have provided an overview of the theoretical background of internalisation and give an overview of the legal state of the art and the existing pricing measures per mode. In this section we make the step to internalisation approaches by discussing several cross cutting issues:

- Most important cost categories per mode (section 3.2.1).
- Options for incentive base (section 3.2.2).
- Options for incentive level (section 3.2.3).
- How to deal with existing taxes and charges (section 3.2.4).
- Charging for infrastructure costs (section 3.2.5).
- Use of revenues (section 3.2.6).
- Some mode particular issues (section 3.2.7).

### 3.2.1 Relevant external cost categories per mode

Based on the handbook on external costs (also developed in IMPACT), the table below gives a rough indication of the most important external cost categories per mode of transport[19].

Table 2 Indication of the relevant categories per mode of transport

| | Road-HGV | Road-cars | Road-LDV | Rail | Shipping | Aviation |
|---|---|---|---|---|---|---|
| Congestion | X | X | X | | | |
| Scarcity | | | | X | | X |
| Accidents | X | X | X | | | |
| Climate | X | X | X | X | X | X |
| Air pollution | X | X | X | X | X | X |
| Noise | X | X | X | X | | X |
| Additional ext. costs (nature & landscape) | X | X | X | X | X | X |

19 The external cost of security of supply is not included here because of the high uncertainty in the estimation.

Note that especially the costs of congestion, air pollution, noise and accidents differ to a large extent by the specific location and time of the day and/or vehicle characteristics. For urban transport, those cost categories are much more important than for transport in other areas.

Additional external costs include the costs of damage to nature and landscape. These are fixed costs which depend more on the existence of transport infrastructure than on transport use. Additional external costs also include up- and downstream costs, like the external costs of fuel production and refining. These costs are only indirectly related to transport activity. They should ideally be internalised in the up- and downstream processes. That way it will also become part of the price transport users pay. Security of energy supply is also a relevant cost category, but there is not enough scientific basis to come to reliable estimations of its size (see also IMPACT Deliverable 1).

### 3.2.2 Options for incentive base

Pricing measures that aim at influencing behaviour give incentives to users to change behaviour leading to reduction of external costs. To be effective and efficient, these incentives need to be based on good proxies for the true cost drivers (see section 2.3.3). Table 3 gives an overview of options for the incentive bases for the various cost categories. In addition, in the third column an indication is given of the correlation between the proxy provided by the incentive base with the marginal cost level[20]. The fourth column lists the most relevant non-pricing options.

For any specific pricing instrument, there is a preference to keep the incentive base as simple as possible to avoid unnecessary complexity of the pricing scheme. The implementation and transaction costs of more complexity should be balanced against the potential additional benefits.

[20] This assessment has been made on the basis of the Handbook on external cost, Deliverable 1 of this project.

Table 3 Options for incentive base and their correlation with marginal cost levels

| Cost component | Options for the incentive base of pricing measures | Correlation with marginal cost level (current situation) | Most relevant other instruments |
|---|---|---|---|
| Accident costs | a Fuel use<br>b Kilometres driven (road/rail)<br>c Number of LTO's (aviation) or port visits (shipping)<br>d a/b + time of the day<br>e d + location (accident risk) + vehicle type<br>f e + driver/carrier characteristics | Low<br>Low<br>Low<br><br>Low<br>Medium<br><br>High | – Liability regulation<br>– Insurances<br>– Regulation for vehicles, drivers, etc.<br>– Speed limits<br>– Other traffic rules<br>– Infrastructural provisions (e.g. traffic lights) |
| Noise costs | a Fuel use<br>b Kilometres driven<br>c Number of LTO's (aviation)<br>d b/c+ time of the day (day or night)<br>e b/c + location (number of people exposed, population density, urban/non-urban)<br>f b/c + vehicle noise emission class<br>g Combination of b/c, d and e | Low<br>Low<br>Low<br>Medium<br>Medium<br><br><br>Low/Medium | – Noise emission standards for vehicles<br>– Non building zones<br>– Regulation of operations (aviation)<br>– Limits to noise levels or annoyance<br>– Speed limits |
| Air pollution costs | a Fuel use (differentiated to fuel type)<br>b Kilometres driven/sailed<br>c Number of LTO's (aviation) or port visits (shipping)<br>d b/c + location (number of people exposed, population density, urban/non-urban)<br>e b/c+ Euro-standard & fuel type<br>f combination of d and e | Low/Medium<br>Low/Medium<br>Low/Medium<br><br>Medium<br><br><br>Medium<br>High | – Emission standards<br>– Environmental zoning<br>– Limited access for certain vehicles<br>– Driving bans<br>– Speed limits |
| Climate change costs | a Fuel use + $CO_2$ content of the fuel<br>b Kilometres driven (road)<br>c Kilometres flown or sailed<br>d Vehicle: average vehicle fuel efficiency (class)<br>e b/c + d | High<br>Medium<br>Medium<br>Low<br><br>Medium | – Emission trading<br>– $CO_2$ emission standards for (new) vehicles<br>– Fuel regulation (e.g. bio fuels)<br>– Speed limits |
| Additional environmental costs (water, soil) | a Kilometres driven<br>b Number of LTO's (aviation) or port visits (shipping)<br>c Quality Management Certification<br>d Location | Low<br>Low<br><br>Low<br>Low | – Regulation<br>– Technical measures (e.g. drains, waste water treatment) |
| Additional costs in urban areas | a Kilometres driven<br>b a + Location<br>c b + Time of the day | Medium<br>Medium/high<br>High | – Various types of urban transport policy (esp. infrastructure policy for non-motorized transport) |
| Congestion costs (separate cost category) | a Fuel use<br>b Kilometres driven<br>c b + Time of the day and location (peak/off peak, based on average congestion level in peak hours)<br>d Times or days of entering a certain congestion zone | Low<br>Low<br>High<br><br><br>Medium | – New or extension of existing infrastructure<br>– Traffic demand management<br>– Speeds limits<br>– Access control/ramp metering |
| Scarcity | a Kilometres travelled<br>b Number of port visits (shipping)<br>c Number of paths/slots (rail/aviation)<br>d b/c + Location + Time of the day | Low<br>Medium<br>Medium<br>High | – Auctioning of slots/paths |

For most cost categories a good proxy for the cost driver is a combination of parameters (for instance kilometres driven and some vehicle characteristics, location or time of the day). The main vehicle characteristics that can be used are the Euro standard and for some modes (i.e. rail and aviation) the noise emission class.

To differentiate to location, a feasible way is to use a few categories, e.g. for road this can be the type of infrastructure (metropolitan roads, other urban roads, motorways and other interurban roads), in combination with the distinction between 'normal' and 'sensitive' areas.

Differentiation to time of the day can be done by defining time windows, e.g. day/night, peak/off peak. For congestion more than two rates (like high peak, peak, busy hours, off peak) or even rates that change continuously with the time of the day, stay closer to the actual cost driver and therefore are preferable from a theoretical point of view. However, for practical reasons, all congestion schemes introduced so far in Europe use only very few rates to increase transparency and to minimise transaction costs of the system. For congestion, an alternative for a combination of distance and time of the day as a proxy, is the number of days or times a congestion zone is entered (like used in the London Congestion Charge).

For aviation and waterborne modes, for some cost categories the number of visits to a port or airport may be more relevant than the distance because of the relative large share of costs that are related to these parts of the trips.

For the costs of climate change, the actual fuel use (in combination with the carbon content of fuel) is the optimal incentive base, because it is an excellent proxy for the greenhouse gas emissions. Pricing fuel with a $CO_2$ based fuel tax gives incentives to reduce greenhouse gas emissions in all possible ways. Distance related charges are also a good proxy, but they do not give incentives for buying fuel efficient vehicles or applying a fuel efficient driving style and make it harder to distinguish between the various types of fuel in particular bio fuels.

Also for other costs than climate, fuel taxes have the advantage of low implementation costs and might therefore be considered as a relatively easy way of internalisation for other cost categories than climate as well. However, fuel consumption is poorly correlated with the actual marginal costs.

Like fuel consumption, vehicle kilometres are on their own not very well correlated with marginal costs for noise, air pollution and accidents. The main reason behind this is that the external costs induced by a kilometre driven or a litre of fuel used depend very much on other parameters that have a large impact on the marginal external cost level. These are in particular the vehicle characteristics (e.g. Euro standard), location and time of the day. For air pollution and noise, this holds particularly because a charge per litre of fuel used or a flat kilometre charge lacks the ability to differentiate between vehicle characteristics and location (and for noise also time of the day). As an example, the difference in external air pollution costs of a Euro 5-car on rural road and Euro 1-diesel car in a dense urban area is enormous as e.g. particle emission standards are 36 times higher. The same is true for the difference between the noise costs of a noisy train or aircraft at night in an urban area and a relatively silent one in an area with a low population density.

The GRACE project comes to the same conclusion, saying[21]:

> *Substituting all existing taxes on transport by a fuel tax equal to the external costs would lead to an irrealistically 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 between countries.*[22]

We conclude that is important to distinguish:
- **Climate change costs** which are related to **fuel consumption**.
- **Air pollution, accidents, noise and congestion** costs which are related to **kilometres driven** in combination with **characteristics** of the vehicle, location and time of the day and for accident costs also driver characteristics. Marginal infrastructure costs are related to kilometres driven in combination with location and vehicle characteristics.

### 3.2.3 Options for incentive level

The level of pricing measures aimed at internalisation of an externality should ideally be based on the corresponding marginal external costs. The estimation of marginal costs for the various cost categories has been elaborated in Deliverable 1 of IMPACT (Handbook on external cost estimates). In the scenarios, these results have been taken as starting point. The value transfer procedures presented in Deliverable 1 have been applied to retrieve values for all Member States. Air pollution and Climate Change costs have been calculated using emission data from TREMOVE.

### 3.2.4 How to deal with existing taxes and charges

In a ‘Greenfield’ situation, i.e. without any existing taxes or charges, all internalisation of external costs can be purely based on the principles of Marginal Social Cost Pricing, namely with a system of taxes and charges at marginal social cost level. Note that the marginal costs of a transport activity relate both to the marginal costs of the different externalities and to the marginal infrastructure costs. The best proxy for the marginal external costs is a combination of carbon based fuel taxes and user charges per vehicle kilometre or LTO, differentiated to the main parameters that affect the marginal external costs of a vehicle movement.

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21 Source: policy conclusions presented at the final GRACE conference at 5 & 6 December 2007.

22 This is important since marginal external cost levels differ a lot between countries, but also between other parameters to which fuel taxes can not differentiated.

However, in the current situation, many taxes and charges are already in place. This raises the question how they should be taken into account. Some of the existing taxes and charges may already internalise external costs or charge for (marginal) infrastructure costs, albeit not necessarily effectively or efficiently.
First of all it should be noted that setting taxes and charges at total *marginal* social cost level (i.e. including social, environmental and infrastructure costs) is not possible with average charge or tax levels that are the same for all vehicles and traffic situations, but only with the marginal tax and charge level *in each specific traffic situation*. Consequently, charge *structures*, are of particular interest in order to give the right incentives to change behaviour.

Below we discuss the main types of existing taxes and charges and how they should be taken into account.

**Fuel taxes**
The foremost example of an existing variable tax or charge that should be accounted for is fuel excise duty. Fuel excise duty is an important fiscal instrument with high revenues.

In the previous section we concluded that fuel taxes are apt to internalise external climate change costs. For other cost categories than climate, fuel excise duties do not correlate well with the marginal external costs (see section 3.2.2), neither with the marginal infrastructure costs. Therefore they cannot be regarded as adequately internalising these costs.

Table 4 shows how different shadow prices for $CO_2$ would translate into rates per litre fuel, petrol and diesel respectively.

Table 4 Various shadow prices of $CO_2$ expressed in Euro per litre fuel[23]

| **$CO_2$ shadow price** | **Petrol** | **Diesel** |
|---|---|---|
| Euro/tonne | Euro-ct/l | Euro-ct/l |
| 18 | 4.10 | 4.73 |
| 25 | 5.70 | 6.57 |
| 50 | 11.40 | 13.15 |
| 70 | 15.96 | 18.40 |
| 85 | 19.38 | 22.35 |
| 180 | 41.04 | 47.33 |

[23] These data are based on the carbon content of the various fuels.

For comparison, the minimum levels for fuel excise duties according to Directive 2003/96/EC are 30.2 Eurocents per litre of diesel (33.0 Eurocents as of 1 January 2010) and 35.9 per litre of petrol[24]. Existing fuel taxes for road transport are higher thus much than the midrange estimates for climate change costs from the IMPACT handbook on external costs (25 Euro per tonne for 2010, corresponding to 6 to 7 Eurocents per litre). This is true for the short term but also for the midrange climate cost estimation at the longer term (85 Euro per tonne in 2050). The minimum fuel tax according to the Commercial Diesel Proposal (38 Eurocents per litre) corresponds with a $CO_2$ shadow price of 145 Euro per tonne for diesel and 162 Euro per tonne for petrol.

So existing fuel taxes are considerably higher than the external climate change costs. However, it should be noted that fuel taxes have different functions, which may also vary between countries:

1 *The fiscal function*
Excise duties as a general tax for fiscal reasons; non earmarked taxes belong to this category. In all Member States, the fiscal function of fuel taxes is very important. It can be regarded as a kind of Ramsey pricing, gaining tax revenues with low distortions to the economy.

2 *The infrastructure financing function*
In many countries, together with vehicle taxes, a part of excise duty taxes (sometimes earmarked) can be considered as a contribution to infrastructure cost recovery. This is particularly the case in Member States where infrastructure costs are not covered by revenues from tolls.

3 *A payment for (external) costs of security of supply*
The external costs of security of energy supply can be considerable and fuel taxes are a proper instrument to cover these costs. Currently there are no reliable estimates available, so it is impossible to indicate which part of excise duties should be considered as internalising these costs.

4 *The environmental function*
Within some countries, an identifiable $CO_2$ tax is levied with the specific aim of reducing greenhouse gases and the achievement of environmental goals and energy efficiency.

It is not possible to quantify the parts of existing fuel excise duties that should be regarded as serving each of these aims.

The question is what this means for the internalisation of climate change costs. The following positions can be taken:

1 Existing fuel taxes should be regarded as already internalising external climate change costs.
2 Existing fuel taxes should be regarded as mainly a fiscal instrument and covering costs (e.g. infrastructure costs and external costs of energy supply). Internalisation of climate change costs should be done on top of existing fuel taxes (by carbon content based taxes).

[24] There are various exceptions, particularly for non-road modes.

The main argument for the first option is that the existing fuel taxes are much higher than the external climate change costs and that they are already high enough to meet the various aims listed above. One might even argue that when the other pricing measures are introduced such as kilometre based charges for internalizing other external costs, additional revenues are generated and therefore fuel taxes could be lowered.

At the other hand, from the perspective of climate change policy and in the light of the ambitious $CO_2$ reduction targets of the EU and various Member States, higher fuel taxes could contribute to a further reduction of greenhouse gas emissions from transport. This was also one of the arguments for the increase of the minimum excise duties in the Commercial Diesel proposal. Lowering fuel taxes would make it more difficult and maybe even impossible to meet the ambitious $CO_2$ reduction targets.

At the other hand, from the perspective of climate change policy and in the light of the ambitious $CO_2$ reduction targets of the EU and various Member States, higher fuel taxes could contribute to a further reduction of greenhouse gas emissions from transport. In this context, it is often referred to the ongoing increase in $CO_2$ emission of transport where these emissions have recently gone down in most other sectors. The need for further emission reduction was also one of the arguments used for the increase of the minimum excise duties in the Commercial Diesel proposal. Lowering fuel taxes would make it more difficult and maybe even impossible to meet the ambitious $CO_2$ reduction targets.

An important issue related to internalisation of climate change costs, is whether an efficient climate change policy should aim at the same $CO_2$ price in all sectors of the economy or that higher costs in some sectors compared to others should be accepted.

As long as climate change policy is regional and not covered by a fully global scheme, there are strong arguments for the second. A major argument for $CO_2$ price differentiation over sectors is the phenomenon of 'carbon leakage'. Energy intensive sectors which also face strong competition from outside the EU could be less capable of dealing with the same level of $CO_2$ tax as other sectors, as with such a tax, their clients would leave them to buy their products elsewhere at lower cost. The consequence could be that production in those sectors would shift from the EU to outside of the EU without any $CO_2$ emission reduction. This situation would exist as long as there would be significant differences between the EU climate change policy and those of other regions in the world. As it is argued that road and rail transport and inland navigation do not directly compete outside the EU, they would be candidate for a higher than average $CO_2$ price and/or a more ambitious $CO_2$ reduction target than the general one.

We conclude that internalisation of climate change costs with extra charges on top of existing fuel taxes may be appropriate. However there are also good arguments to state that climate change costs of road transport are yet internalised by the existing fuel taxes. Based on purely scientific arguments it is currently not possible to decide between these two approaches.

In the IMPACT scenario definitions, a conservative approach is chosen, assuming that existing fuel taxes at the level of at least the external climate change costs (as is the case for road, see Table 4) can be regarded as internalising external climate change costs (see further the scenario descriptions in section 3.5).

**Infrastructure charges**

In various countries road infrastructure charges are in place, sometimes for all vehicles (like in France and Italy), sometimes for HGV only (like in Germany). These charges relate to infrastructure costs. The existing infrastructure charging schemes do not charge for external environmental, congestion or accident costs, except for the Swiss HGV charge[25]. This is line with the Eurovignette Directive, which says that for HGV infrastructure charges may not exceed infrastructure costs (with a few exceptions, see section 2.4). In the scenarios, various approaches have been chosen (see the next section).

Another example relates to infrastructure charges for rail. In general, these are based on variable infrastructure cost pricing[26]. However, in some countries mark-ups are applied to raise sufficient revenue for financing the infrastructure. Ideally, these mark-ups could be accounted for in setting marginal charge levels to internalize external effects of rail transport. In the scenarios, this has not been taken into account.

Also for other non-road modes, existing infrastructure charges do partially cover infrastructure costs, but no external costs.

**Fixed taxes and charges**

In addition to fuel related taxes (excise duties) and kilometre related charges (all types of tolls), some road users also pay other types of taxes or charges in particular those related to purchasing a vehicle (vehicle purchase taxes or vehicle registration taxes) and those related to owning a vehicle (circulation taxes). In some cases they can give incentives at the purchase decision of a vehicle (e.g. to buy a relatively fuel efficient car). Though these fixed taxes can reduce the external effects of transport, they can not be regarded as internalisation of external costs of transport activity. However, they might in some cases be regarded as being related to fixed infrastructure costs or to external costs that are not related to transport activity but rather to owning a vehicle (e.g. costs of nature and landscape, external costs of vehicle production and scrappage).

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[25] The existing Swiss HGV infrastructure charges have been based on both infrastructure and external cost.

[26] Sometimes they are based on variable infrastructure cost as a proxy for marginal infrastructure cost.

**Congestion charges**
In a few European cities congestion charges are in place. These charges are focused at highly congested areas and usually also differentiated to the time of the day. Depending on their level, they can be regarded as internalising external congestion costs, though often in rough way: from the viewpoint of Marginal Social Cost Pricing the tariffs of the London and Stockholm schemes appear too little differentiated.

**Conclusion on existing taxes and charges**
Except for excise duties with regard to climate change costs and local congestion schemes with regard to congestion costs, existing taxes and charges can not be regarded as already properly internalising external costs. With regard to excise duties we conclude that internalisation of climate change costs with extra charges on top of existing fuel taxes may be appropriate. However there are also good arguments to state that climate change costs of road transport are yet internalised by the existing fuel taxes. Based on scientific arguments it is currently not possible to decide between these two approaches. In some cases existing taxes and charges might be lowered to compensate for the price increases and to avoid overpricing.

### 3.2.5 Charging for infrastructure costs

With regard to charging for infrastructure costs, three approaches can be followed, in line with the considerations of section 2.3.4:
1 Leave all existing charges for infrastructure costs as they are and put internalisation measures on top of them.
2 Abolish all existing charges for infrastructure costs and replace them by charges based on both *marginal* infrastructure costs and marginal external environmental, congestion and accident costs.
3 Abolish all existing charges for infrastructure costs and replace them by charges based on both *average* infrastructure costs and marginal external air pollution, noise and accident costs.

For road transport the first two options are reflected in the scenarios. In case of the second option, the levels of the marginal costs of infrastructure have been based on the variable infrastructure cost estimates of IMPACT Deliverable 2. For that option, the fixed road infrastructure costs are assumed to be recovered by the other taxes and charges.

The third approach, internalisation on top of charges at average infrastructure cost level has not been modelled. In this approach revenues from charges of both marginal infrastructure costs and marginal congestion costs are supposed to match the level of the revenues of average infrastructure costs. Particularly in interurban networks this seems an appropriate, pragmatic approach, since fixed infrastructure costs are much related to investments in extending the infrastructure capacity. So, high revenues are particularly needed when congestion levels are high. In urban networks and on and mountainous corridors, this approach may be less appropriate since there the options for extending infrastructure capacity are usually very limited. In those cases higher congestion charges will be needed to combat congestion in an efficient way.

For all other modes only the first option has been applied, because in this project no assessment has been mode of (marginal) infrastructure costs for these modes and data are not readily available.

### 3.2.6 Use of revenues

Internalisation taxes and charges generate revenues. These revenues can be used in many ways, as was discussed in section 2.3.8. Whether this is done by earmarking or not, is a political issue, related to acceptability. In this section we explain the general approach we have chosen for the scenarios that have been subject to the impact assessment (see also section 3.5).

When internalisation measures are introduced, the revenues of the internalisation measures could be used for lowering existing taxes and charges in order to compensate for the price increases and to avoid overpricing. From the perspective of Marginal Social Cost Pricing this is efficient, because it brings the overall marginal price level of a transport activity closer to its marginal costs. However, other options of lowering taxes (like lowering labour taxes) may be even more efficient (see also GRACE, 2007).

In some cases lowering existing transport taxes and charges may not be feasible or desirable. Large differences in fuel taxes of Member States lead to undesired effects at country borders and Member States are not allowed to lower their fuel excise duties below the EU minimum levels. Circulation and registration taxes are used to influence fleet mixes and car sales. Abolishment of these taxes may have undesired impacts on the composition of the vehicle fleet.

In the internalisation scenarios, various options for the reduction of existing taxes and charges have been chosen. In some scenarios fuel excise duties remain unchanged, while in others they are assumed to be lowered in all countries to the minimum levels. Existing tolls or circulation taxes have been removed in those scenarios where new infrastructure charges were introduced.

### 3.2.7 Special issue: Do we need a kilometre charge system for passenger cars?

In theory, setting a charge at the marginal social cost level would be optimal to internalise external costs. The theory abstracts however from the required investments in charging systems. To be able to take full account of differences in external costs (related to e.g. time of day and location) a fairly sophisticated charging scheme would be required. The question is whether a comprehensive kilometre charging scheme for passenger cars covering all roads (as opposed to local tolls and charges) and fully differentiated as regards the time- and location specific determinants of marginal cost levels would be worth setting up, given the implementation, operational and administrative costs.

Without going into details here, to decide whether such a system may be called for, we discuss briefly for which external effects such a system may be set up.

For air pollution, congestion, accidents and noise the external effects may differ by time and location. Above we have argued that the costs of air pollution may be relatively small by 2020. However, depending on the speed of fleet renewal, it may be still relevant, at least in some Member States.

Similarly, for congestion in urban areas, toll rings or cordons may also be appropriate[27]. These may of course be differentiated to time, and are by definition differentiated by location. Similarly, bottleneck congestion and congestion on major arteries may best be regulated by specific tolls. However, the costs of many local congestion charging systems may be of the same order or even exceed the costs of a national kilometre charging system.

For accidents a very different charging scheme, introduced via insurance companies, might be as appropriate as a differentiated kilometre charge. The marginal noise costs for passenger cars are low compared to the other cost categories (see the IMPACT Handbook).

Based on these considerations it might not be worthwhile to introduce overall sophisticated systems for kilometre charging that apply to the whole network for the purpose of reducing external effects, in particular in countries with low congestion levels.

Other perspectives, such as a fairer way of charging for the use of infrastructure (user pays principle), provide additional rationale for a comprehensive kilometre charging. If such a system is indeed introduced for such reasons, it may also be used for differentiated charges with regard to internalisation of external costs. Already today for some urban regions a sophisticated charging system is deemed reasonable to internalise external effects of congestion and noise; especially if no urban sprawl is expected (e.g. a metropolis with very high attraction).

It should be noted that the costs of an electronic charging system is expected to decrease with technological innovation and an increasing number of countries that already have (electronic) tolls on parts of their road network. Also the options offered by such a system may increase. An example is that a kilometre based charging system for passenger cars may offer insurance companies a possibility to introduce so called Pay As You Drive insurances (based on premiums per kilometres driven). This can also be regarded as being more efficient than the lump sum premiums of most existing car insurances.

[27] Ring tolls have the advantage of cheap implementation costs - but operating costs are similar than with fairly sophisticated charging system discussed above. Furthermore they are with some respect imprecise and inflexible - especially with regard to urban sprawl.

### 3.3 Internalisation approaches for the different external costs

In this section we discuss the internalisation approaches for different external costs. We discuss the most relevant market-based instruments. In addition, we also discuss the context, including the link with the most relevant non-market-based instruments.

#### 3.3.1 What to do about congestion?

Congestion problems on the road can basically be split into two categories:
1 Congestion in urban areas.
2 Congestion at major corridors.

These two categories may require different solutions. Congestion around **urban areas** may best be addressed by city (area) tolls (area licensing/cordon charge, e.g. London, Shanghai or Stockholm). The examples so far show that urban congestion can be decreased significantly, with support from the general public, if alternatives (e.g. public transport) are sufficiently available. Tolls may be differentiated according to time of day (e.g. peak and off peak). To improve accessibility and provide alternatives, revenues may be earmarked for investments in the transport sector, including the financing of public transport alternatives.

The second type of congestion is related to congestion at **major corridors** outside of city centres. This can be bottleneck congestion related to the passing of a certain point or construction work (i.e. a bridge or tunnel). Alternatively, congestion on a link between large cities may arise. If such bottlenecks or arteries become congested, there is by definition a capacity problem that can not always be solved by alternative links or modes[28].

Real life examples show that there are two possibilities for tackling congestion on corridors. The one is optimal capacity management by differentiating a congestion toll according to time of day, in order to guarantee optimal traffic flows with low congestion risk. This is generally an efficient way to ensure that the available capacity is used in the most efficient way.

**HOT lanes**

A special case of value pricing is when it is applied to specific lanes only, combined with incentives to increase load factors. The examples in the US show that these so-called high occupancy traffic (HOT) lanes function if there are transparent pricing systems, enough lanes and a willingness to pay of the users. However, from an economic point of view, the available capacity of HOT lanes is not used in the most efficient way. Also in the US public and political support for the HOT lanes which are sometimes called 'Lexus Lanes', seems to decline.

[28] An exception might be Alpine corridors, where railway alternatives might be viable.

The second possibility for reducing congestion on corridors is increasing capacity. The congestion toll is a pre- or post financing instrument of the capacity increase. This increase can be a new lane (also priced with value pricing) or a new bypass.

A proper approach would therefore be to levy tolls at such links, and to earmark revenues for road infrastructure investment. Especially, but not exclusively, in mountainous areas, it may be relevant to invest in alternatives that have minimal impact on the environment. In general, the investments of the funds should be based on cost benefit analysis, including options within the road sector as well as investment in other modes.

As discussed in section 2.3.4, in some cases efficient congestion charging could be introduced as differentiation of existing weighted average tolls rather than additional charges. It was suggested at the final GRACE conference in 2007 that revenues of the existing scheme could be regarded as being equal to revenues from charges of both marginal infrastructure costs and marginal congestion costs. This approach may be valid, particularly in interurban networks, but requires more research. In urban networks and on and mountainous corridors, higher congestion charges will be needed to combat congestion in an efficient way.

In addition to the instruments discussed so far, a transit bourse has been proposed to solve congestion problems in alpine regions. Such a system is a cap and trade system for limiting the number alpine transits. The impact of such a system can be similar to a bottleneck congestion toll mentioned above. The implementation costs of a transit bourse will probably be much higher than of a congestion toll.

### 3.3.2 What to do with air pollution?

The Euro standards for road vehicles have proven very effective in reducing the emission of air pollutants. In all other modes such standards have been introduced more recently. Further tightening the Euro standards and other international standards are probably the most effective way to reduce the external costs of air pollution.

In addition to the standards, financial incentives are now used in some countries to:
- Speed up the introduction of new/cleaner vehicles in the fleet.
- Use most recent technology in critical areas (urban areas, sensitive areas such as alpine transit).

In theory, the differentiation of circulation taxes and road user charges (vignettes) and tolls could be used for this purpose. Registration taxes are not suitable, since (almost) all newly sold cars adhere to the latest Euro standards.

Differentiation of tolls have the advantage over user charges and circulation taxes that they can be differentiated to both Euro standard and location. In addition, differentiated tolls give also incentives to reduce vehicle kilometres, particularly for the dirtiest vehicles. Therefore this is the recommended internalisation approach.

The need for a speedup of the fleet renewal may decrease over time, particularly when the fleet has become much cleaner because of autonomous fleet renewal. The need for incentives for cleaner cars may then be smaller than nowadays. However, this may only be expected at the very long term when almost the entire fleet consists of low and near zero emission vehicles.

Also in other modes than road, there may be reason to differentiate existing taxes and charges with respect to the emission of pollutants (e.g. differentiated harbour dues, differentiated LTO charges), or even to introduce regulatory charges, potentially differentiated to location.

There is no real argument for earmarking the revenues from internalisation of air pollution costs. Most effective measures for reducing air pollution costs are related to vehicles and vehicle usage. The costs of these measures are paid by transport users, not by governments. Only in a wider sense, earmarking may be effective, e.g. to promote public transport or rail alternatives in sensitive regions (as in the Swiss and London pricing schemes). Revenues could be used for subsidising fleet or engine renewal and the implementation of catalysts or particulate filters. This may be particularly relevant for the non-road modes, because the lifetime of locomotives, vessels and aircraft is generally much longer than for road vehicles.

### 3.3.3 How to address the costs of noise?[29]

Especially in the road, rail and aviation sector, noise costs may be substantial. The costs of noise relate both to the type and characteristics of the vehicle used and the location/time of day where it is used.

Similar to air pollution, the most effective way to mitigate noise is regulation, in the case of noise particularly related to vehicles and tyres. In addition, financial incentives can be used to:
- Speed up the introduction of more silent vehicles in the fleet.
- Use most recent technology in critical areas and time frames (particularly night time).

Internalisation for the (remaining) noise externality seems to be a useful supplement for these initiatives. Ideally, charges for internalising noise costs should give these type of incentives. This requires charges differentiated to vehicle characteristics, location and time of the day.

[29] In addition differentiation to vehicles with and without particulate filters would be useful to give incentives for retrofitting.

Differentiation according to time of the day can be done by differentiating to day (7-19) evening (19-23) and night (23-7) as fixed by default by the Directive 2002/49/EC. A daily (24 hours) charge could be derived from the $L_{den}$ related exposure maps[30], a daytime/evening/night time charge could be derived from the $L_{day}$, $L_{evening}$ and $L_{night}$ related exposure maps.

In addition noise charge should be differentiated to vehicle characteristics. For road transport the difference between passenger cars and HGV is the most relevant one. Also various noise standards exist, but the differences between the resulting noise levels are relatively small and driving styles play an important role. The type of tyres are also important, but a differentiation to that may be hard to enforce.

For rail transport, differentiation factors reflecting the main differences in noise emissions of trains are particularly:
- Conventional passenger trains and high speed passenger trains.
- Wagons equipped with and without low noise break blocks for freight trains. Several countries are using such a noise bonus for silent brake systems.

For air transport the noise charge should be set per movement or LTO. It should be differentiated according to at least the noise performance of aircraft (a noise classification system could easily be derived from certified noise levels published at the web of the European Agency on Safety of Aviation which is the EU body responsible for issuing aircraft noise certificates), per category of movement (landing or takeoff, if the charge is set per movement), and time of day. Currently, landing charges differentiated to noise emissions and/or time of day are widely applied. In some situations, surcharges are levied to finance insulation or property acquisition.

Different to air pollution there is a direct link to the use of revenues, since infrastructure or home based noise measures (noise walls, windows) are appropriate and effective. Their installation does, however, not completely reduce external noise costs as disturbance outside closed walls remain. Nevertheless, this link should be considered for all modes. For road transport, a noise charge and sensitive corridors is useful.

### 3.3.4 What to do about external accident costs?

Accident costs are odd external effects of transport. UNITE (D2) classifies them as being placed somewhere between (sector internal) congestion costs and sector external effects, such as air pollution, climate change and noise. In principle, accident costs causing real financial flows are covered by insurances. However, a large part of the costs associated with accidents are non financial, and are often not yet covered by insurances. E. g. the 'statistical value of human life and heath', e. g. the 'risk value' representing society's preference to prevent traffic fatalities, accounts for up to 80% of accident costs, see also chapter 2.

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[30] 'Den' stands for day, evening and night. $L_{den}$ is a measure for the weighted average noise level for a whole day.

Depending on the liability laws, even parts of values of human lives are paid by compensation for bereaved. This is especially the case within the US law.

Marginal accident costs depend on a complex set of cost drivers. For road they can be internalised by a kilometre based charge differentiated to parameters like location, time of the day and vehicle type. However, though already rather complex, the correlation with the actual marginal accident costs are still moderate. A better proxy for the actual cost driver is obtained when also driver characteristics and accidents history is included. This is complex and may be hard to implement because of privacy reasons.

For the other modes, internalisation is not straightforward either. For railways there could be an additional charge to the infrastructure charge. For aviation, the enlargement of the liability system seems to be most appropriate, but also a charge per LTO might be useful. For maritime transport and inland waterways, the costs of fatal accidents are small.

For the government to develop a pricing scheme that adheres closely to the true cost drivers is not straightforward. An alternative would be to charge the insurance company involved a lump sum at the level of the estimated external costs for each accident. In all countries, insurance is obligatory. Insurance companies have detailed information on cost drivers and differences in the risk rates between drivers.

Insurance companies are expected to pass on the costs to their clients through higher insurance rates. The insurance companies are better able to differentiate these costs according to the accident risk involved with different drivers, driving times, routes, etc. Drivers thus receive further incentives to reduce their risks. Insurance companies may then judge whether it is worthwhile to switch to pay-as-you-drive schemes[31], providing optimal incentives at the margin, or that the costs of introducing such schemes do not weigh up against averaging.

A disadvantage of this proposal is that insurance companies are faced with increased uncertainties. On top of their current expenditures on the internal accident costs there will be additional payments to the governments for each accident to cover the external costs. It is however the core business of insurance companies to deal with such uncertainties.

Both type of schemes (differentiated kilometre charges and internalisation via insurances) generate revenues for the government. The earlier discussed options for revenue use apply also here. More specifically, part of the revenues could be invested to augment a fund for compensation and safety of infrastructure use. Parts could be redistributed to the insurance holders per capita.

[31] Which may be connected to potentially existing kilometre charging schemes for infrastructure costs to limit transaction and implementation costs.

### 3.3.5 What to do about climate change costs?

With the use of fossil fuels, carbon dioxide is emitted into the atmosphere. This is highly probable to contribute to climate change. A broad set of measures can contribute to the reduction of greenhouse gas emissions from transport. As for the environmental costs, regulation is important, e.g. concerning $CO_2$ emissions of new cars. Also market-based instruments internalising external costs can contribute to the reduction of greenhouse gas emissions. Internalisation of climate change costs of transport should be related to its main cost driver, which is fuel consumption.
From a fairness perspective (polluters pay principle) and also from an efficiency perspective, it can be argued that all modes should be treated the same and receive the same incentive (per ton of $CO_2$) to reduce the emission of carbon dioxide. However, the climate impacts of aviation and shipping has more aspects than the impact of $CO_2$ emissions alone. Related to aviation are the emissions of $NO_x$ at altitude and contrail formation. Both have a net warming effect on climate. On the other hand, related to shipping are the emissions of sulphates. Even though these remain in the atmosphere for only a limited amount of time, they have a substantial cooling effect.

How to deal with this? Neglecting for the moment the non-$CO_2$ climate effects, we propose on the basis of the fairness and efficiency arguments to provide the same incentives across all transport modes to reduce emissions of $CO_2$. There are three main options for this:

1. A $CO_2$ tax could be levied upon fuel, explicitly based on the carbon content of fuel. The charge per litre of fuel would thus be higher for diesel than for gasoline. The charge per ton of $CO_2$ would be the same across all transport modes, and could be based on external cost estimates. This is also the approach recommended in D3 of the GRACE project (GRACE, 2007). A disadvantage of this approach is that there may be some possibilities to fuel up outside of Europe, thus avoiding the charge. This holds especially for maritime transport. Another potential problem is that the levying of such a charge may not be allowed for all modes. For aviation, many bilateral air service agreements exist that preclude such charges. For inland waterways, the Mannheim convention can pose a problem. It should however be taken into account, that in the long run such legal arrangements may be adapted. For road fuels, the approach proposed may just be implemented by relabeling part of the excise duties.
2. A connection could be made with the EU ETS. In line with the proposal for the aviation sector, and in line with the current practice for the electricity used for electric trains, all transport modes could be included in the EU ETS. The advantage of this approach is that the incentive to reduce $CO_2$ emissions in the transport sector will be in line with incentives in the other sectors. Inclusion of all transport modes in the EU ETS is not straightforward, several levy points exist depending on which actors will have to trade emission permits: upstream (fuel producers, refineries), midstream (resellers, filling stations) or downstream (final consumers). It is important to make a good choice for the actors to be included, so to limit transaction costs and to keep the incentives of the ETS. For example, transaction costs may become

unacceptably large if all passenger car owners would be made to trade on the EU ETS market (downstream implementation)[32]. On the other hand, upstream implementation will just arrive like additional costs per litre at the final users (CE, 2006b). It must further be noted that inclusion of all modes in the EU ETS may not end the discussion of level playing field across modes. A similar allocation method for all modes, such as auctioning may provide, would be further required.

3 A further alternative besides an inclusion of transport in the existing European ETS would be a separate ETS for the transport sector. In doing so, the price per tonne of $CO_2$ for transport may allowed to be higher than in sectors that face strong competition with market players that do not operate within the ETS (see also section 3.2.4). This is especially attractive because of the high willingness to pay for ‘fuel inefficient’ but prestigious vehicles in the main $CO_2$ contributor - the road passenger transport. From an political point of view this higher price might be preferred.

Because of the difficulties with fuel taxes for aviation and maritime transport, (both legislative and with respect to economic distortions), the internalisation scenarios assume that these sectors are included in the EU ETS. For the other sectors a $CO_2$ based fuel tax is included.

As discussed in section 3.2.4, especially in the road mode, excise duties already impose marginal costs on transport users that exceed the external climate change costs. The excise duties may therefore be revised when internalisation measures are imposed. This can be done explicitly by relabeling part of fuel excise duties as a $CO_2$ tax or charge. With regard to emissions trading, existing taxes might be lowered so that the total revenue from fuel excises is reduced by the revenue from any auctioned allowances under emissions trading. Total revenues for the government will so remain unchanged, and the charging scheme is closer to marginal cost based pricing[33]. It should be noted that internalisation of climate change costs with extra charges on top of existing fuel taxes may be appropriate as well. However, as was explained in section 3.2.4, the IMPACT scenario definitions consider the existing fuel taxes at the level of at least the external climate change costs (as is the case for road) as internalising external climate change costs.

When a $CO_2$ tax or charge or emission trading is implemented, account is taken of the potential of bio-fuels to limit the net $CO_2$ emissions of fuel. This should be based on the total well-to-wheel impacts of bio fuels, which depends on the type of bio fuel.

With regard to the non-$CO_2$ climate impacts of aviation[34], additional flanking instruments are the most appropriate approach. Closer regulation of flight paths can reduce the formation of contrails. In additional, standards for new aircraft

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[32] There are several potential alternatives, each with its merits. Fuel suppliers are for example an option.

[33] Note that lowering excise duties is likely to be compensated completely by an increase in the prices of $CO_2$ credits and therefore have no impact on the overall fuel price.

[34] For maritime transport, it is more complicated. The science behind these non-$CO_2$ climate effects of shipping is not at a stage in which concrete policy recommendations can be made.

may reduce the emissions of $NO_x$ at altitude. For practical reasons this has not been included in the scenarios.

A $CO_2$ tax on fuel or inclusion in the ETS may provide the correct incentive at the margin, but there is evidence that at least car owners may not make fully rational decisions with regard to fuel efficiency of vehicles on purchase. Today usually less than the first three years of fuel use are taken into account. If longer periods were taken into account, people would be more likely to opt for more fuel efficient cars. A differentiation of registration taxes, or if these are abolished, circulation taxes may be a good instrument, in line with the Commissions proposal. However, this type of measures do not directly internalise external costs and are therefore not included in the scenarios.

## 3.4 Comparison of current and marginal cost based taxes/charges

In this section we make a comparison of the current taxes and charges and the level of taxes and charges based on marginal costs. This comparison is limited to **road** transport based on the results of Deliverable 2 of IMPACT, the external cost estimation from Deliverable 1 of IMPACT and the output of the scenario 1 runs with TREMOVE. The comparison assesses whether the existing taxes and charges are in line with the principle of Marginal Social Cost Pricing (see section 2.3.2.): are marginal taxes/charges equal to marginal costs?

The comparisons help to identify the situations in which there is a significant gap between the tax and charges road transport users pay and the marginal costs they induce on society. However, they are based on limited data and extrapolations, so they should be interpreted with care.
As concluded in section 3.2.2 it is important to distinguish costs that are related to **fuel consumption** and costs that are related to **kilometres driven**. Fuel related costs can be internalised by fuel taxes; kilometre related costs can be internalised by kilometre related charges that are differentiated to relevant vehicle characteristics, location and time of the day. Consistent with this recommended internalisation approach, we compare fuel related costs with the existing fuel taxes and kilometre related costs with the existing kilometre charges. Fixed taxes and charges are presented separately, because they do not give incentives in line with main cost drivers as fuel consumption or kilometres driven (see also reasoning in section 3.2.4).

The comparison of fuel related costs and fuel related taxes per litre of fuel in the various Member States is presented in section 3.4.1. Section 3.4.2 shows the comparison of kilometre related costs and charges in various Member States.

As was explained before, the marginal kilometre related external costs depend heavily on various parameters like Euro standard, location and time of the day (see Table 3). For a proper comparison, it is important to compare various types of vehicles in various traffic situations. Therefore, we have selected a few exemplary cases for which this comparison has been made.

Finally section 3.4.3 shows a comparison of costs and charges at a macro level. This is done by comparing the total revenues from the existing taxes and charges (EU-wide) and the total revenues from taxes and charges that would be based on the marginal cost.
For the non-road modes, there is no consistent overview available on the overall level of existing taxes and charges. Also data of infrastructure costs are poor or not available. With only exceptions, existing taxes and charges for the non-road modes relate to infrastructure costs, based on cost recovery. The main exceptions, existing taxes or charges that can be regarded as already internalising external costs, are the energy taxes and inclusion in the ETS for rail electricity.

### 3.4.1 Fuel related costs and existing fuel taxes

In all Member States road users pay fuel excise duties for the motor fuel they purchase. Directive 2003/96/EC requires Member States to respect minimum tax levels for energy products, including motor fuels for road transport. Current levels of fuel taxes vary significantly between Member Sates. With the Commercial Diesel Proposal, the minimum fuel excise duties are increased and harmonized for diesel and petrol.

Climate change costs are related to fuel consumption (see also section 3.2.2). The external costs of climate change (caused by greenhouse gas emissions from fuel combustion) are expressed in Euro per tonne of $CO_2$. As discussed in IMPACT Deliverable 1, the valuation of climate change costs faces the high uncertainties of both the damage costs of climate change and the costs of mitigating greenhouse gas emissions. Based on a broad assessment, IMPACT Deliverable 1 comes to a valuation of $CO_2$ emissions that increases over time from 25 Euro per tonne of $CO_2$ in 2010 to 85 Euro per tonne of $CO_2$ in 2050.

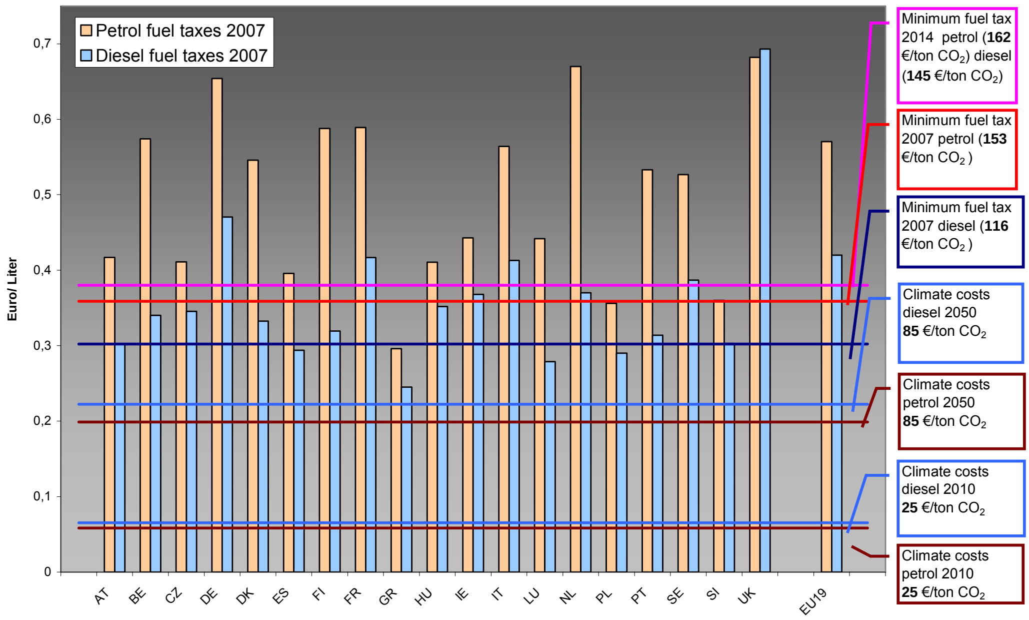
Besides climate change there are some other external costs related to fuel consumption, notably:
- Upstream costs, related to emissions from fuel production.
- External costs related to security of supply.

External costs of fuel production are preferably internalised in the upstream sectors (e.g. refining industry). This way, the external costs will be reflected in the fuel costs themselves. For the external costs of security of supply no reliable valuation does yet exist and therefore they could not be included in the comparison below.

Figure 1 shows the fuel excise duties in various Member States in 2007. In the same graph the minimum excise duties for petrol and diesel are shown, both the current levels and the ones according to the Commercial Diesel Proposal. Also the climate change costs with a valuation of 25 Euro per tonne (mean value for 2010) and 85 Euro per tonne (mean value for 2050) are indicated.

The graph shows that fuel excise duties are much higher than the external costs of climate change. This does not mean that from the perspective of efficient pricing, fuel excise duties could be lowered (see discussion on this issue in section 3.2.4).

Figure 1 Fuel excise duties in 2007 for road fuels in various Member States




Source: EC, 2007, Commercial Diesel Proposal and own calculations based on external cost of climate change from IMPACT Handbook on external costs.

### 3.4.2 Marginal kilometre related costs and existing kilometre charges

Most external costs are related to kilometres driven, vehicle characteristics, location and/or time of the day. In this section these costs are compared with kilometre based charges, being all kinds of road tolls.

As was explained before, the marginal kilometre related external costs depend heavily on various parameters like Euro standard, location and time of the day (see Table 3). For a proper comparison, it is important to compare various types of vehicles in various traffic situations. Therefore, we have selected a few exemplary cases for which this comparison has been made.

The existing Eurovignette Directive enables charging *average* infrastructure costs, so both *variable* and *fixed* infrastructure costs. Existing tolls are often based on average infrastructure costs. To be able to compare the existing kilometre based charges with both the variable costs and the total infrastructure costs, also the fixed infrastructure costs have been included in the graphs. To distinguish them easily from the marginal costs and charges, we used solid colours for *fixed* infrastructure costs and hatched colours for *marginal* costs and charges.

The external costs and charges are all for 2010 (in Euro-2000) and are based on the Handbook on external costs (IMPACT Deliverable 1). Air pollution costs have been calculated with TREMOVE emission data (model version 2.5.1). In line with UNITE and INFRAS/IWW (2004) congestion costs are treated as a separate information item. They are included with transparent bars showing congestion costs in situations where the traffic volume equals the maximum road capacity[35].

The infrastructure cost values are estimated based on the European infrastructure cost model developed in Deliverable 2 and are expressed in Euro-2000. In many cases the infrastructure costs are based on data for earlier years. For some Member States[36] these cost estimates are based on extrapolation of data for other Member States. *Marginal* infrastructure costs are estimated by estimating the variable part of infrastructure costs.

Revenues are from kilometre based charges (tolls), also based on the model developed for IMPACT Deliverable 2. They are generally derived from specific charge rates; they may not in every case represent the statistical average per vehicle category. Note that the tolls for HGV on motorways in the Czech Republic that were introduced in 2007 are not included.

We show comparisons for both metropolitan areas and interurban motorways. These two cases can be regarded as a kind of best case and worst case, respectively, because external cost levels per kilometre are highest in metropolitan areas and lowest on motorways. All cases are at daytime (noise costs). For passenger cars we show two cases: a Euro 3-diesel car in metropolitan area (Figure 2) and a Euro 5-petrol car on interurban motorways (Figure 3). For LDV (Figure 4, Figure 5) and medium size trucks (about 12 tonnes; Figure 6 and Figure 7) we show a Euro 2 both in a metropolitan area and on interurban motorways, because other Euro standards are not available from the data of Deliverable 2. For the largest trucks of more than 32 tonnes, the most relevant ones in the light of the Eurovignette Directive, we show a Euro 2-truck in metropolitan areas (Figure 8) and both a Euro 3- and Euro 5-truck on interurban motorways (Figure 9).

Because of the fact that the data has been gathered from various data sources and is partly based on extrapolation, the graphs shown in this section should be interpreted with some care. Particularly some of the estimates for infrastructure costs have been constructed using rather rough extrapolation. From the comparison of marginal costs and marginal taxes/charges, the following conclusion can be drawn:

- There are no kilometre related charges on urban and metropolitan roads, while kilometre related costs in metropolitan areas are much higher than in interurban areas, making the gap between charges and costs highest there.
- In most countries there are no kilometre related charges on motorways, thus also on motorways transport users do not pay their marginal costs. Even in countries with motorway tolls (either electronically or with office boxes), their

[35] See also the chapter on congestion cost in IMPACT Deliverable 1.

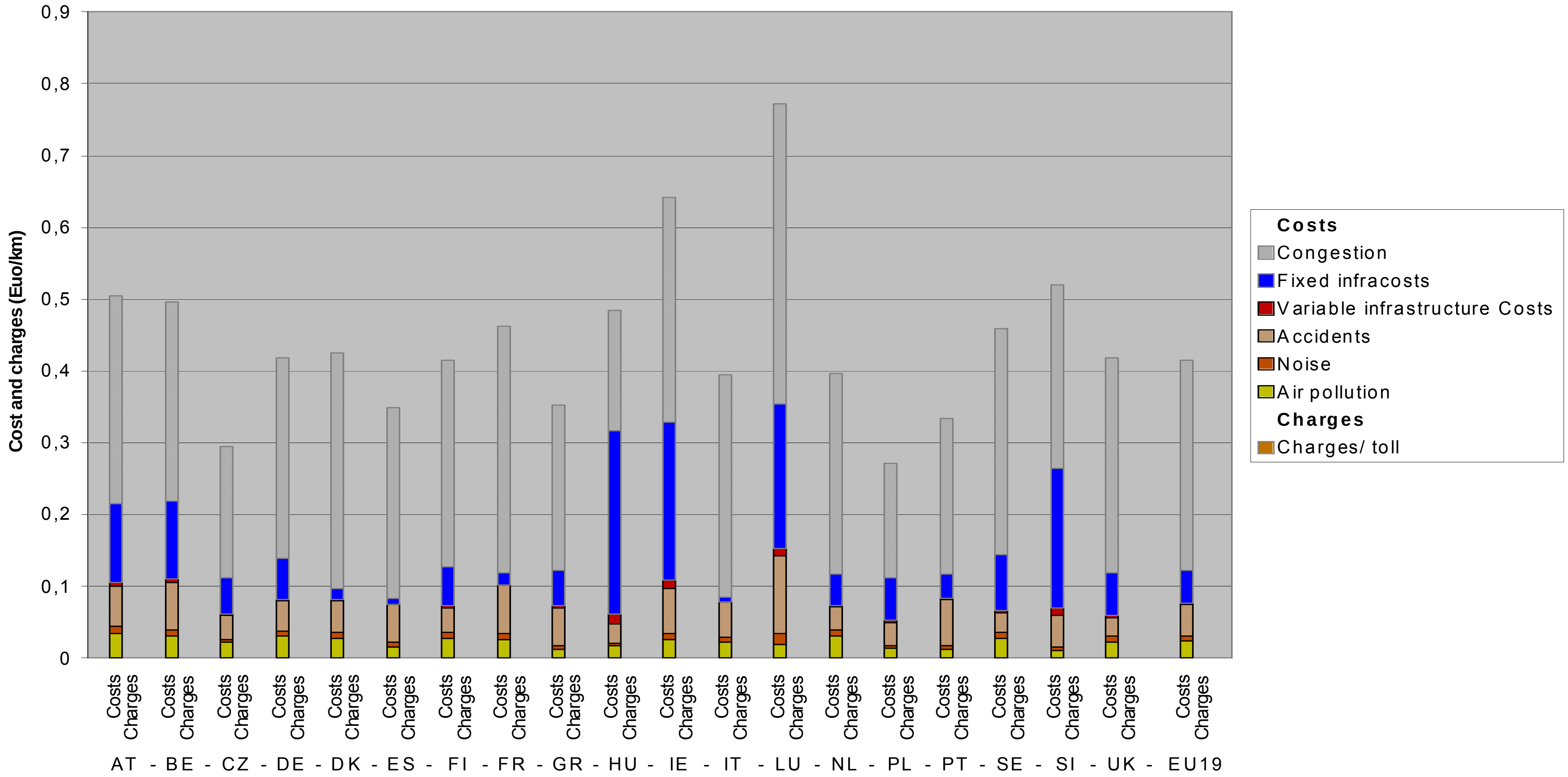
[36] This is the case for BG, CY, CZ, EE, LT, LV, MT, NO, PL, RO, SI and SK; see also IMPACT Deliverable 2.

level is still much lower than the marginal costs in congested areas. On non-congested motorways, the existing charges do sometimes cover just part of the infrastructure costs, while in a few exceptions they cover or even exceed the total infrastructure and marginal external costs, particularly for small trucks.

- In heavily congested areas, congestion costs are dominant. In non-congested metropolitan areas accidents are generally the highest externality; for HGV also air pollution costs (and for the largest HGV in some countries marginal infrastructure costs as well) can be very significant. For HGV on motorways air pollution and marginal infrastructure costs are the dominant marginal cost components.
- For a big HGV (>32 tonnes), the marginal external and infrastructure costs of a Euro 3-truck on a congested motorway can be several times higher than the marginal external and infrastructure costs of a Euro-on a motorway without congestion.

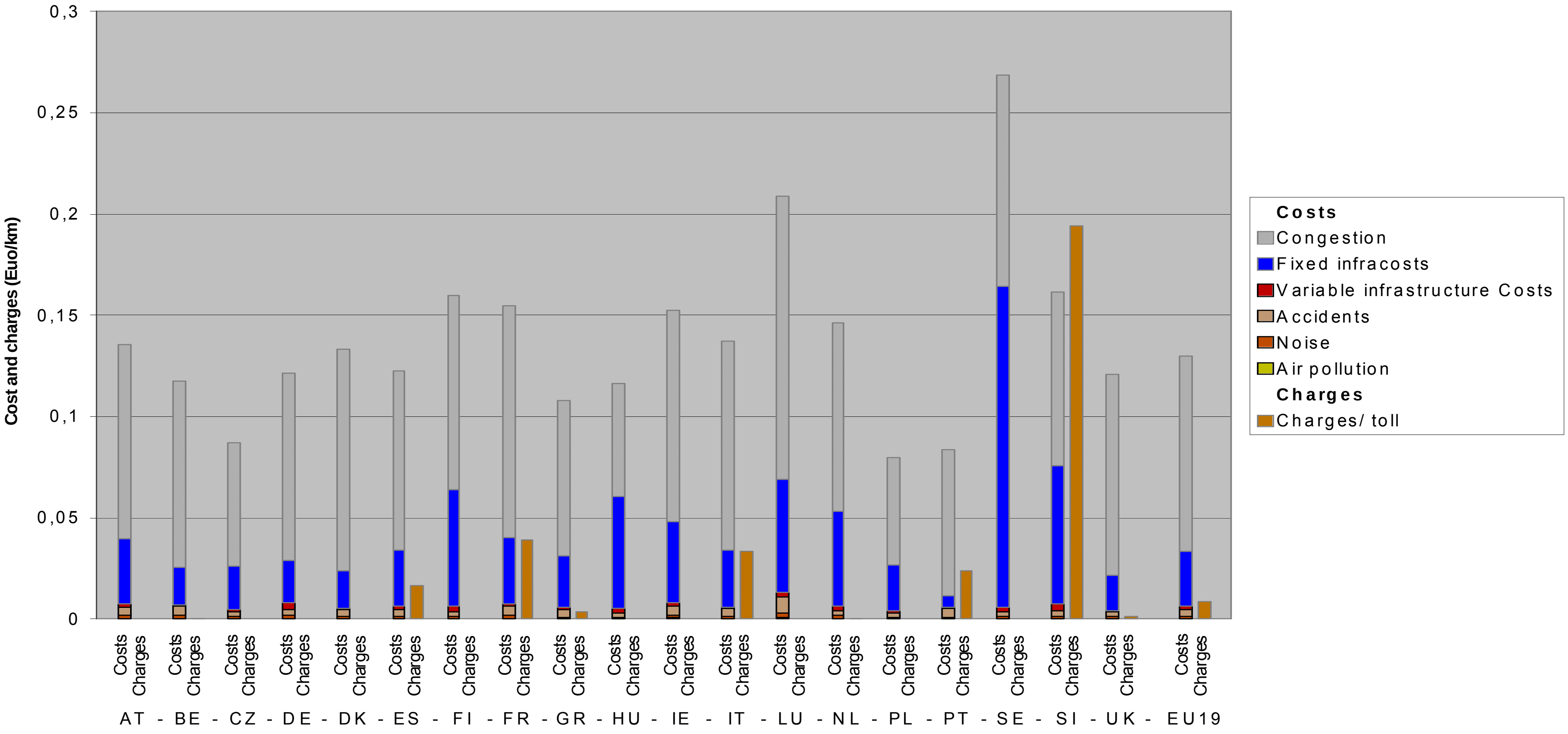
The data from the graphs for EU-19 have been include in Annex J.

Figure 2 Marginal kilometre related costs and existing kilometre charges (which are zero for all countries) - Big passenger car - Diesel - Euro 3 - Metropolitan (€$_{2000}$/vkm, 2010)



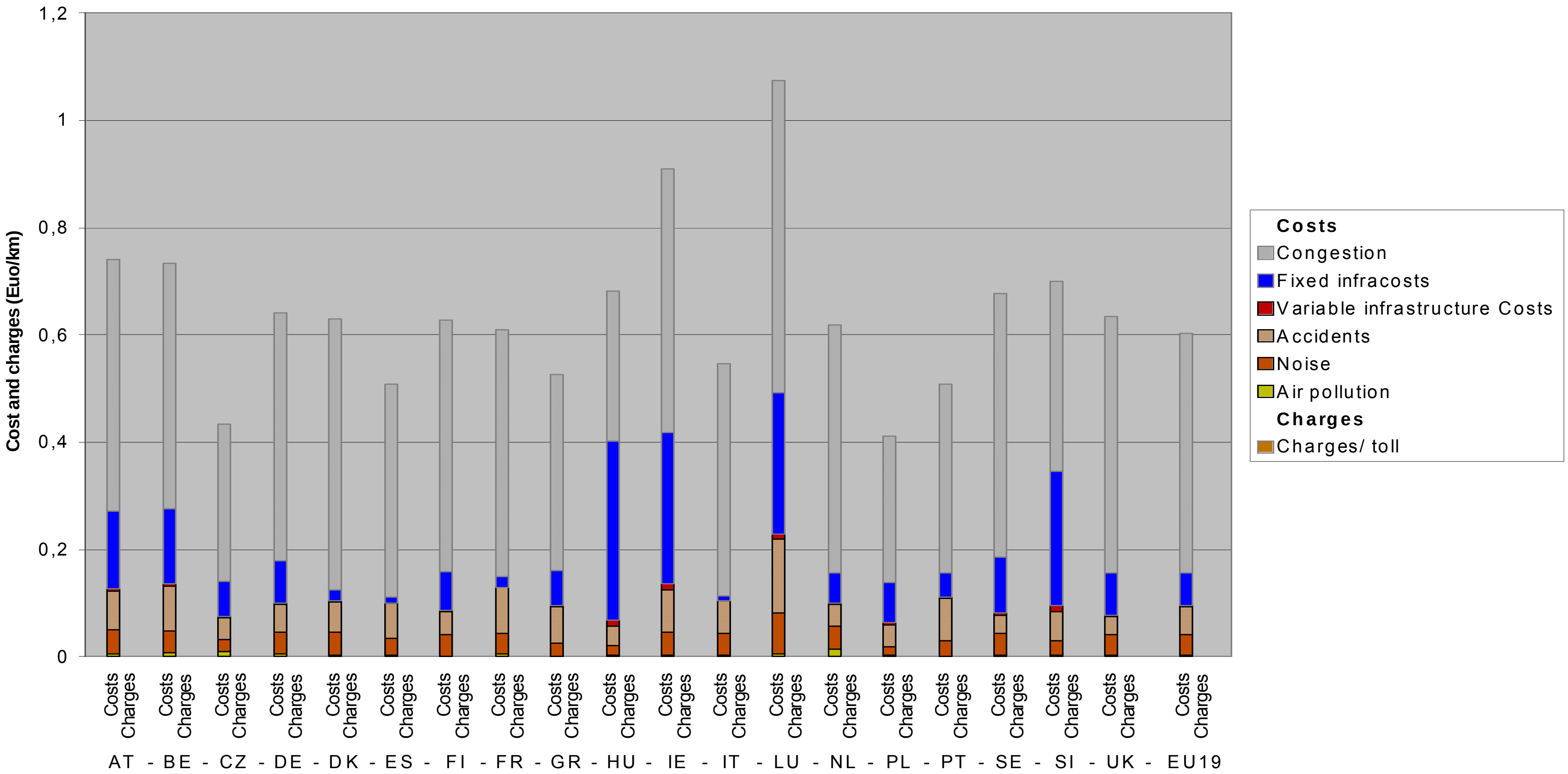

Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

Figure 3 Marginal kilometre related costs and existing kilometre charges (which are zero for many countries) - Big passenger car - Petrol - Euro 5 - Motorway (€$_{2000}$/vkm, 2010)



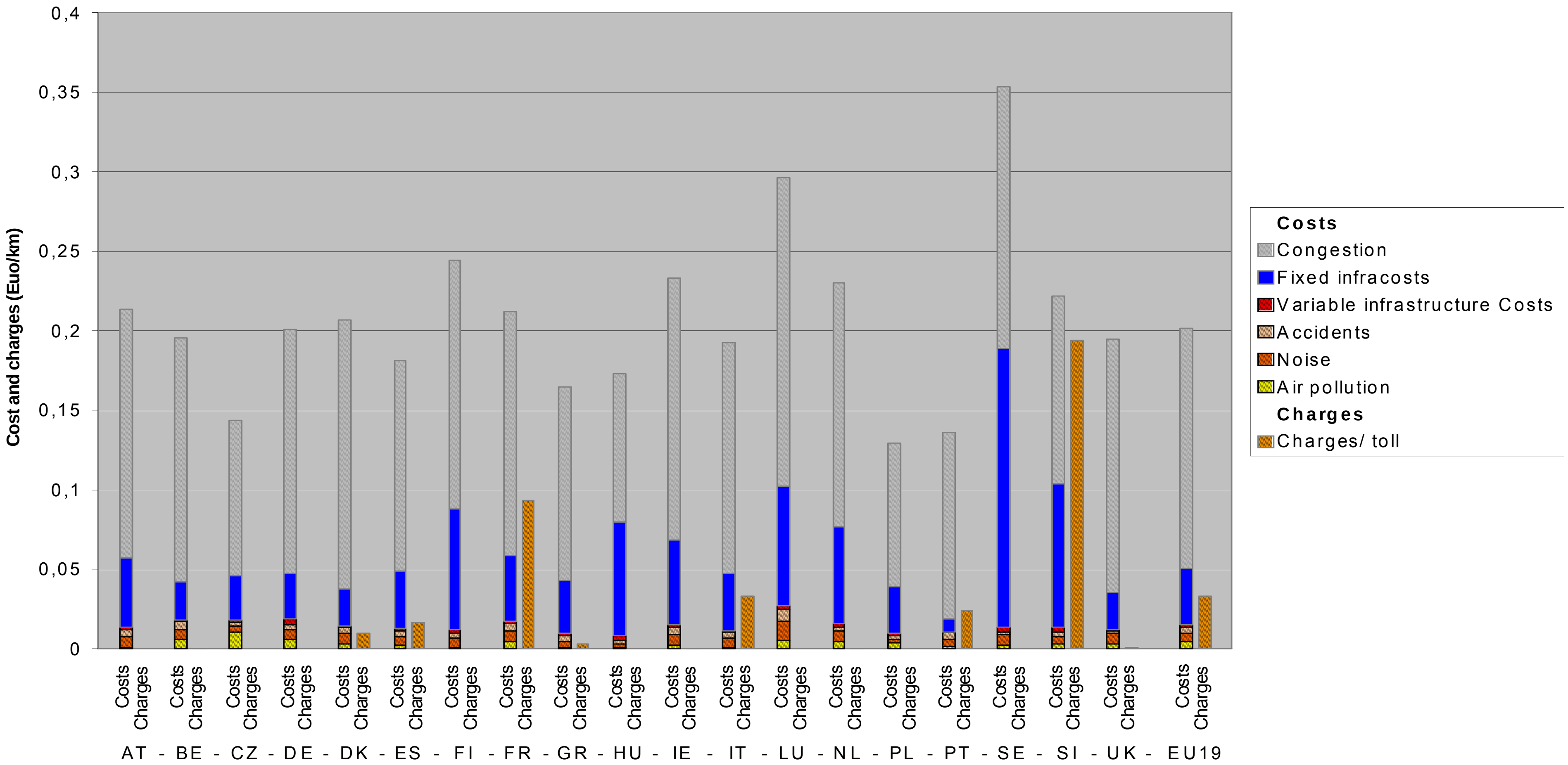

Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

Figure 4 Marginal kilometre related costs and existing kilometre charges (which are zero for all countries) - LDV - Diesel - Euro 2 - Metropolitan (€$_{2000}$/vkm, 2010)



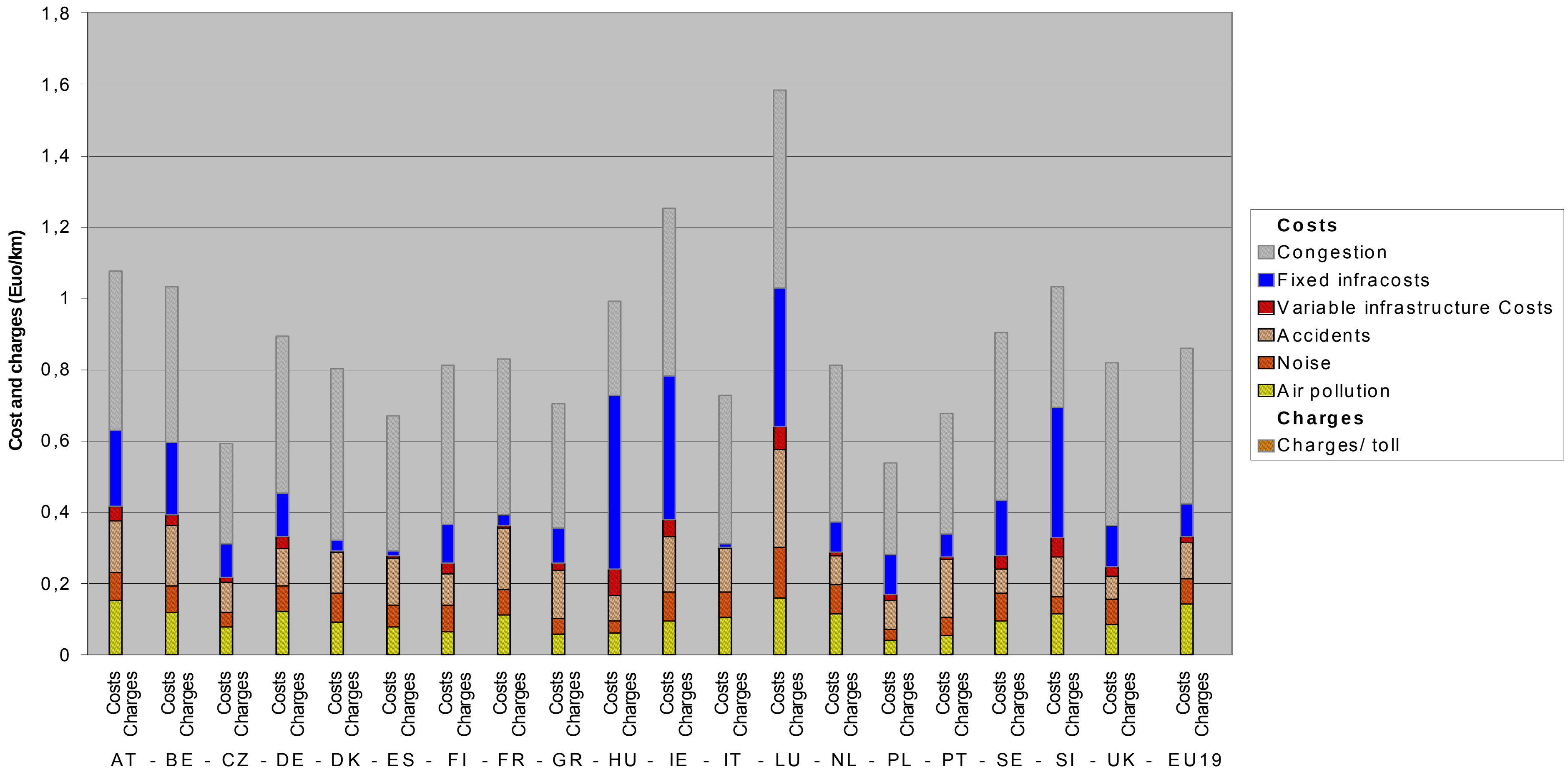

Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

Figure 5 Marginal kilometre related costs and existing kilometre charges (which are zero for many countries) - LDV - Diesel - Euro 2 - Motorway (€$_{2000}$/vkm, 2010)



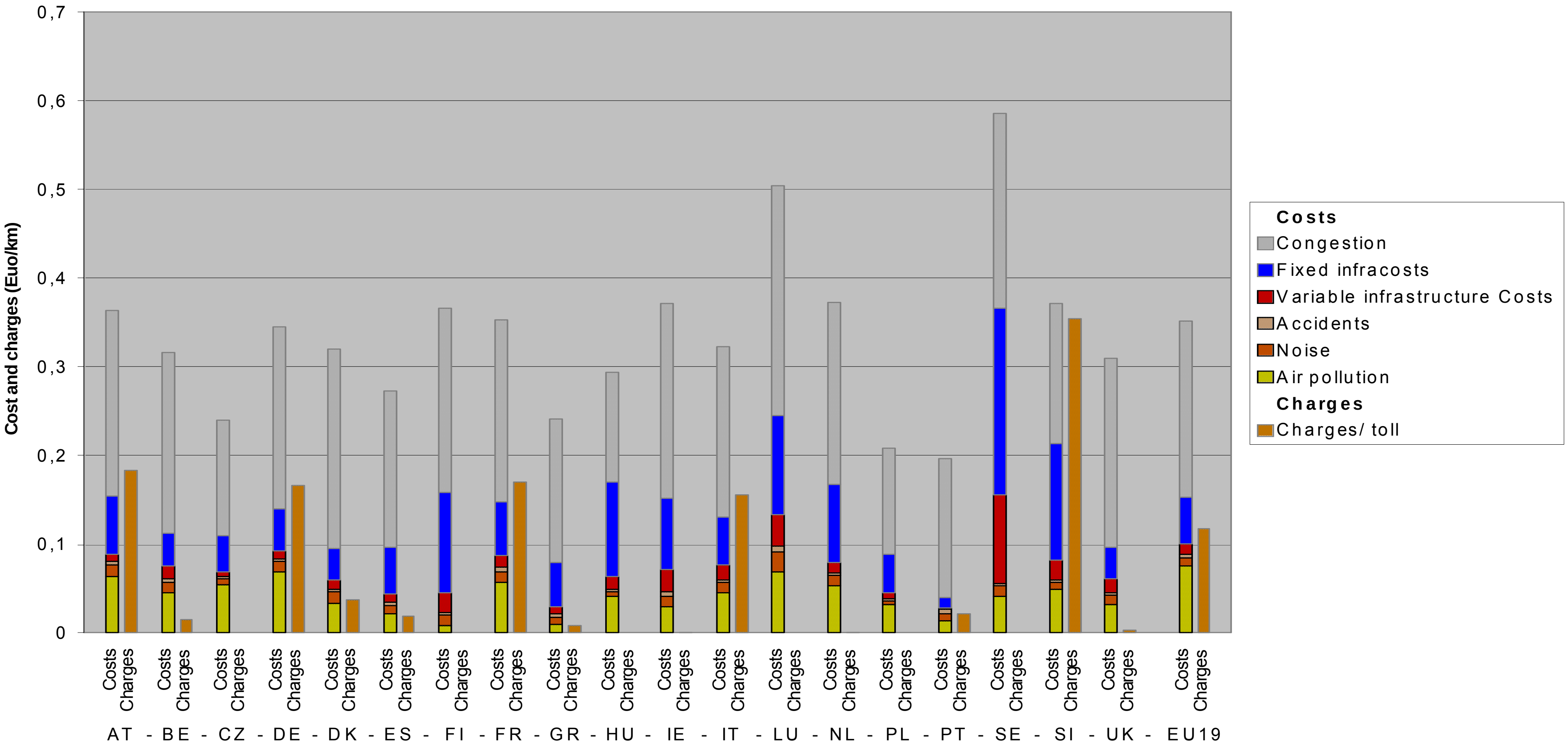

Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

Figure 6 Marginal kilometre related costs and existing kilometre charges (which are zero for all countries) - HGV -7.5-16 tonnes - Euro 2 - Metropolitan (€$_{2000}$/vkm, 2010)



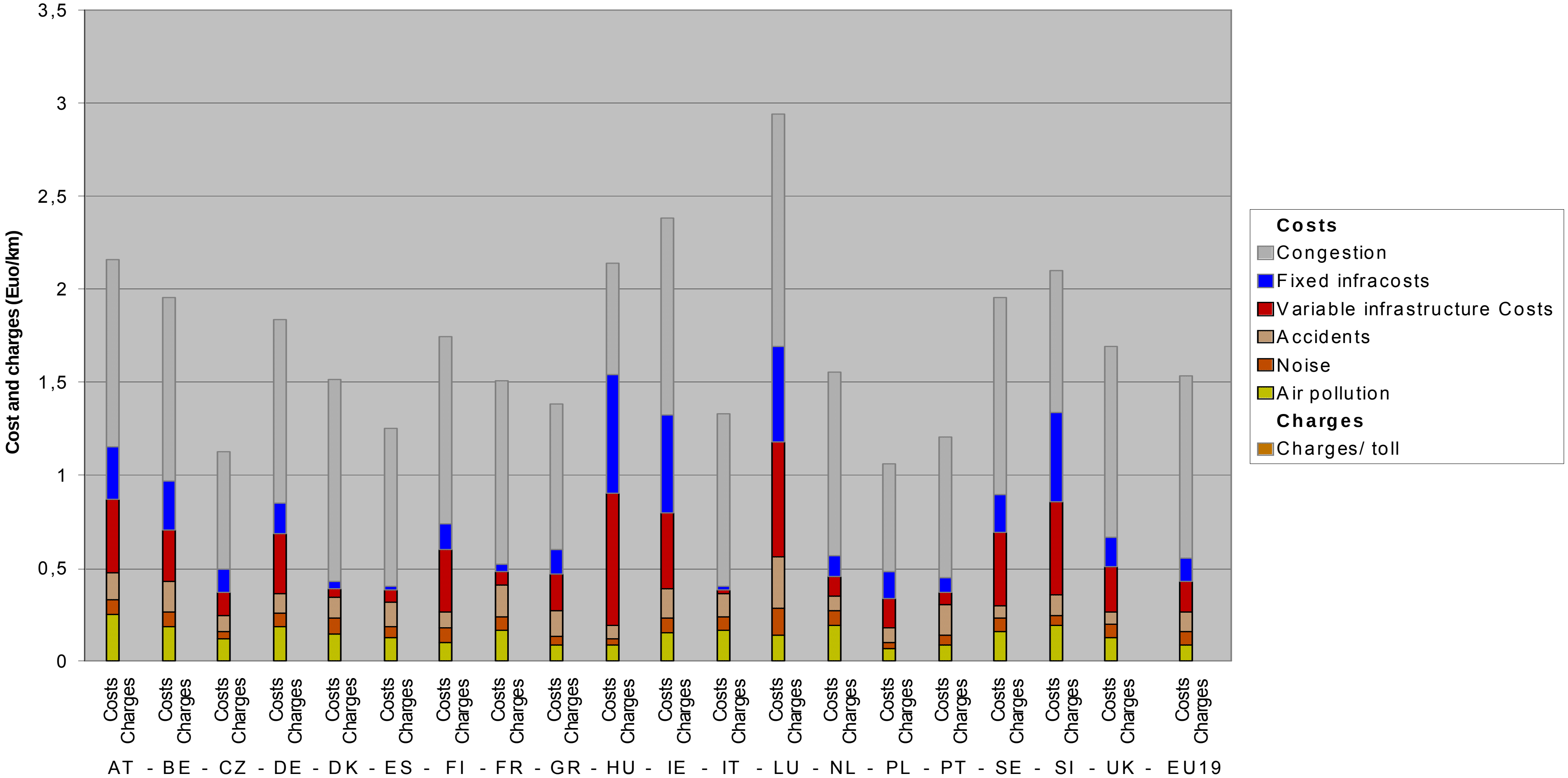

Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

Figure 7 Marginal kilometre related costs and existing kilometre charges (which are zero for some countries) - HGV -7.5-16 tonnes - Euro 2 - Motorway (€$_{2000}$/vkm, 2010)



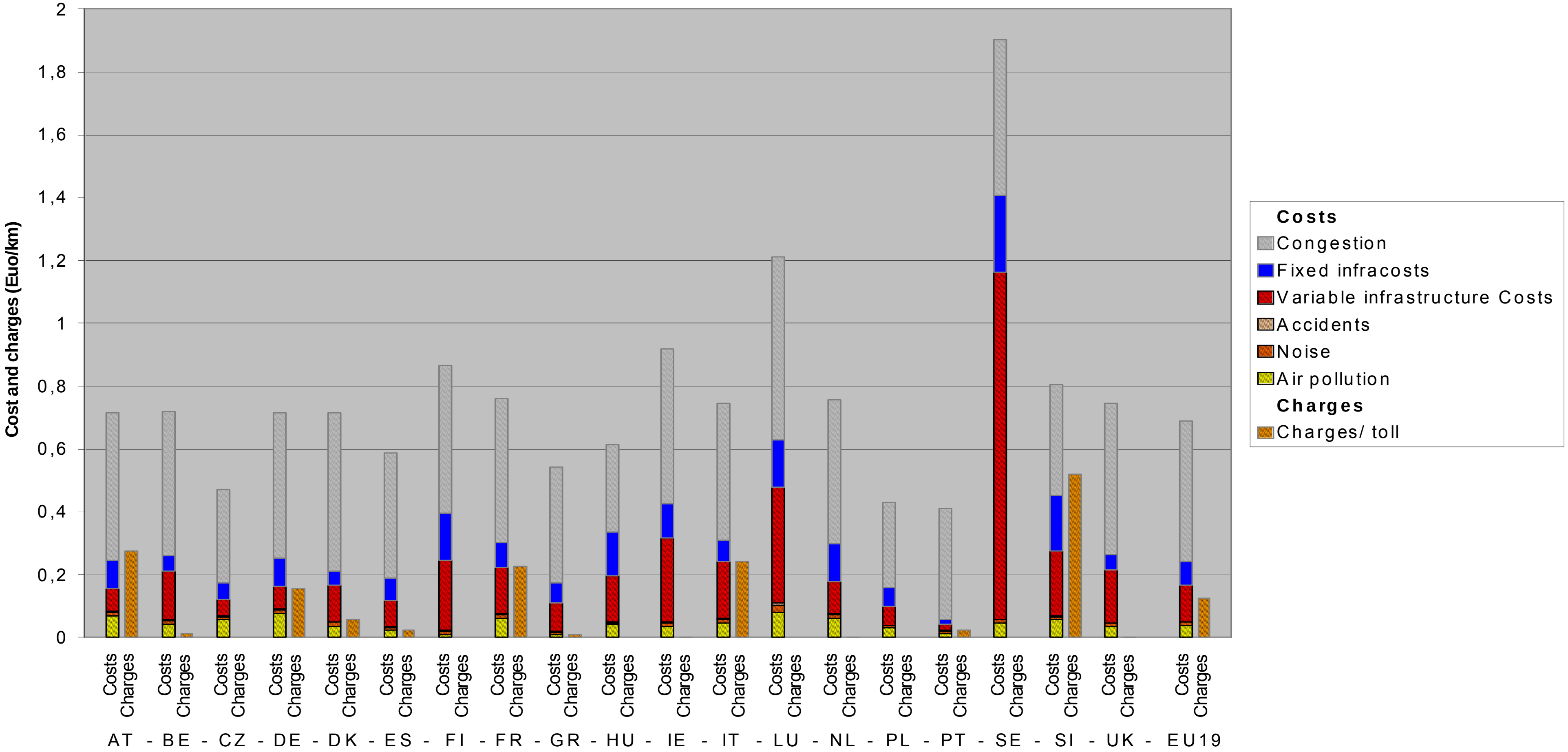

Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

Figure 8 Marginal kilometre related costs and existing kilometre charges (which are zero for all countries) - HGV - 32+ tonnes - Euro 2 - Metropolitan (€$_{2000}$/vkm, 2010)



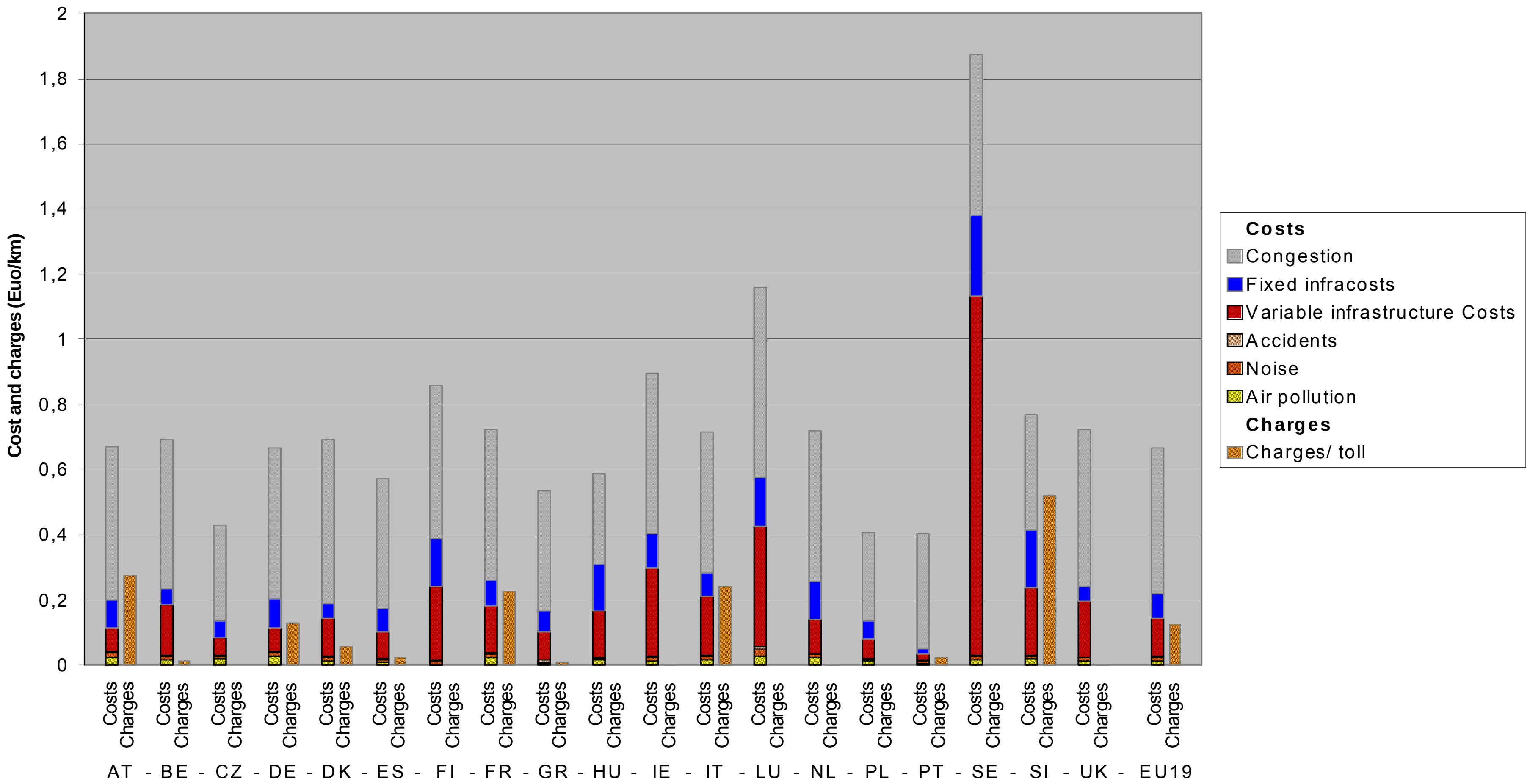

Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

Figure 9 Marginal kilometre related costs and existing kilometre charges (which are zero for some countries) - HGV - 32+ tonnes - Euro 3 - Motorways (€$_{2000}$/vkm, 2010)




Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

Figure 10 Marginal kilometre related costs and existing kilometre charges (which are zero for some countries) - HGV - 32+ tonnes - Euro 5 - Motorways (€$_{2000}$/vkm, 2010)




Note: Infrastructure costs for some countries based on extrapolation. Based on TREMOVE emission data.

### 3.4.3 Revenues from marginal social cost based pricing

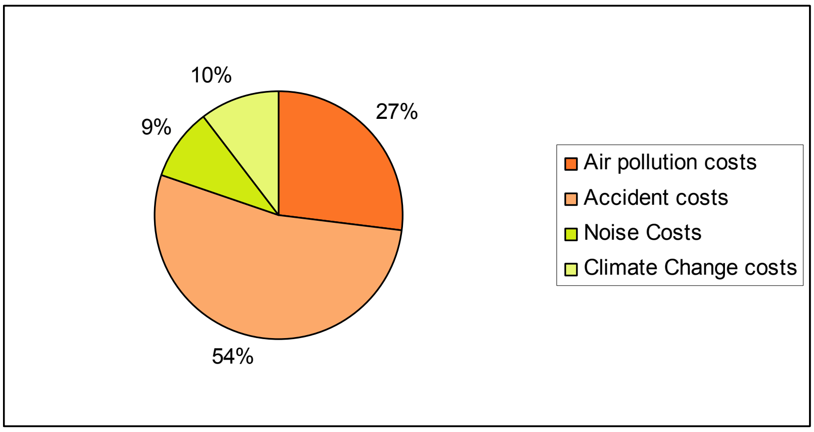
In this section we present a similar comparison as in the previous two sections, but at a macro-level. Applying the TREMOVE data on emission factors and vehicle-kilometres, the marginal cost and existing taxes charges per vehicle have been summarized.

With the TREMOVE model and the external cost estimates from the handbook (IMPACT Deliverable 1), the summarized marginal external costs of climate change, air pollution, noise and accidents for road transport in the EU-19 in 2005 have been calculated to be more than 153 billion Euro (in Euro-2000). This estimate should be regarded as a lower boundary since it does not include higher cost estimation of noise at night times nor the higher external costs in specific sensitive areas (e.g. alpine regions). External costs that are not directly related to vehicle use are not included: costs of up and downstream processes, nature and landscape and security of energy supply.

Note that this estimate does not yet include congestion costs. The congestion costs in EU-15 plus Norway and Switzerland have been estimated at 63 billion Euro-2000 by (INFRAS/IWW, 2004a). UNITE estimated the congestion costs even higher: 68 billion Euro in 1998 (Euro-1998) for EU-15, but without Italy, Belgium, Sweden, Finland and Luxemburg. COMPETE (2006) has also investigated congestion levels in many countries. Because of different estimation methods applied in the various countries, COMPETE did not manage to present congestion estimates nor external cost estimates for the whole EU. However, various country case studies of COMPETE show that the overall congestion levels increase strongly. More recently the Eddington study presented forecasts with strongly increasing congestion levels for the UK (DfT, 2006). With the estimates from UNITE and (INFRAS/IWW, 2004a) and the strongly increased congestion levels, the summarized marginal congestion costs in EU-19 can be expected to be in the order of magnitude of 100 billion Euro a year.

The shares of the main cost categories in external road transport costs are shown in Figure 11. Congestion costs are not included. As an indication of the change in shares with congestion included: based on the rough 100 billion estimate, congestion would get a share of 40% of the total costs (the share of accidents is then reduced from 54 to 32%; and all other costs are reduced proportionally.

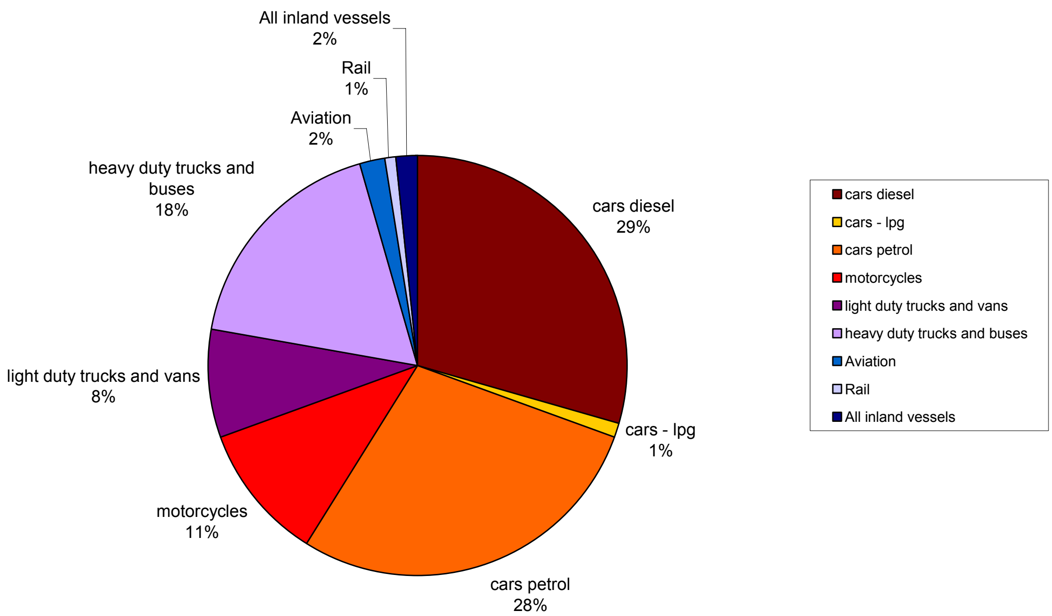
Figure 11 Share of the various cost categories in the external costs of road transport (excl. congestion)




Note: The shares depicted relate to costs for EU-19 in 2005.

The external costs of the non-road modes are considerably lower. Figure 12 shows the shares of the various modes. Again, higher valuation of night time noise is not taken into account because of lack of data. Maritime shipping is also not included because of lack of data. The share of aviation includes all flights departing from an airport in the EU. The climate impacts of non $CO_2$ emissions from aviation are not included. Including these, the share of aviation would roughly doubly.

Figure 12 Share of the various modes in the summarized marginal external costs (excl. costs of congestion and maritime shipping)




Note: The shares depicted relate to costs of climate, air pollution, noise and accidents for EU-19 in 2005 and are based on TREMOVE data on vehicle kilometre, emissions and fuel consumption. Congestion costs and the external costs of maritime shipping are not included because of lack of data. The non-$CO_2$ climate impacts of aviation are not included either.

For road transport, the assessment above and IMPACT Deliverable 2, makes it possible to make an overview of both the summarized marginal external costs[37] and the total infrastructure costs. This overview is given in Table 5. For comparison also fixed and total costs and revenues and the total revenues[38] from taxes and charges from Deliverable 2 are included as well as cost coverage percentages. For the non-road modes such an overview has no added value because it lacks taxes or charges that could be regarded as internalizing external costs[39].

The table shows the costs and revenues at four different levels:
1 Kilometre-related costs and revenues.
2 Fuel-related costs and revenues.
3 Fixed costs and revenues.
4 Total costs and revenues.

The overview of Table 5 shows the same picture as Figure 2 to Figure 10: kilometre related charges are much lower than the kilometre related marginal costs even when congestion costs are not yet included. Existing fuel taxes (serving also other aims, see section 3.2.4) exceed climate change costs.

Note that unlike the graphs in section 3.4.3, the table shows the data summarized for all traffic situations and vehicle types within each mode. Therefore the cost coverage data are different from the ones presented in Table 5 and Annex I, which are all per vehicle-km and for *specific traffic situations and vehicle types*.

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37 As stated before, these are not equal to the *total* external costs because of the difference between marginal and average costs. The total costs will be higher.

38 The revenues from Deliverable 2 which are for 2005 have been extrapolated to 2010 by using the expected growth rate of vehicle-kilometres as a proxy for the growth of the revenues.

39 Apart from payments for covering infrastructure costs.

Table 5 Comparison of revenues from existing and marginal costs based taxes and charges for road transport, **excluding congestion costs** (EU-19, for 2005 in billion €-2000)

| Billion Euro | Cars | LDV | HGV | Bus | Motorcycles | All road vehicles |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Marginal kilometre-related costs** | **91** | **14** | **50** | **20** | **9** | **184** |
| Variable infrastructure | 6 | 0.5 | 25 | 16 | 0.1 | 47 |
| Air pollution | 18 | 5 | 16 | 2 | 0.4 | 41 |
| Noise | 8 | 3 | 3 | 0.4 | 0.3 | 14 |
| Accidents | 61 | 6 | 6 | 1.2 | 8 | 81 |
| Congestion (rough estimate) | | | | | | (100) |
| **Kilometre charges/tolls** | **5** | **3** | **15** | **0.1** | **1** | **24** |
| **Cost coverage. excl. congestion** | **5%** | **22%** | **31%** | **0%** | **6%** | **13%** |
| | | | | | | |
| **Marginal fuel-related costs** | **24** | **3** | **8** | **0.9** | **0.3** | **42** |
| Climate change | 10 | 1.2 | 4 | 0.4 | 0.1 | 22 |
| Well to tank emissions | 14 | 1.4 | 4 | 0.5 | 0.2 | 20 |
| Security of supply | | | | | | Pm |
| **Fuel taxes** | 176 | 20 | 32 | 3 | 2 | **250** |
| **Cost coverage** | **726%** | **752%** | **418%** | **384%** | **517%** | **599%** |
| | | | | | | |
| **Fixed costs** | **132** | **13** | **21** | **3** | **2** | **172** |
| Fixed infra costs | 119 | 12 | 15 | 2 | 2 | 151 |
| Other external costs | 13.1 | 1.4 | 6 | 0.7 | 0.4 | 22 |
| **Fixed taxes/charges** | **58** | **3** | **5** | **1.4** | **6** | **73** |
| **Cost coverage** | **44%** | **25%** | **24%** | **45%** | **242%** | **42%** |
| | | | | | | |
| **Total costs. excl. congestion** | **248** | **30** | **79** | **24** | **11** | **398** |
| **Total costs. incl. congestion (rough estimate)** | | | | | | **498** |
| **Total taxes and charges** | **238** | **27** | **52** | **5** | **8** | **348** |
| **Cost coverage excl. congestion** | **96%** | **89%** | **66%** | **20%** | **71%** | **87%** |
| **Cost coverage incl. congestion (rough estimate)** | | | | | | **70%** |

Note: Calculated with data on vehicle kilometres, fuel consumption and emissions from TREMOVE (version 2.5.1) and valuation of external costs from IMPACT Deliverable 1. Revenues and infrastructure costs from IMPACT Deliverable 2. Total external costs are higher than shown here since the marginal costs are in some cases lower than the average costs. Note that the data on revenues and infrastructure costs are based on estimations and extrapolation of data for a limited number of countries (from IMPACT D2). Over time the revenues from marginal cost based charges for climate change strongly increase, while for air pollution they tend to decrease. Data for other years are given in Annex I.

From a fairness point of view, it is also interesting to compare total revenues and total costs. However, we can not really make a valid comparison since summarized marginal costs are not equal to total external costs. Still, comparing the total revenues of all existing taxes and charges of road transport (about 350 billion) we can see that they are lower than the summarized marginal infrastructure and external costs (about 500 billion, including a rough estimate for congestion).

So, we conclude that total revenues from existing taxes and charges are much lower than total external costs of road transport. The difference between costs and revenues is largest for buses and HGV. For passenger cars costs and revenues are almost balanced. Note that this type of comparison is particular important from a fairness point of view, but less relevant from the perspective of Marginal Social Cost Pricing.

## 3.5 Overview of selected scenarios

In this section we present the scenarios that have been modelled. Some reflect many of the considerations of section 3.2 and 3.3. However, scenarios sometimes also deviate from the proposals made there, for the following reasons:

- Not all measures that would be preferable can be modelled, in particular many types of differentiation and congestion charging[40].
- The ultimate list of scenarios for the modelling work is a compromise, which was the result of a joint meeting with various DGs from the European Commission. Particularly scenario 2 and 3 have been added there as simplified variants of the more sophisticated scenarios 4 and 5.

In addition to the set of scenarios presented here, the Commission services have also carried out an Impact Assessment on a different set of scenarios, which was further developed with the draft results of the impact assessment of IMPACT. The results of this impact assessment will be presented by the Commission Services.

All scenarios describe the changes in price levels and price structures compared to the baseline (time period 2005-2020). They cover all transport modes and all relevant external cost categories. To some extent they are hypothetical, because they assume all Member States to implement a similar set of internalisation measures.

Under guidance by the Commission services, the scenarios have been inserted into two models (TRANS-TOOLS and TREMOVE) to assess the impact, of the different scenarios (see also section 4.2).

[40] It was not possible to model differentiation of LTO charges to noise class or $NO_x$ emission factor, differentiation of kilometre charges to Euro standard, time of the day (peak/off peak, day/night) and vehicle noise emission class, differentiation of harbour dues to emission standard (e.g. Euro standard for inland vessels).

The scenarios that have been subject to the modelling are the following:
- Scenario 1 - Reference scenario - including policy in pipeline.
- Scenario 2 - Internalisation through fuel and energy taxes.
- Scenario 3 - Internalisation through km based, LTO based and harbour charges.
- Scenario 4 - Smart charging:
  - Variant A - efficient infra charging.
  - Variant B - existing fuel excise duties.
- Scenario 5 - Pragmatic approach:
  - Variant A - HGV kilometre charges on all roads.
  - Variant B - HGV kilometre charges on motorways only.

Note that all scenarios 2-5 describe the changes with respect to the reference scenario, Scenario 1. Scenarios 2 to 5 contain various approaches for internalizing the five following externalities: climate change, air pollution, noise, accidents and congestion[41]. All scenarios:
- Have the same approach for using revenues: recycling in general budget.
- Use per cost category the same level for external cost estimates.

The scenarios have different strategies for internalising the external costs of transport throughout the EU. Scenario 2 internalises all costs by flat fuel taxes. Scenario 3 internalises all costs via flat kilometre charges. It should be noted that both scenarios have a very crude way of charging for external costs, which can not be regarded as true internalisation since the charges do not well reflect the cost drivers. Scenario 4 can be regarded as reflecting the internalisation approaches proposed most closely. It internalises external costs by a combination of fuel taxes (climate change costs) and kilometre based charges (environmental and accident costs). In scenario 4, congestion costs are internalised by congestion charges, differentiated to the average daily congestion level (not modelled with TREMOVE). Scenario 5 is an adapted scenario 4, without kilometre charging for passenger cars in order to limit implementation costs. Scenario 5 also includes a pragmatic approach for the internalisation of congestion costs by the introduction of local congestion charges at the most congested roads only (not modelled with TREMOVE).

In section 3.4.2, we saw that there are big differences between the toll levels in the various Member States. Existing tolls do generally not match with the infrastructure costs. In the various scenarios two alternative treatments of road infrastructure costs have been considered: leaving current charge levels unchanged (Scenarios 1 to 3) or replacing current charges by the variable external infrastructure costs as a proxy for the marginal external infrastructure costs (Scenarios 4 and 5). Scenario 3, 4 and 5 include also measures for internalising congestion costs. A short summary of the scenarios is given in Table 6. A more detailed scenario description can be found in Annex C.

The various scenarios have an impact on the differences between marginal costs and the kilometre related charges which were presented in section 3.4.2. The

[41] Security of supply is out of the scope of the study.

impacts depend on the scenario. In scenario 2, the gap in kilometre related costs and kilometre related charges is not filled at all because this scenario only includes changes to fuel taxes. In scenario 3, the charges for internalising marginal external costs are put on top of the *existing* infrastructure charges. In countries where current tolls exceed the marginal infrastructure costs, this results in overall charges higher than the marginal cost level, while in countries with current tolls below marginal infrastructure cost level, the overall charges in Scenario 3 are still below marginal costs. In scenario 4 (and for HGV also in scenario 5A), the road tolls are on average equal the marginal external cost; so the gap has been reduced to zero. In scenario 5B, this is just the case for HGV on motorways. It should be note that also in scenario 4 and 5, in specific situations there can still be differences in external costs and charge levels, because of the limited differentiation to vehicle type, time of the day and location.

Table 6 Summary of IMPACT scenarios

| Scenario | Infra charges | Circulation. tax | Fuel tax | Bottleneck/ cordon charges |
|---|---|---|---|---|
| 1 Reference | Km tolls, incl. fixed infra charges (revenue neutral) | Current purchase + circulation taxes, $CO_2$ based (revenue neutral) | EU minimum where national rates are lower; elsewhere current rates | - |
| 2 Internalisation through fuel taxes | As (1) | As (1) | EU minimum + external costs (accidents, air, noise) | |
| 3 Internalisation through kilometre charges | As (1) + circulation taxes (1) for cars (revenue neutral) + externalities (accidents, air, noise) for all vehicles, all roads | None for cars *(TREMOVE only)*, as (1) for HGVs | EU minimum | Flat charge on all roads at average congestion costs *(TRANS-TOOLS only)* |
| 4A Smart charging with minimum fuel tax | Marginal infra costs + externalities (air, accidents, noise) for all vehicles | None for cars *(TREMOVE only)*, as (1) for HGVs | As (3) | Congestion charge, differentiated to location, not to time of the day *(TRANS-TOOLS only)* |
| 4B Smart charging with current fuel tax | | | As (1) | |
| 5A Pragmatic, HGV charges on all roads | As (1) for cars, marginal infra costs + externalities (air, accidents, noise) for HGVs on all roads | As (1) for all vehicles + externalities (noise, air, accidents) for cars *(TREMOVE only)* | As (1) for all vehicles except HGV; reduction by increase of other taxes (not below minimum) for HGV | As (4) |
| 5B Pragmatic, HGV charges on motorways | As (5A) with HGV charges on motorways only | | | |

EU minimum = minimum excise duty rates as foreseen by the Commercial Diesel Proposal.

### 3.5.1 Scenario 1: Reference scenario - including policy in pipeline

The reference scenario is built on the current situation. So for all modes all currently existing taxes, charges and regulation remain in force. This includes existing infrastructure charges, fuel taxes, harbour dues, etc. The baselines of the models used for the model runs are designed to reflect the current situation, so including all existing taxes and charges.

In addition to the current situation, the reference scenario assumes that all policy proposals that are in the pipeline are implemented as well as the options offered by 2006/38/EC are used by all Member States, including (introduction year of these measures assumed according to current plans):

- Commercial Diesel Proposal (an increase of the minimum fuel excise duties on road diesel and petrol).
- $CO_2$ car taxation proposal (abolishment of purchase tax and increase of circulation taxes by the same amount (revenue neutral per country), differentiation of 50% circulation taxes to fuel efficiency of the car, based on $CO_2$ emission rate compared to the average).
- ETS for aviation with a trading price of € 30 per ton of $CO_2$ (equal to the average shadow price in 2005-2020).
- Fuel efficiency target for new passenger cars (130 g/km target from 2012).
- 10% bio fuels target from 2010.
- Toll system for HGV in all Member States on all Motorways replacing all fixed user charges for HGV (only the 'Eurovignettes', revenue neutral per country[42]).
- Mark-up of 25% in mountainous areas, with special focus on regions in Alps and Pyrenees[43].

With regard to the car taxation proposal, the differentiation of half of the circulation taxes to the fuel efficiency is not so straight forward. The impacts of differentiation to fuel efficiency within a size category can not be modelled by TREMOVE and TRANS-TOOLS. Differentiation of circulation taxes to size categories is already significant all over Europe. It is not clear if the car taxation proposal would change these existing differentiations of circulation taxes to size categories. Therefore, no further differentiation to size categories has been added.

With regard to the Commercial Diesel Proposal, the table below lists the minimum excise duties for diesel and petrol according to this proposal. Some Member States benefit from transitional periods and will only reach the minimum levels later (up to 2013). Under the new proposal they would all have to introduce the further increases two years later than the old Member States, i.e. up to 2017.

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42 This is actually a variabilisation measure. This may result in relatively low rates for the infrastructure cost part. The reason for proposing this particular specification, is that this project is not about new methods for infrastructure cost recovery. Scenario 4 and 5 include an alternative approach for this.

43 (EC, 2004) on analysis of mountain areas in EU Member States, acceding and other European countries has been used.

Table 7 Minimum excise duties for diesel and petrol according to proposal, €/100 l

| | 2007 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|
| Diesel – EU-15 | 302 | 330 | 359 | 380 | 380 |
| Petrol – EU-15 | 359 | 359 | 359 | 380 | 380 |
| Diesel – EU-10 | Per country | 302 | 302 | 359 | 380 |
| Petrol – EU-10 | Per country | 359 | 359 | 359 | 380 |

Source: Commercial Diesel Proposal.

### 3.5.2 Scenario 2: Internalisation through fuel and energy taxes

This scenario is based on internalisation through fuel taxes for all relevant cost categories, for all modes of transport. In this scenario all existing kilometre charges (of scenario 1) remain unchanged. No new systems are introduced, because this scenario assumes internalisation via fuel taxes in addition to existing kilometre charges.

The idea behind this is that all external costs are internalized at low implementation costs, but in a relatively rough way.

Compared to scenario 1, the following changes are made. In all countries, the road fuel taxes for petrol and diesel are first decreased to the minimum levels according to the Commercial Diesel Proposal and then increased by the average level of the external costs (air pollution, accidents and noise). Note that in this scenario, road diesel taxes for HGV and passenger cars differ from each other.

The fuel excise duties in rail (diesel)[44] and aviation are increased/introduced by the level of the external costs (air pollution, accidents and noise). For electric trains energy taxes (per kWh) are increased by the level of the external costs (air pollution, accidents and noise). For inland and maritime shipping fuel taxes are introduced at external cost level as well (air pollution and climate).

For some modes climate change costs are regarded to be internalised already (for road by existing fuel excise duties; for aviation and electric trains by ETS).

### 3.5.3 Scenario 3: Internalisation through km based, LTO based and harbour charges

This scenario is similar to scenario 2, but instead of internalising of the external costs through an increase of the fuel taxes, in this scenario charges are used for all the external costs for all modes. The type of charges is based on kilometres, LTO's or harbour visits, depending on the mode.

This scenario assumes that kilometre charges are introduced in all countries for all **road** vehicles on all roads. The base levels of these charges for passenger cars and LDV will replace the revenues of the existing circulation taxes of

[44] Ideally we should correct for the existing fuel excise duties for rail diesel (also in scenario 3-5). However, it lacks an overview of the rates and it is unclear how these existing excise duties for rail diesel are included in the models.

scenario 1, which are abolished in this scenario (note that in scenario 1 vehicle purchase taxes were already replaced by higher circulation taxes)[45].
For HGV, the base charge per km (on all roads), is equal to that in scenario 1.

For **all other modes**, the existing infrastructure charges are used as base level and increased by external cost charges per kilometre (rail and inland shipping), LTO cycle (aviation) or harbour visit (maritime shipping).
For road, additional charges per km are introduced for the following external costs[46], in TRANS-TOOLS differentiated to type of road (in the TREMOVE modelling differentiations were not possible):
- Air pollution.
- Accidents.
- Noise.

In line with the approach of scenario 2, all road fuel taxes (both petrol and diesel) in this scenario are set at the minimum fuel tax levels.

For rail (both diesel and electric), mark-ups to the existing infrastructure charges are introduced, for the following external costs:
- Air pollution.
- Accidents.
- Noise.
- Climate (for diesel only, for electric trains already internalised by ETS).

The charges for inland waterways, aviation and maritime shipping are for the same external costs as in scenario 2 and they not further differentiated, because this was not possible for the models.

### 3.5.4 Scenario 4: Smart charging

In this scenario, new variable taxes and charges are introduced to adhere as close as possible to the cost drivers that cause the external effects. This scenario is as close as possible related to marginal cost pricing principles, to the extent possible with the available models[47] (except for fuel taxes which are not lowered below the minimum fuel tax levels[48]). Scenario 4 has two variants that differ in the way the existing taxes and charges for road transport are dealt with.

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45 For the modelling this change in price structure has no effect, since both TREMOVE and TRANS-TOOLS use generalized costs in which fixed and variable costs are reflected similar way.
46 In this scenario, climate cost are regarded to be internalised already by existing fuel tax.
47 Charges are much less differentiated than in an optimal scheme, because of limitations of the models.
48 Note that this constraint was added for fiscal and political reasons. From the perspective of economic efficiency this constraint is not optimal.

On top of scenario 1 a mix of kilometre/harbour/LTO charges (all modes) and fuel/energy taxes (waterborne modes and rail diesel only) is introduced. For all modes, climate change costs are internalised like in scenario 2[49] and all other external costs are internalised like in scenario 3 (with the same type of differentiations).

As scenario 3, this scenario assumes that kilometre charges are introduced in all countries for all road vehicles on all roads. The base level of these charges is different however. The base levels of the kilometre charges in this scenario are the marginal infrastructure costs.

Congestion costs of road transport are internalised by bottleneck charging (cordon charging can be modelled by neither TRANS-TOOLS nor TREMOVE).

The fuel excise duties for road diesel and petrol in this scenario are the following:
- Scenario 4A: in all countries the minimum levels according to the Commercial Diesel proposal (see Table 7).
- Scenario 4B: same levels as in scenario 1.

### 3.5.5 Scenario 5: Pragmatic approach

This scenario is the same as scenario 4B, with the following adjustments:
- No new kilometre charges for passenger cars. Internalisation of external costs of passenger cars by increasing the existing circulation taxes of scenario 1 by external costs of air pollution, noise and accidents (only modelled by TREMOVE) and the introduction of local congestion charging schemes for passenger cars in heavily congested areas (also not modelled by TREMOVE).
- Excise duties for trucks are lowered with the increase of the total revenues of all other taxes and charges but not below the minimum fuel tax levels[50].
- Km charging for HGV only (at marginal cost level).

There are two variants of scenario 5:
- Scenario 5A: HGV km charging on all roads.
- Scenario 5B: HGV km charging on motorways only.

[49] The fuel based internalisation of climate cost may be implemented by a fuel tax or ETS. The impact of these two options in the modelling work is the same, in practice the impacts of these two options may be different.

[50] Except for the UK, this means road fuel excise duties for HGV end up at the minimum level of the Commercial Diesel proposal, because the current diesel excise duties are lower than the sum of the minimum diesel excise duty in the Commercial Diesel Proposal (€ 380 per ton) and the sum of the new charges for internalisation (calculated per litre of fuel). Only in the UK the level remains higher than the minimum level.

# 4 Impact assessment of selected scenarios

## 4.1 Introduction

This chapter gives an overview of the results of the impact assessment that has been carried out for the internalisation scenarios presented in the previous chapter. For the impact assessment, two models have been run: TRANS-TOOLS (by the Joint Research Centre of the European Commission (IPTS, Seville), under responsibility of DG TREN) and TREMOVE (by LAT, under responsibility of DG Environment).

Section 4.2 gives a brief introduction to the models that have been used and their input data.

In section 4.3 to 4.5 we present and discuss the modelling results per type of impact:
- Impacts on transport sector (section 4.3).
- Impacts on the external effects (section 4.4).
- Economic impacts (section 4.5).

The models used were not able to catch all relevant impacts. Particularly the impacts of congestion charging and the impacts of charge differentiations could not be modelled appropriately. Therefore, in addition to the modelling results, information from other sources has been included in these sections, to get a more complete picture of the impacts that are to be expected from the internalisation scenarios.

An assessment of the implementation costs has been included in section 4.6. Finally, section 4.7 gives an overview of the main conclusion from the impact assessment.

In addition to the set of scenarios presented here, the Commission services have also carried out an Impact Assessment on a different set of scenarios, which was further developed with the draft results of the impact assessment of IMPACT. The results of this official Impact Assessment on various policy options will be presented by the Commission Services.

## 4.2 Overview of models used

The models used for the impact assessment are both models with a European scope. The type of modelling is different however: TRANS-TOOLS is a network model in which national and international traffic patterns are simulated. TREMOVE consists of transport models at country level. Each country model is based on aggregated data, not with a network model. TREMOVE has sophisticated data on vehicle fleets, technology and emissions. A more detailed description of both models can be found in Annex F.

Table 8 shows per indicator used in the impact assessment which model provided the data.

Table 8 Overview of indicators used for the impact assessment and the models used for assessing them

| **Impact, changes in:** | **TREMOVE** | **TRANS-TOOLS** | **Assessment by CE Delft, based on literature** |
|---|---|---|---|
| ***Transport*** | | | |
| The vehicle stock per vehicle type | ✓ | | |
| Mileage given in vkm, pkm and tkm (*transport demand*, *modal shift*) | ✓ | ✓ | |
| Occupancy rates or load factors | ✓ | | |
| Number of transport fatalities | | ✓ | |
| ***Environment and other external effects*** | | | |
| Emissions ($C_6H_6$, $CH_4$, CO, $CO_2$, FC, $N_2O$, NMVOC, $NO_X$, PM, $SO_2$, and VOC) due to modal choice and reducing mileage | ✓ | | |
| Total fuel consumption | ✓ | | |
| Infrastructure bottlenecks and congestion points (lowest regional average travel speed due to congestion) | | ✓ | |
| ***Economy*** | | | |
| External costs through emissions | ✓ | ✓ | |
| Implementation costs | | | ✓ |

Note: All TRANS-TOOLS results do not include the impacts on intra-NUTS-3 traffic, which is roughly the traffic for which origin and destination are within one and the same province.

### 4.2.1 Limitations of the modelling work

The TRANS-TOOLS runs for IMPACT do not include intra-NUTS-3[51] traffic. This is roughly all traffic of which origin and destination are both in the same province. Therefore the results of the two models are not in all cases comparable.

The model results show many impacts, but they are not able to show the full potential of pricing measures because of some limitations of the models used. The main impacts which can not or only partly be assessed by the models are the following:
- Impacts of smart congestion charging, in particular congestion charging in urban areas and smart bottleneck charges differentiated to both location and time of the day. In the TREMOVE modelling, congestion charges and their impacts are not included at all.
- Impacts of various types of differentiation which are relevant from the perspective of smart charging but which were not included in the modelling scenarios because of model limitations. Differentiation to Euro standard, location and time of the day have not been included in the TREMOVE runs.

[51] NUTS-3 is a grid for geographical models in which the cells have the size of about the size of provinces.

- In TRANS-TOOLS no changes in the fleet mix are modelled, as they are implemented as an exogenous variable. This means that the impacts of changes in fixed taxes such as circulation taxes or vehicle purchase taxes can not be modelled by TRANS-TOOLS. Also the impacts of variable taxes and charges on fleet mixes are not modelled. The TREMOVE runs do also not include the impacts of price changes on the shares and volumes of different vehicle types (fuel type, small/big cars, Euro standard). Impacts on the fuel efficiency of cars *within* each vehicle class are modelled neither. This means that both models do strongly underestimate the impacts of internalisation measures on emission reduction.
- Impacts on load factors are not included as they are implemented as an exogenous variable in TRANS-TOOLS.
- The maritime module of TREMOVE can not deal with taxes and charges and therefore has not been used here. Within TRANS-TOOLS maritime shipping could only be included in a very rough way (based on average data for all ships, so without distinguishing any ship characteristics, including size).

The modelling work by TREMOVE covers 19 countries: EU-15 + Poland, Czech Republic, Hungary and Slovenia. The modelling work by TRANS-TOOLS covers the whole EU-25 and also Romania, Bulgaria, Switzerland and Norway.

### 4.2.2 Model input

Scenario 1 has been modelled by adjusting the regular baseline of both models according to the definition of scenario 1 (see section 3.3.1). This modelling step was carried out by the modellers without additional input from the IMPACT consortium.

The model input for all other scenarios (scenario 2-5) describes the changes in taxes and charges. These changes have been calculated by the IMPACT consortium based on:
- The scenario definition (see section 3.3).
- The external costs from the IMPACT handbook on external costs (Deliverable 1 of this project, (CE Delft, 2008):
  - Congestion costs: Central values from Table 7 (page 34). Values for all countries were retrieved by scaling with GDP/capita (PPP adjusted).
  - Accidents costs: Unit values for each country from Table 10 (page 44 and 45).
  - Air pollutions costs: Unit values for each country from Table 13 (page 54) and Table 14 (page 55); emissions factors from TREMOVE Base Case (model version 2.5.1).
  - Noise costs: Unit values from Table 22 (page 69) and Table25 (page 71). Values for all countries were retrieved by scaling with GDP/capita (PPP adjusted).
  - Climate change costs: Central values from Table 27 (page 80); emissions factors from TREMOVE Base Case (model version 2.5.1).

For the translation of the changes in taxes and charges per tonne of emission to changes per vehicle kilometre, LTO or litre of fuel, data from the TREMOVE scenario 1 output has been used (fuel consumption, vehicle kilometre and emissions). The result of this translation was a set of input data for EU-19. The Joint Research Centre has extrapolated the input data for the other 6 EU Member States, in order to run the TRANS-TOOLS model for EU-25.

## 4.3 Impacts of the internalisation scenarios on the transport sector

In this section and the following sections, we present the impacts of the internalisation scenarios:
- Impacts on transport sector (section 4.3).
- Impacts of the internalisation scenarios on the external effects (section 4.4).
- Economic impacts (section 4.5).
- Estimation of implementation costs (section 4.6).

Except for the estimation of implementation costs, these impacts are based on the output of the modelling work. Because of limitations of the modelling work also additional evidence has been added on potential impacts of internalisation measures.

In this section 4.3 we discuss the impacts on the transport sector. First of all we give an overview of the changes in the average tax and charge level per mode. Next, we present the impacts of the scenarios on the transport volumes.

Table 9 gives an overview of the changes in the overall level of taxes and charges per mode in each of the scenarios (without the impacts of these changes on the transport volumes, so not showing the net revenues). A more detailed overview is given in Annex G.

Table 9 Summarized changes in total taxes and charges per scenario, per mode (2010)

| Total increase in charges/taxes in 2010 (billion €$_{2000}$) | Freight | | | | Passenger | | | |
|---|---|---|---|---|---|---|---|---|
| Scenario | Road | Rail | IWW | Total freight | Road | Rail | Aviation | Total passenger |
| 2 | 29 | 1 | 1 | 31 | 60 | 1 | 2 | 63 |
| 3 | 29 | 1 | 1 | 31 | 60 | 1 | 2 | 63 |
| 4A | 51 | 1 | 1 | 54 | 30 | 1 | 2 | 33 |
| 4B | 56 | 1 | 1 | 59 | 66 | 1 | 2 | 69 |
| 5A | 53 | 1 | 1 | 55 | 96 | 1 | 2 | 100 |
| 5B | 4 | 1 | 1 | 6 | 96 | 1 | 2 | 100 |

Source: Summarized modelling input data (based on TREMOVE 2.44 fleet and mileage data for 2010, EU-19).

Remark: These data do NOT show changes in overall revenues, since they are based on traffic volumes in the baseline. For TREMOVE runs, so not including congestion charges.

### 4.3.1 Freight transport volume

The changes in taxes and charges result in changes in transport volumes. TRANS-TOOLS calculates the changes in both tonnes lifted and the number of tkm.

Figure 13 shows the TRANS-TOOLS results for the impact of the different scenarios on the absolute freight volumes in tonnes lifted.
In Figure 14 and Figure 15 the changes in freight volumes expressed in tkm are shown as calculated by TRANS-TOOLS and TREMOVE respectively.

According to both models the road transport volumes in tkm decrease and the largest decrease is shown in scenario 4B and 5A (TREMOVE: 5%, TRANS-TOOLS 7% decrease). Also scenario 3 shows a relatively large decrease in transport volumes in both models. The smaller decrease in scenario 4A compared to scenario 3 in TRANS-TOOLS can be explained by the more differentiated congestion charges giving road users more options for avoiding high charges.

Both models show quite a big difference between scenario 5A and 5B: the charge on motorways only has a much smaller effect than a charge on all roads.

According to TRANS-TOOLS, in almost all cases the decrease in numbers of tonnes lifted is significant lower than the decrease of the number of tkm. This implies a decrease in average trip length for all modes (the load factors are constant in the TRANS-TOOLS model).

The two models show different impacts on the non-road modes. TREMOVE results show a modest decrease in transport volumes which is almost constant over the various scenarios (2% for rail, 4% for inland waterways). This can be explained as the impact of the price changes for the non-road modes which are also (in average Euro per vehicle kilometre) the same in all scenarios. TREMOVE shows decreasing volumes for the non-road modes and no or very small net modal shift. In TRANS-TOOLS it is the other way around. The transport volumes of the non-road modes both expressed in tonnes lifted and in tkm *increase* significantly. The changes in the number of tkm do not vary a lot, except for an increase of rail and inland waterways in scenario 2 that is smaller than in the other scenarios. The tonnes lifted show a more heterogeneous picture. In scenario 2 particularly maritime transport profits from the decrease in road, while in the other modes also rail and inland waterways increase their shares significantly. The increasing volumes for the non-road modes in the TRANS-TOOLS results can only be explained by modal shift resulting from the higher road prices. Note that the non-road modes are priced similarly in all scenarios so the difference between the scenario should be the result of these changes as well[52]. The changes in non-road tkm for TREMOVE seem almost insensitive for the changes in road pricing. In TRANS-TOOLS the non-road modes are much

[52] The measure differs per scenario (fuel tax, charge or mix of both), but the average price changes are identical.

more sensitive but the changes in tkm can not easily be explained by the price changes.

For comparison, we also estimate the changes in transport volumes with available price elasticities. In scenario 2, 2010 fuel prices are first decreased to the minimum values of the Commercial Diesel proposal and then increased by 30 cents per litre for HGV diesel. Together this is a price increase of roughly 25%. With available estimates for fuel price elasticities on kilometres driven (short term -0.10 to -0.14 long term[53]), the transport volume (vehicle kilometre) is expected to decrease by 2.5% on the short run and 3.5% in the long run. This is rather well in line with TREMOVE and TRANS-TOOLS results.

In scenarios 4A, 4B and 5A, the price changes are about twice as high and related to vehicle kilometre instead of fuel. Improving fuel efficiency is in that case no option for users to avoid costs. Therefore, the impact of a given price change on transport volume is expected to be higher than in case of a fuel tax increase of the same size. With this in mind, based on elasticities, the decrease in road transport volume are in the long run expected to be at least more than 7% in scenario 4A, 4B and 5A. Again this does not diverge a lot from the model results.

Zooming in on TREMOVE results, we can see that the transport volumes of LDV and small trucks decrease much stronger than of the larger trucks. This suggests a general shift to larges vehicles and an increase in transport efficiency (because there is no significant drop in load factors).

Overall the main conclusions with respect to freight transport volumes are:
- Road transport volumes decrease because of the price changes.
- The biggest changes are found in scenarios 4B and 5A.
- Some modal shift to non-road modes can be expected. The results of the network model TRANS-TOOLS indicate that particularly for long distance modal shift to rail and waterborne modes is likely to occur.

[53] Based on Graham and Glaisters (2002).

Figure 13 Changes in freight volumes in tonnes lifted per transport mode in 2020 (TRANS-TOOLS)

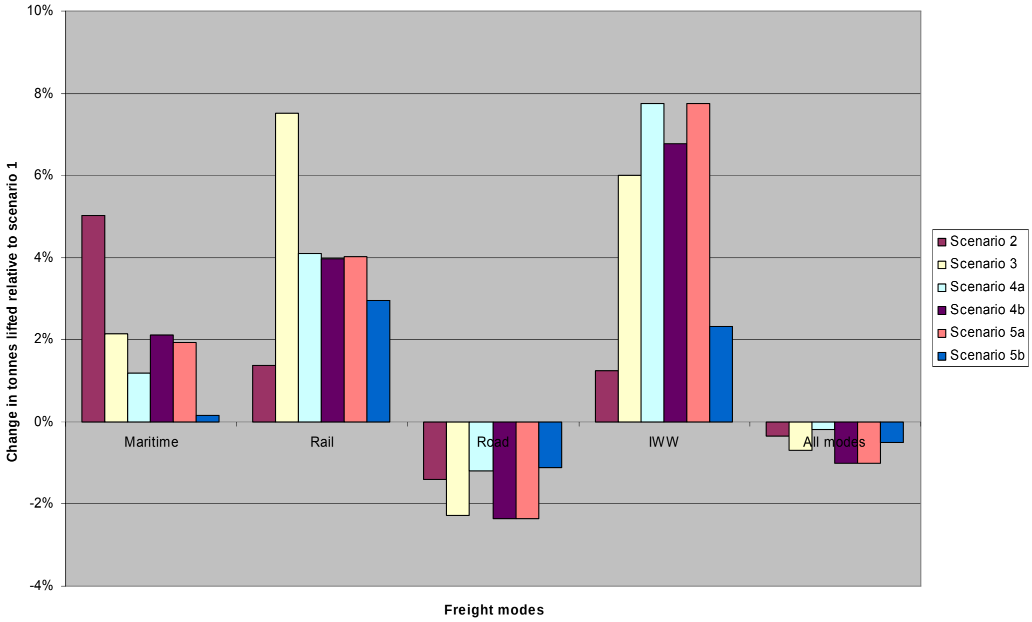



Figure 14 Changes in freight volumes in tkm per transport mode in 2020 (TRANS-TOOLS)

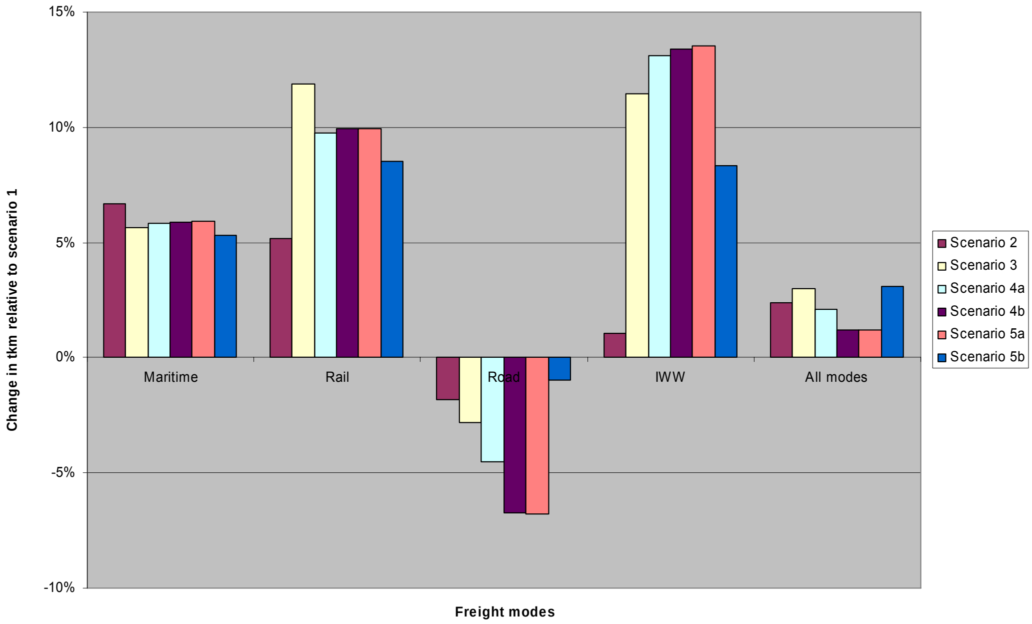
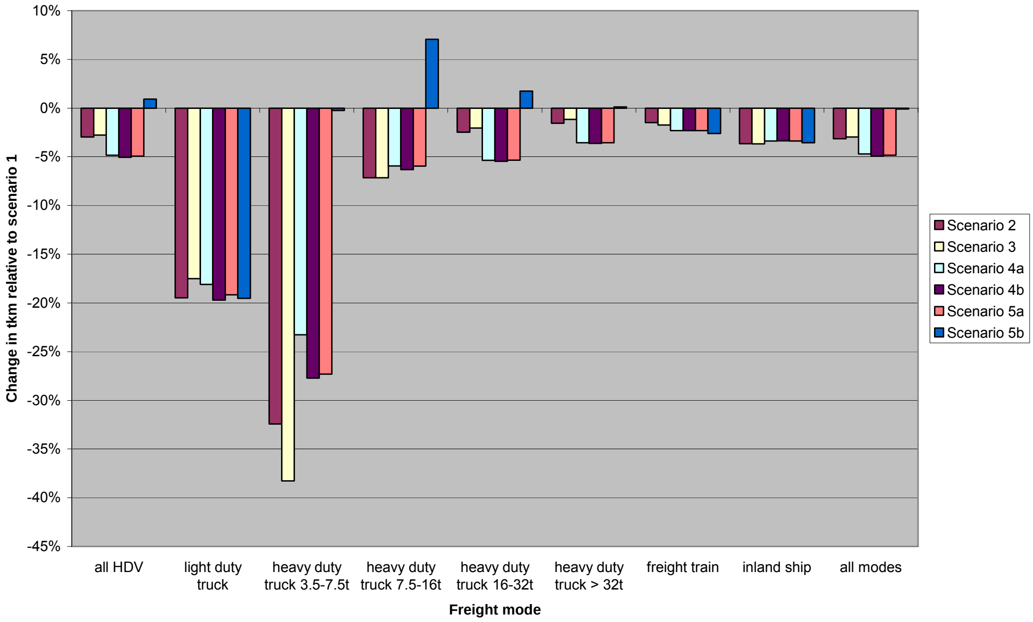


Figure 15 Changes in freight volumes in tkm per transport mode in 2020 (TREMOVE)



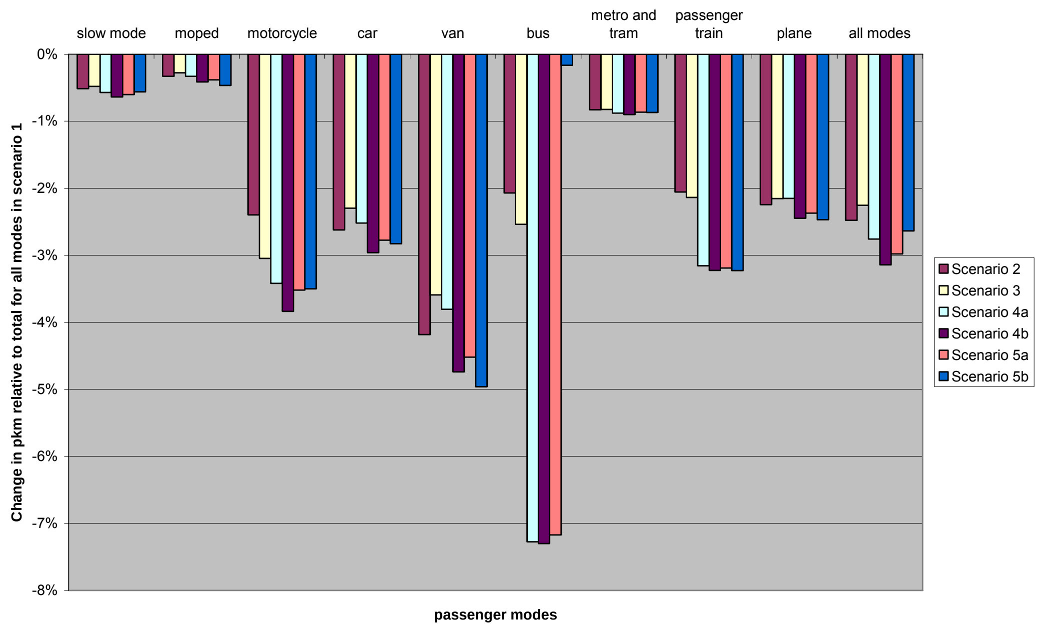

### 4.3.2 Passenger transport volume

For passenger transport only TREMOVE results are presented, because TRANS-TOOLS does not include intra-NUTS-3 traffic, which is a major share of the passenger transport related traffic.

Figure 16 depicts the changes in pkm from the TREMOVE runs. Passenger transport volumes show a modest decrease in transport volume for all modes for all scenarios. For most scenarios and most modes, the changes are all in the same range. Note that price changes in scenario 5 are changes in fixed costs (circulation taxes), while in the other scenarios the major changes are in kilometre or fuel consumption dependent taxes and charges. This explains why despite a relatively high net price increase (see Annex G), scenario 5 does not show much larger decreases in the transport volumes. The TREMOVE results suggest that there is no significant modal shift. However, as for freight transport the results of the network model TRANS-TOOLS indicate that particularly for long distance modal shift to rail transport is likely to occur.

For comparison, we also estimate the changes in transport volumes with available price elasticities. The net price increase of scenario 2 is on average about 18 cents per litre for petrol and 40 cents per litre for diesel, corresponding with a price increase of about 13 to 40%. With a price elasticity of -0.1 to -0.14 this is expected to result in a volume decrease of 1.3% (short term, petrol cars) to 7% (long term, diesel cars). This is well in line with the TREMOVE results that show a decrease of 2 to 3% for all passenger cars.

Figure 16 Changes in passenger volumes in pkm per transport mode in 2020 (TREMOVE)




## 4.3.3 Impacts on load factors and occupancy rates

The TREMOVE runs delivered data on changes in load factors and occupancy rates. The model results show only very small changes in load factors and occupancy rates (generally less than 0.5% changes). The most notable change is an increasing occupancy rate for buses of 2% in scenarios 2 and 3 and about 5% in scenarios 4A, 4B and 5A.

For comparison we also mention here the evidence from some other sources, in particular German and Swiss HGV charging. After the introduction of the German HGV charge, the share of empty rides decreased slightly, but this trend had already been going on since long and was not affected by the introduction of the charges (BGL, 2007b). In Switzerland, the average load increased with 10.6% (inland traffic) and the number of vehicle kilometre decreased significantly (23% compared with business as usual) with the introduction of the HGV charge together with a simultaneous increase in the weight limit of vehicles was (ARE, 2007). It is unclear which part can be contributed to the increase in weight limit or to the HGV charge.

## 4.4 Impacts of the internalisation scenarios on the external effects

In this section we show the impacts on fuel consumption, emissions, fatalities and congestion. Impacts on fuel consumption and emissions have been calculated by TREMOVE, impacts on fatalities are based on TRANS-TOOLS results. Impacts on congestion were not calculated by the modelling. Therefore impacts of congestion charging are discussed based on the impacts of existing schemes.

TREMOVE can show the changes in fuel consumption and emissions caused by changes in transport volumes in various parts of the network (metropolitan, urban, interurban) and types of road (motorways, urban, other roads). This includes modal shift effects. TREMOVE can also model shifts between size classes caused by the overall price changes.

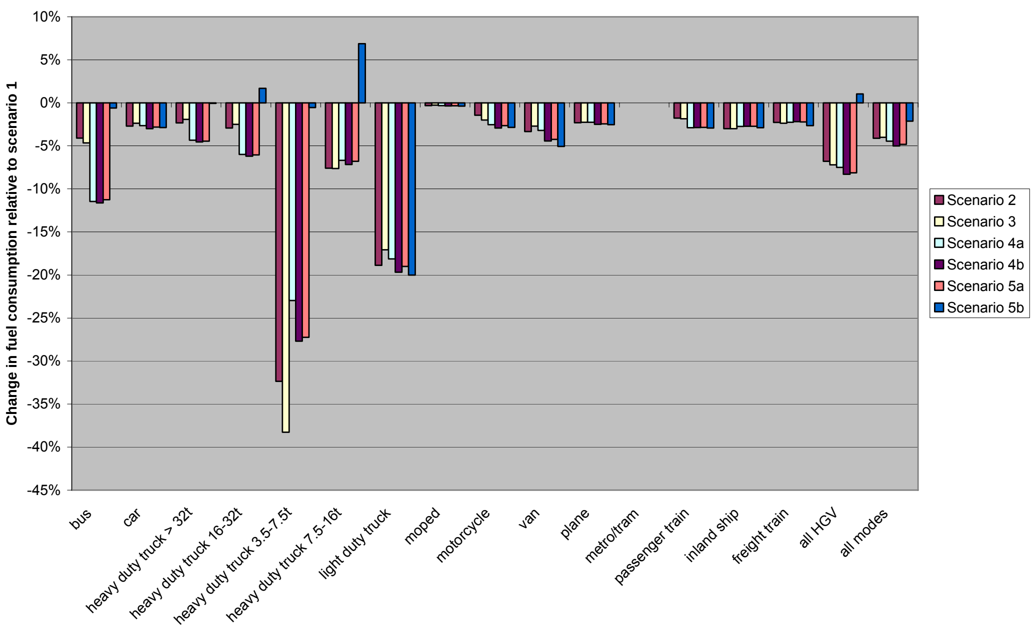
The fuel consumption (and to some extent also pollutant emissions) in scenario 1 are much lower than in the TREMOVE baseline. This can be explained by measures like binding requirements for $CO_2$ emissions of new passenger cars that are included in scenario 1, but not in the TREMOVE baseline. In this section we show the changes compared with scenario 1, indicating the impacts of the internalisation measures.

In addition it should be noted that the TREMOVE results do not include the impacts of faster fleet renewal and technological improvements resulting from charge differentiation. Therefore, the impacts on fuel consumption and emissions calculated by TREMOVE are underestimated, because important market responses on the incentives given (particularly changes in emission factors due to fleet renewal and technological improvements) can not be modelled. With evidence from implemented schemes, a more complete picture is obtained.

### 4.4.1 Fuel consumption

Figure 17 shows the relative changes in fuel consumption (TREMOVE results). The overall fuel consumption decreases with 4 to 5% in most scenarios. Only in scenario 5B, this decrease is much smaller. The reason is that in scenario 5B the charges for HGV (and buses as well) are limited to motorways.

Figure 17 Impact of the different scenarios on the fuel consumption in 2020 relative to scenario 1 (TREMOVE)



The impacts on road fuel consumption can also be estimated by applying fuel price elasticities: short term -0.25 to long term -0.64 (Graham & Glaisters 2002). Based on these numbers and the average increase in fuel price in scenario 2 of about 20% (all fuels), the fuel consumption is expected to drop 5% in the short run and up to 13% in the long run. Compared with this, the TREMOVE estimates are at the low end. This can be explained by the fact that not all impacts of higher fuel prices have been included, in particular a shift to more fuel efficient cars and driving styles. We conclude that the decrease in overall fuel consumption can be expected to be at least 10% in scenario 2. In scenario 3, 4 and 5A, the extra charges give incentives to drive less but not to drive more fuel efficient vehicles. In these scenarios the fuel consumption will be more in the order of 5%.

### 4.4.2 Emissions: model results and evidence from existing schemes

TREMOVE results show a decrease of all emissions in all scenarios. Both $CO_2$ and PM emissions decrease in most scenarios with about 5%. Only scenario 5B shows a smaller decrease (2%). Finally $NO_x$ emissions decrease with 6% in scenario 2 and 3 and with 7% in 4A, 4B and 5A. Only scenario 5B shows a smaller decrease (less than 1.5%). As stated before these results are just the emission reductions caused by the changes in vehicle kilometre.

With a differentiated charge (possible in scenario 3, 4 and 5), there is a significant shift to be expected to cleaner vehicles, particularly at locations where charge levels are highest (urban areas).

Because of the model limitations, we compare the impacts with the impacts from the Swiss HGV charge. Discussing the impacts of the Swiss scheme, it is important to realise that the introduction of the charge was accompanied by an increase in the maximum allowed weight of HGVs (from 28 to 34 tons in 2001, and to 40 tons in 2005).
The scheme lead to a significant emission reduction. In the four years after introduction (2001-2005), emissions decreased about 6% for $CO_2$, 14% for $NO_x$ and 10% for PM emissions in comparison to the values expected without the scheme (ARE, 2007). The reasons for this decrease, caused by the combination of change in weight limit and the kilometre charge, are:
- A decrease in vehicle kilometres for road transport.
- An accelerated replacement of old vehicles by new ones.

Below both effects are further discussed. In the first four years of the toll system, an absolute reduction of 6% in vehicle kilometres was observed resulting in a traffic volume that is 23% lower than the forecasts for the business as usual scenario (ARE, 2007). Despite this strong reduction in vehicle kilometres, the transport by road (in ton kilometres) was about the same as in the business as usual scenario. The number of tonne kilometres by rail in 2005 was about 8% higher than in the business as usual scenario. Together this resulted in a small increase in the overall transport volume. So, the advantage for the road sector caused by the higher weight limit was counterbalanced by the kilometre charge. Overall the effect of the charge was thus a considerable modal shift. The other main effect of the HGV toll was its incentive for fully exploiting the logistic potential to optimise utilisation of the vehicle fleet and especially avoiding empty runs.

The other main impact of the scheme was the increased share of Euro 3- and Euro 4-trucks compared to business as usual scenario. The share in of Euro 3 and Euro 4 in vehicle kilometre in 2005 was 60% with the scheme, while it was expected to be only 40% without (ARE, 2007). It should be noted that this is the result of the introduction of the HGV charge, which is differentiated to Euro standard, and the simultaneous increase of the overall weight limit on the Swiss network. It may be possible that in the current Swiss scheme hauliers use the cleanest lorries in Switzerland while using the older lorries in other countries. On the other hand, in case of a broader implementation of this type of differentiated charges incentives can be higher which may result in even stronger effects on the fleet mix.

Overall we conclude that the impacts on emissions will be considerable higher than found in the TREMOVE runs, because shift to cleaner vehicles and efficiency gains (higher load factors, avoiding empty runs).

Figure 18 Impact on $CO_2$ emissions in 2020 relative to scenario 1 (TREMOVE)

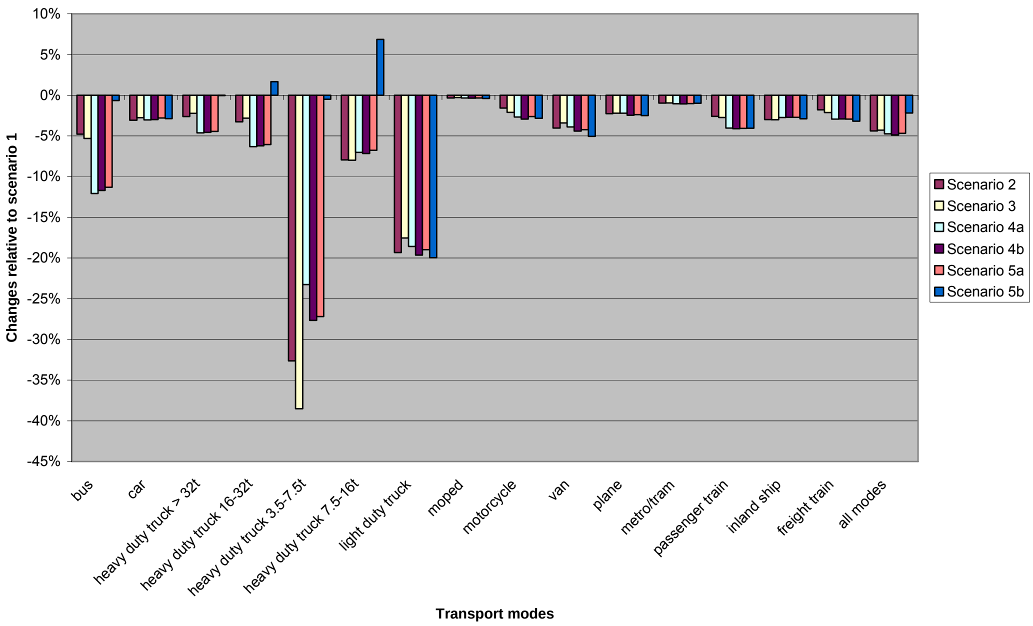


Figure 19 Impact on PM emissions in 2020 relative to scenario 1 (TREMOVE)

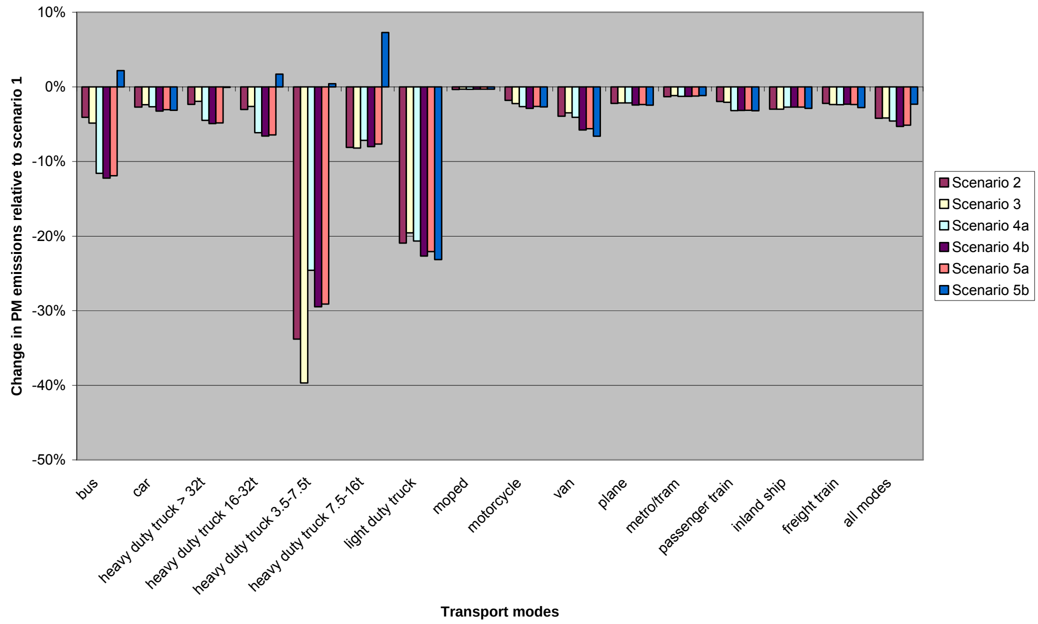
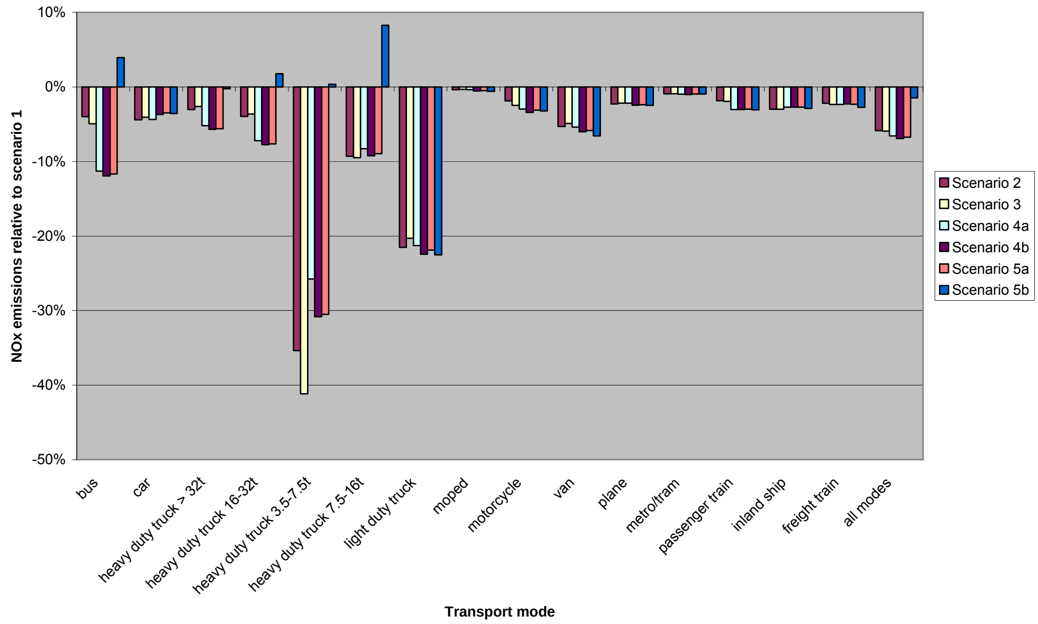


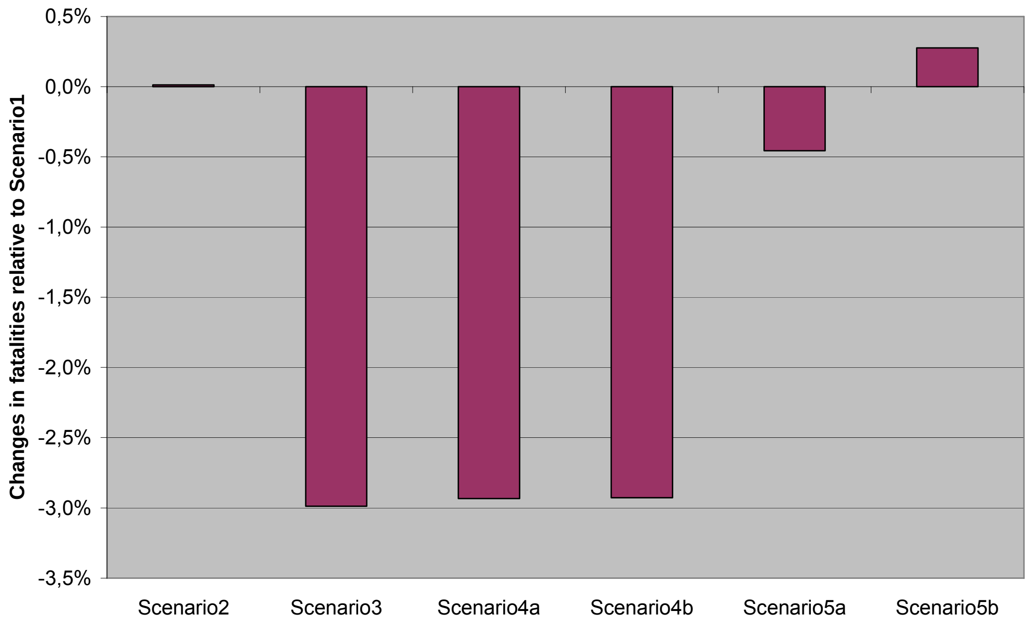

Figure 20 Impact on $NO_x$ emissions in 2020 relative to scenario 1 (TREMOVE)



### 4.4.3 Fatalities

Impacts on fatalities are only modelled by TRANS-TOOLS not by TREMOVE. The results are shown below. They can be explained by the changes in vehicle kilometre and modal shift effects. Note that these impacts do not include reduction of fatalities for intra-NUTS-3 traffic. It is not clear whether the relative reduction in fatalities for intra-NUTS traffic (which includes most of the urban traffic) will be different from the reduction for the intra-NUTS-3 traffic as modelled by TRANS-TOOLS.

Figure 21 Impact of the different scenarios on the number of fatalities in 2020 relative to scenario 1 (TRANS-TOOLS)



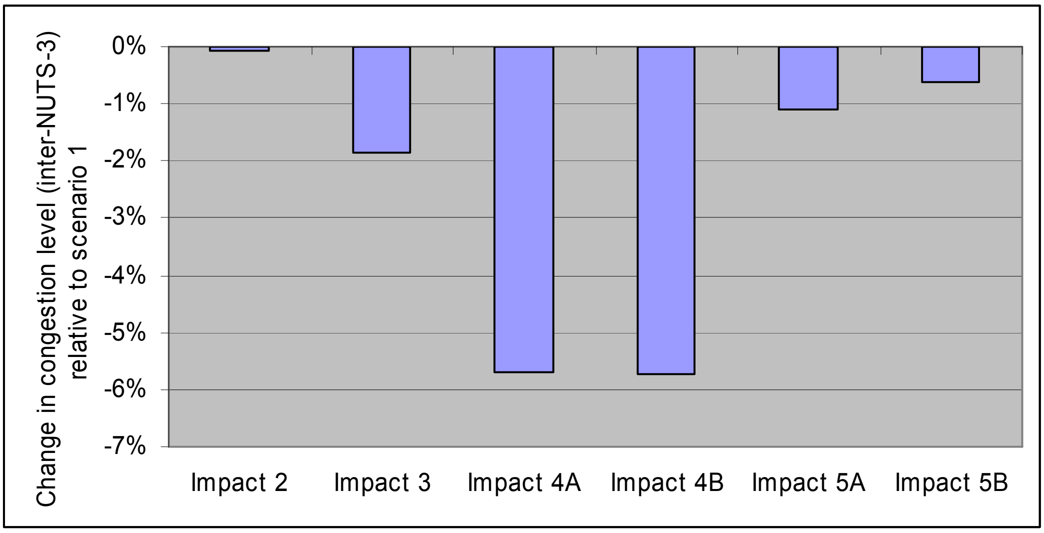

Sophisticated charging schemes giving incentives for risk avoiding behaviour (like charges differentiated to time of the day, vehicle type or driver characteristics) can be expected to have higher reduction of accident rates. We conclude that even with a very simple way of internalising external accident costs, a small reduction of fatalities can be obtained.

### 4.4.4 Congestion: model results and evidence from existing schemes

The TRANS-TOOLS runs provide results for changes in road traffic congestion. The results are based on the indicator: share of the total driving time that is spent in congested areas. The relative changes to this indicator compared to scenario 1 are depicted in Figure 22. Note that these results, like all other TRANS-TOOLS results relate only to inter-NUTS traffic. This is expected to be only a relatively small part of all congestion, because particularly traffic in urban areas face congestion. In addition the type of congestion charge modelled in scenario 4, is a relatively simple type based on the daily weighted congestion costs of a road segment.

Figure 22 shows that even this type of congestion charging has a considerable impact on the congestion level.

Figure 22 Impact of the different scenarios on the congestion level in 2020 relative to scenario 1 (TRANS-TOOLS)




Because of the very limited capabilities of the two models to show the possible impacts on congestion, additional evidence has been gathered on the impacts of congestion charging. Below we summarize the main impacts of three existing congestion schemes (see also Annex A.3 for more information on the London Congestion Charge) and estimates for nationwide schemes in the Netherlands and the UK based on earlier model work.

In London, the congestion charge has decreased traffic volumes by 15%, reducing congestion by up to 30%. In addition, emissions of pollutants and $CO_2$ has gone down by about 20% (Transport for London, 2006).

In Stockholm the introduction of congestion charges on all road to and from the city centre reduced queuing times by 30 to 50% while traffic to/from the inner city decreased by 20 to 25% (Stockholmförsöket, 2006). At the same time emissions within the inner city decreased by 14%[54] and fatalities by 5 to 10%. Also nuisance from traffic noise was reduced. The net social benefits of the scheme were estimated at about 85 million Euro a year. Less than half of the car trips shifted to public transport. Change of departure times was not a large effect. Travel pattern changed also by change of route, change of destination and trip chaining. Both private and commercial traffic adjusted their travel pattern.

[54] Note that only traffic to and from the inner city is charged. Therefore emission level decrease less than traffic volumes to/from the inner city.

Singapore introduced yet in 1975 a manual congestion charge system (Area Licensing Scheme, ALS) which was replaced in 1998 by an electronic system (Electronic Road Pricing, ERP). From the start, the ALS system showed strong impacts on peak hour traffic. In the year after introduction, morning peak hour inbound traffic decreased with almost 80% (ECMT, 2005). The introduction of the ERP system in 1998 resulted in a 7-8% decrease in morning peak hour traffic. At the same time evening traffic increased because of the lower of rates compared to the manual system.

In the Netherlands the government is preparing the introduction of  a nationwide kilometre charge for all road vehicles. Since 2005, various studies have been carried out assessing the various impacts, social costs and social benefits of various variants for this system. These studies have been based on extensive model runs with the national transport model LMS. The most important variants include a charge per kilometre which is differentiated to vehicle type, location and time of the day in order to give incentives for reducing congestion. This modelling shows overall reduction of congestion levels of 45% up to 58% for a scheme which is comparable to IMPACT Scenario 4 (Ecorys & MuConsult, 2007 and CPB, 2005). The net social benefits of the scheme are estimated at 1.0 to 1.6 billion Euro a year. The main benefits are from congestion reduction and are valued at 1.6 billion Euro per year (in variants with 35% congestion reduction) up to 2.3 billion Euro per year (in variants with 55% congestion reduction) (CPB, 2005).

As a part of the so called Eddington study (DfT, 2006) the congestion cost were estimated for the UK. It showed that the congestion cost of business traffic alone are expected to increase from 9 billion Euro in 2003 to 23 billion Euro in 2025. Moreover the overall road congestion costs are expected to increase by even 31 billion Euro between 2003 and 2025. The study states that road pricing could reduce congestion levels by 50%, raising the GDP by about 18 billion Euro and leading to welfare benefits for the UK of 35 billion Euro in total.

The impacts on congestion from existing congestion charging schemes and previous modelling are considerably higher than the impacts from the TRANS-TOOLS runs. This can probably be explained by the limited scope of the model, covering only inter-NUTS-3 traffic and so not the most important congestion zones.

Based on the evidence from the London, Stockholm and Singapore cases it is not possible to quantify the possible impacts of congestion charging schemes in the EU. The effects depend on the local situation, charge levels, etc. However, the impacts of these schemes make clear that urban congestion charging schemes can contribute significantly to congestion reduction in urban areas and that they can also contribute to reduction of emissions, noise nuisance and, last but not least, lead to an overall gain in social economic welfare.

Model runs in the Netherlands and the UK, suggest that the congestion reduction that can be achieved by the scenarios with congestion charges on all roads (like in Scenario 4A and 4B) are likely to be in the order of 50% rather than the 6% from the TRANS-TOOLS results. The congestion reduction in scenario 5 will be considerably smaller, since in that scenario congestion charging for all vehicles is only applied at the most congested areas. The London and Stockholm schemes show that with such an approach local congestion can be reduced significantly. A reduction of the overall congestion level of about 25% seems possible.

## 4.5 Economic impacts of the internalisation scenarios

The model results do not include all economic effects of the internalisation scenarios. In this section we present first the TREMOVE model results on social environmental costs. Second, a discussion on potential welfare impacts is included. This has partly been based on previous work, because it was not possible to assess the various welfare impacts with the available modelling results.

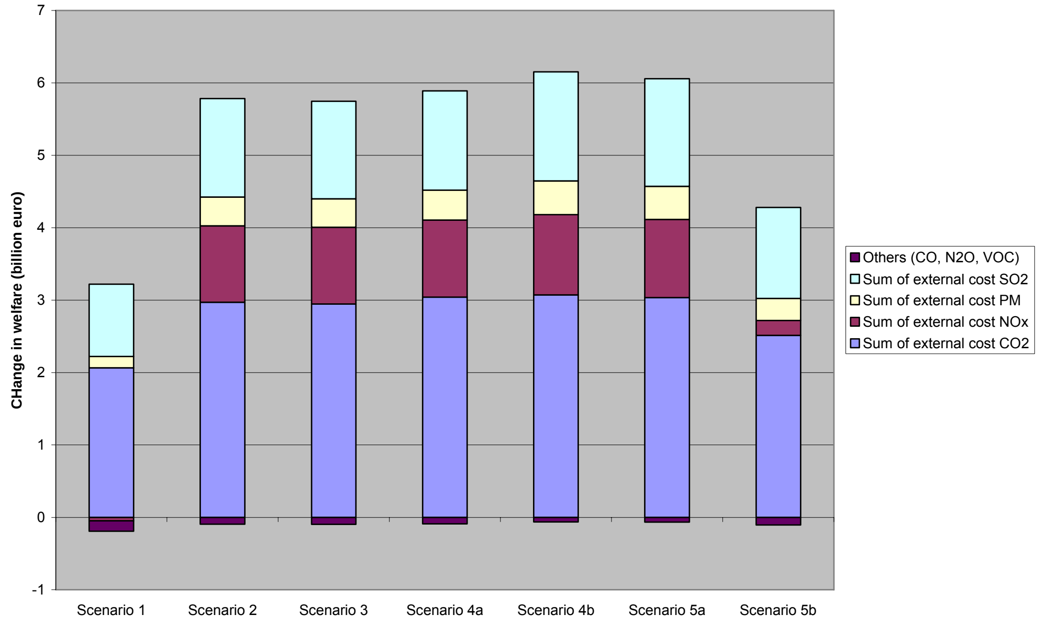
### 4.5.1 Economic benefits from reduced emissions

In this section we present the benefits from the emission reduction for the various scenarios. There is a difference in the external costs from climate change and air pollution in scenario 1 compared to the TREMOVE baseline. Just like for the emissions themselves, the costs in scenario 1 are much lower, because of the measures like binding requirements for $CO_2$ emissions of new passenger cars that are included in scenario 1, but not in the TREMOVE baseline. In this section we show the changes compared with the baseline. Scenario 1 results are included as well to be able to distinguish the impact of the measures in scenario 1 and the impacts of the internalisation measures.

From Figure 23 we can see that the policies in the pipeline from scenario 1 reduce external costs from air pollution and climate with about 3 billion per year. Internalisation measure can reduce them by up to another 3 billion Euro per year. This corresponds with about 6% of the air pollution and climate change costs in scenario 1. This is about the weighted average of the overall decrease in emissions.

Just as for the impacts on emissions, the impacts of internalisation on external costs can be much higher than estimated here, because:
- Emission reductions will be higher when charges are differentiated to vehicle technology (emission standard).
- Impacts on air pollution can be much higher when charges are differentiated to location, because than emissions in sensitive areas will be further reduced.
- Note that noise is not included here.

Figure 23 Benefits from emission reduction of the different scenarios in 2020 relative to **the TREMOVE baseline**




Note: The valuation of $CO_2$ emissions is according to the IMPACT handbook. The other emissions are valuated according to the TREMOVE valuations (based on CAFE CBA), not much diverging from the valuation used within IMPACT.

### 4.5.2 Welfare

Based on the results from TRANS-TOOLS and TREMOVE, no analysis of the complete welfare effects could be made[55]. However, based on the various quantified impacts and the valuation according to the Handbook, we made some rough estimations of the benefits of the:

- Decrease in accident rates (based on reduction of fatalities from TRANS-TOOLS and the calculation approach for average accident costs from the IMPACT handbook (page 41).
- Congestion reduction (For scenario 2 and 3, we use the low estimate based on the TRANS-TOOLS reduction rates. For scenario 4 and 5, we use the rough estimate of 50% and 25% respectively, from section 4.4.4, based on model results from the Netherlands and the UK. For the total congestion costs we use the rough indication given in 3.4.3).
- Emissions reduction (directly from section 4.5.1, which is an underestimation because impacts of fleet renewal are not included).
- Saved variable infrastructure costs because of decrease in vehicle kilometres (based on variable infrastructure costs from Annex I and changes in vehicle kilometres from TREMOVE).

[55] The TREMOVE results from LAT Thessaloniki did not include the impacts on Utility of households, Production costs and cost of public funds. For the Impact Assessment carried out by the Commission services, the ASTRA model has been run to model the economic impacts. These results are not included here because they are mostly fro a different set of scenarios.

The results of this assessment are presented in Table 10. It should noted that the benefits from reduced emissions do not include all benefits that can be expected from a sophisticated pricing scheme. Particularly the impacts of fleet renewal is not yet included. This is particularly relevant for scenario 4 and 5. The estimation of congestion reduction are based on very crude estimates made in section 4.4.4. The benefits of noise reduction are not included.

The numbers in Table 10 show that even with the underestimation of some of the benefits for particularly scenario 4, this scenario shows the highest benefits. The benefits of particularly these scenarios (4A and 4B) are dominated by the congestion reduction.

Table 10 Estimation of benefits from reduced external costs of the various scenarios

| **Rough estimation of benefits in billion €/year** | **Scenario** | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 3 | 4A | 4B | 5A | 5B |
| Emission costs (underestimation) | 2,7 | 2,6 | 2,8 | 3,1 | 3,0 | 1,1 |
| Accident costs | 0,0 | 1,6 | 1,5 | 1,5 | 0,2 | 0,1 |
| Road congestion costs (very rough estimates) | 0,1 | 1,8 | *50** | *50** | *25** | *25** |
| Variable road infrastructure costs | 3,5 | 3,8 | 4,5 | 4,9 | 4,8 | 0,1 |
| Total (very rough estimates) | 6,2 | 9,8 | 59 | 60 | 33 | 26 |

* Benefits from congestion reduction in scenario 4 and 5 are based on **a very rough** extrapolation of existing congestion charging schemes and national studies in the UK and Netherlands, instead of the TRANS-TOOLS or TREMOVE model results.

Note: The numbers are indicative and should be interpreted as a very rough estimates of possible benefits. Benefits from noise reduction could not be not included.

In this project no full cost benefit analyses (CBA) has been carried out for the set of scenarios. In other studies this has been done showing that in most cases the overall benefits of smart pricing exceed the costs. As presented in section 4.4.4, a full social CBA in the Netherlands for various road pricing scenarios shows significant welfare gains up to 1.6 billion Euro a year from variabilisation of fixed vehicle taxes and in particular of congestion charging, mainly resulting from congestion reduction (CPB, 2005). The benefits from nationwide road pricing in the UK were estimated at 35 billion Euro, also dominated by the 23 billion Euro congestion reduction (DfT, 2006). An earlier study by the ECMT estimated the welfare gains from efficient pricing for all modes of inland transport in Germany, France and the UK (the three largest Member States of the EU) at over 30 billion Euro per year[56] (ECMT, 2003).

[56] The gain in welfare recorded is a net gain: it is what remains after subtracting the welfare losses at various points - in particular, the reduction in the consumer surplus currently enjoyed by motorists who are under-charged - from the sum of the various elements of welfare gain, including the increase in revenues, the reduction in travel time for motorists and freight traffic in the newly decongested roads, the reduction in the real cost to society represented by pollution and accidents, and so on.

## 4.6 Estimation of the implementation costs

In this section the implementation costs of the various internalisation scenarios are discussed. First an overview is given of the implementation costs per type of measure (section 4.7.1). Second, based on these estimates, additional implementation costs compared to the current situation (e.g. scenario 1) for each of the scenarios 2-5 have been estimated (section 4.7.2). A distinction is made between investments and operational costs. The estimates are based on both a review of the (rare) studies on the implementation costs of internalisation measures and experiences with national internalisation schemes.

The implementation costs are heavily dependent on the way internalisation measures proposed in the scenarios are internalised. Moreover, literature and real experiences with respect to the implementation costs of internalisation costs is very limited. Therefore, the figures presented in this section should be considered as indications of the actual implementation costs of the various scenarios instead of accurate estimations of these costs.

### 4.6.1 Implementation costs per internalisation measure

In Table 11 an overview of the internalisation measures proposed in the various scenarios is presented. In this section we will present the implementation costs for all these separate measures. In the next section, this information will be used to estimate the implementation costs of the various scenarios.

Table 11 Overview of internalisation measures

| Internalisation measure | Traffic modes involved | Scenarios involved |
|---|---|---|
| Fuel/energy taxes | Road, rail, aviation, inland and maritime shipping | 2 |
| Kilometre charges | Road, rail, inland shipping | 3, 4, 5 |
| Congestion/bottleneck charges | Road | 4, 5 |
| Harbour charges | Maritime shipping | 3, 4, 5 |
| LTO charges | Aviation | 3, 4, 5 |
| ETS | Rail, maritime shipping | 4, 5 |
| Charges to insurance companies | Road, rail, aviation, inland and maritime shipping | 4, 5 |

***Fuel/energy taxes***

The implementation costs of internalisation through fuel taxes will be limited for road. Since fuel taxes currently apply for all road vehicles in all Member States, the required tax infrastructure is already available. Increasing the tax levels will only lead to very marginal implementation costs. The same holds for diesel trains, for which also a fuel tax infrastructure is available in most countries.

In some Member States, energy taxes have to be paid for the electricity used by trains. Increasing the tax tariffs to environmental cost levels will not lead to significant implementation costs. In some other Member States electric rail traffic is exempt for energy taxes. The introduction of energy taxes for rail traffic in these countries could lead to implementation costs. However, since the infrastructure for electricity taxes is available in these countries no new administration needs to be developed. The implementation costs of introduction of energy taxation on fuels for rail transport could even be negative because what costs is in fact the administration of the exemption.

International aviation is currently exempt from fuel taxes. However, in some countries (e.g. the Netherlands, Norway) fuel taxes are in place for domestic flights. A study from the OECD on the implementation of kerosene taxes for domestic flights in Norway concludes that the implementation costs for the government related to the aviation fuel tax are very limited (OECD, 2005). The main reason for this is probably that the aviation fuel tax is part of an already well established overall tax system on all oil based fuels, implying that the required administrative systems for tax collection, etc. are already in place. The fact that the tax rates vary between products and users does not add significantly to the administrative costs. The same kind of reasoning can be applied on fuel taxes for international flights.

Like international aviation, inland and maritime shipping are both exempt from fuel taxes. But also these modes can profit from the existing tax infrastructures on oil based fuels. Hence, the implementation costs of fuel taxes for these transport modes will also be limited. An important remark to make is that for maritime shipping enforcement can be difficult, because there is no reliable registration of fuel bunkering.

***Kilometre charges***

An extensive review of studies on and experiences with road pricing schemes is given in Annex E. An important conclusion from this review is that in general three types of technology are available for rather sophisticated road pricing schemes: ANPR, DSRC and GPS[57] based technology. Due to the large number of roadside equipment needed for ANPR and DSRC based systems, using these technologies for pricing schemes on all roads will result in rather high implementation costs. Therefore, all studies after countrywide road pricing schemes for all vehicles propose to use a GPS based system. The DSRC based technology is seen as an alternative if road pricing is introduced on a part of the total network only. ANPR based technology seems especially appropriate to be used in combination with other technologies, to ensure enforcement.

The Dutch government has a plan for implementing a nationwide kilometre charging scheme for all road vehicles on all roads. For this, a market consultation has been carried out recently to get reliable estimates for implementation costs. Also in the UK, implementation costs have been estimated. In addition cost figures exist from the HGV charging systems in Germany, Austria and Switzerland.

[57] ANPR = Automatic Number Plate Recognition; DSRC = Dedicated Short Range Communications; GPS = Global Positioning System.

Table 12 shows an overview of the implementation costs found for various road pricing schemes. A distinction is made between road pricing schemes for all vehicles on all roads and road pricing schemes for HGVs only. In Table 12 it is also indicated whether the figures are the result of a study or real experiences, and which technology is involved.

The overview shows that schemes for all vehicles show considerably lower costs per vehicle because of the efficiency gains of the economy of scale. The various examples of HGV pricing show that GPS-based system is more expensive than a DSRC-based system.

Table 12 Overview of implementation costs of road pricing schemes

| Data source | Study or real figures? | Technology involved | Investments per user (€) | Operational costs per user (€ p.a.) |
|---|---|---|---|---|
| **Road pricing for all vehicles on all roads** | | | | |
| Ministry of Transport, 2005 (km charging) - Netherlands | Study | GPS | 280-507 | 53-147 |
| Ministry of Transport, 2005 (km charging + congestion charging) - Netherlands | Study | GPS | 275-513 | 63-138 |
| Ministry of Transport, 2006 (km charging) - Netherlands | Study | GPS | 163-338 | 31-119 |
| DfT (2004) - UK | Study | GPS | 662-4,925 | 128-433 |
| **Road pricing for HGVs only** | | | | |
| Ministry of Transport, 2005 (GPS) - Netherlands | Study | GPS | 818-1,660 | 156-409 |
| Ministry of Transport, 2005 (DSRC) - Netherlands | Study | DSRC | 1,250-1,500 | 250-667 |
| Austria | Real | DSRC | 417-617 | 58 |
| Germany | Real | GPS | 500-1,000 | 393-508 |
| Switzerland | Real | DSRC | 450-565 | 100 |
| Czech Republic | Real | DSRC | 320 | unknown |
| **Cost figures used in this study** | | | | |
| Road pricing for all vehicles on all roads | | GPS | 163 | 31 |
| Road pricing for HGV only (DSRC) | | DSRC | 320 | 58 |
| Road pricing for HGV only (GPS) | | GPS | 375 | 295 |

Source: CE, 2005; DfT (2004); Ministry of Transport, 2005; 2006; Oehry, 2006; Bartl, 2008.

Note: The ranges in the cost figures from the studies of the Ministry of Transport and DfT are caused by uncertainties in the cost estimates. The ranges in the cost figures from real pricing schemes are caused by using figures from various literature sources.

The technology needed for road pricing is still developing. A downward sloping trend in the costs of technology can be seen by comparing the results for the 2005 and 2006 studies from the Dutch Ministry of Transport. It may also be an explanation for the rather high costs for the estimates found in the study from DfT for the UK (DfT, 2004).

It may be expected that the costs of this technology will decrease even further in the future (Ministry of Transport, 2006). Especially the costs for vehicle equipment needed for GPS based systems are likely to decrease, because this kind of technology will be used for other applications in the car too (TNO/CE, 2003). Currently, some expensive car types are provided with GPS based alarm systems, whose application will probably be extended to cheaper car segments in the future. In addition, car manufacturers are planning to connect the GPS based OBU with the tachograph to improve the reliability of the latter. By combining these different functions, the costs of vehicle equipment will decrease significantly. However, since these developments are still uncertain, the various studies do not take them into account. Hence, in the longer run, the cost figures presented in Table 12 should be considered as maximum values.

To estimate the implementation costs for a kilometre charge for all vehicles on all roads, we will use the cost figures from Ministry of Transport (2006) for the Netherlands. These are the most recent and reliable figures available for such a kind of road pricing. To take technology improvements into account, we will use the lower end of the cost estimates from the Dutch system.

For estimating the costs of a HGV kilometre charge, we will use cost figures from the Czech Republic in case a DSRC based technology is assumed. The Czech system was implemented efficiently in only nine months time. These figures are the most recent and reliable ones for this kind of technology. Due to technological improvements, these costs may decline in future. There are no operational costs available for the Czech system; therefore for these costs we use the values from Austria.

The implementation costs of a HGV kilometre charge using a GPS-based system are based on the cost figures from the German system. The cost figures from the German system are rather high, due to reasons such as a partial recovery of the costs and the high cost of the OBU due to commercial functions like fleet management systems which have been embedded in the system but which have finally not been used (given the monopoly position of Toll Collect, this would create distortion of competition). At the other hand, the German system is only applied on motorways. If this kind of a system will be applied on all roads, system costs per user will be higher because of the higher accurateness of the system and the higher number of roadside equipment needed. Overall we expect that the costs of a nationwide GPS-based system still can be lower than the German system. Therefore, we will use cost figures which are 75% of the lower end cost estimates from the German scheme as a most likely estimate for the system cost of a GPS based system.

For all road kilometre charging schemes, the total costs have been calculated by multiplying these costs per user by the number of users. One may argue that economy of scale effects may reduce average costs per user in case of EU-wide implementation. However, in areas with low traffic volumes, implementation costs per user can well be higher. Also the comparison of the available cost estimates for various countries do not suggest large economy of scale effects. Therefore, by lack of more detailed data, the costs per user and the number of road users have been taken for calculating the EU-wide implementation costs.

To implement a kilometre charge for inland shipping a DSRC technology could be used. Since the network of waterways is less complex than the road network, less equipment on the waterside is needed compared to road pricing schemes. Ships are usually equipped with a GPS system. Therefore, implementing a GPS based charging system for inland shipping is likely to be less expensive than for HGV. Hence, with any of the two main technologies, the implementation costs will be lower than for road kilometre charging. Unfortunately no studies or experiences with regard to kilometre charging for inland shipping are available. Therefore, it is not possible to quantify the implementation costs of this internalisation measure.

***Bottleneck charges***

There is little experience with bottleneck charging on motorways. Ministry of Transport (2005) have investigated the implementation costs of toll charging on six locations in the Netherlands (see Annex E). It was assumed that a DSRC based technology is used to register the vehicles. The investment costs per user[58] are equal to € 72 - € 93, while the annual implementation costs are equal to € 43 - € 130 per user.

If vehicles are already equipped with GPS based OBUs because a countrywide kilometre charge has been taken into account, the implementation costs of a bottleneck charge will be limited. Based on the data which is provided by the GPS technology it is probably rather easy to determine the value of the bottleneck charge people have to pay.

***Harbour charges***

Ship operators currently pay harbour dues to port authorities for the use of the harbour. The level of these dues are often based on gross tonnage of a ship (CE et al., 2006). In addition, some harbours levy dues on the basis of the amount of cargo loaded or discharged. Other harbours charge vessels on the basis of their volume.

Since the institutions for charging harbour dues are already in place, increasing the dues to external cost level will only lead to limited implementation costs. Also a differentiated dues approach would take advantage of the fact that (most) ports already impose charges on vessels that use their facilities and waters (NERA, 2004). However, there will be some costs associated with the design of the differentiation scheme and the verification of vessel characteristics. These costs are dependent on the incentive base of the harbour charge. The incentive base is the volume or unit on which the charge is to be levied. With respect to air pollution and climate change costs (the most important cost categories related to inland shipping) the most appropriate incentive base for differentiated harbour dues seems to be a combination of fuel consumption and emission factor of the engine, since this combination correlates strongly to actual emissions (CE, 2004).

[58] A car on which bottleneck charges are imposed.

In addition, it provides a strong incentive for both air pollution and climate change. It is not easy to define the emission factor of the engine. The required test of the engine could be applied at the moment of revision of an engine. It is unclear what costs would be associated with this. However, overall we expect them to be limited compared to technologically more complex systems like fairway dues.

According to NERA (2004) also the costs of monitoring the fuel consumption of vessels could be limited. Other studies (like CE, 2006a) suggest that monitoring fuel consumption of may be difficult. The costs of monitoring of vessels to ensure that engines are maintained properly and that end-of-pipe technologies are not switched off or bypassed, could be limited by combining these monitoring tasks with regularly inspections of the vessels. However, the total costs of these are not clear. Overall we expected that the overall implementation costs of differentiated harbour dues can be limited.

***LTO charges***

Aircrafts are already required to pay landing fees at (most) airports to cover the costs incurred by providing airport services. Currently, most landing fees are tied to aircraft weight NESCAUM (2003). On some European airports LTO charges are also differentiated to noise and/or emissions.

Since landing fees are available on (most) airports, increasing these fees to external cost level would have very limited implementation costs. In case of an introduction of differentiated LTO charges, there will be some costs associated with the introduction of a classification system for aircrafts needed to differentiate the charges.

For noise, the ICAO have developed such a classification system. But most airports already using LTO charges differentiated to noise apply their own classification system. Aircraft are categorized in several classes according to their noise classification, and the level of the LTO charge is based on the noise class. The implementation costs of such a system are rather limited. Apart from consideration of the noise emission of aircraft, most airports impose higher LTO charges at night than during the day (Öko-institut/DIW, 2004). However, differentiation to time of the day does not require any additional implementation costs.

At nine Swedish and two Swiss airports the LTO fees are also differentiated to emissions. The incentive base for this differentiation are default emission values, which depends on the type, number and size of the engines (Fleuti, 2007). Such a differentiation system is easily implemented and hence, the costs will be low.

To conclude, the implementation costs related to LTO charges, both flat and differentiated, will probably be limited.

***ETS***

There is ample scientific literature on the possibility and effects of including maritime shipping in the European emission trading system (ETS). An exception is CE et al. (2006), which explores whether maritime shipping could be included in the ETS. In addition, this study provides an indication of how such a system could be designed. However, the implementation costs of including maritime shipping in the ETS are not investigated.

Recently, CE Delft and Ecofys have provided technical assistance to the European Commission during the process of drafting the impact assessment of the inclusion of aviation in EU ETS (CE & Ecofys, 2007). In this project they investigated, among other things, the transaction costs for the aviation sector. These are the costs involved with setting up and implementing a system by which operators monitor and report upon their emissions and have their emission report verified. Another element of the implementation costs related to the costs for the competent authorities in setting up systems, etc., are not taken into account. Since the transaction costs for the aviation sector are difficult to estimate quantitatively, a wide range has been given, based on the first phase EU ETS experience, of € 3,250 - € 14,625 in the first year, and then an annual cost of € 1,625 - € 5,850 in subsequent years per operator.

There is not much clarity on the way a system of ETS for maritime shipping would be designed, and hence a lot of important cost drivers of the implementation costs of such a scheme are unknown. In addition, since it is not clear how many operators possess ships that call European ports, we are not able to estimate the total costs of including maritime shipping in EU ETS.

***Charges to insurance companies***

The costs of accidents depends heavily on personal characteristics of the vehicle user, such as age, driving experience, etc. Insurance companies have a lot of information on these personal characteristics and they already use this information to differentiate the insurance premiums. By charging the insurance companies for the accident costs, advantage can be taken of this information. By providing insurance companies the possibility to use the infrastructure of the kilometre charging system, they also can accurately differentiate to the distance travelled.

The implementation costs depend on the incentive base. A good proxy for the external accident costs is the number of fatalities and injured. Statistics on these are available for every insurance company. The main costs of such a system will be involved with the reporting and verification of these data. There were no estimates found, but we expect that these costs will be limited.

### 4.6.2 Implementation costs per scenario

Based on the estimates of implementation costs for the separate internalisation measures in the previous section, we will estimate the implementation costs for the various scenarios[59]. Note that the implementation costs of the various scenarios have not been used in the modelling.

***Scenario 2 - Internalisation through fuel and energy taxes***
In this scenario the internalisation is realised by increasing existing fuel taxes and introducing fuel and energy taxes for transport modes which are currently exempt from these type of taxes. As was mentioned in the previous section, the implementation costs caused by increasing tax levels or introducing new fuel taxes are limited. Hence, also the implementation costs of scenario 2 will be limited. Therefore, we assume that these costs are negligible (especially in comparison with the implementation costs of other scenarios).

***Scenario 3 - Internalisation through charges***
The internalisation measures used for the various modes in this scenario are summarized in Table 13. For most modes, the implementation costs are limited. For all road vehicles a kilometre charge on all roads will be implemented. In section 4.7.1 the investment costs of this measure is estimated on € 163 per user, while the operational costs are estimated on € 31 per user. Since in 2010 the number of road vehicles in the EU-29 is about 253 million (source: TREMOVE 2.5.1), the investment and operational costs are estimated to be equal to respectively € 41 billion and € 8 billion. Of these costs 1.5 billion investments and 0.3 billion operational costs relate to HGV. For inland shipping a kilometre charge will be implemented and we were not able to estimate the implementation costs of this measure. However due to the relatively low number of vehicles in this sector, the costs will be very low compared to the total implementation costs for road.

Table 13 Scenario 3: Estimation of implementation costs per transport mode

| Mode | Internalisation measure | Investment costs (billion €) | Operating costs (billion € per year) |
|---|---|---|---|
| Road | Kilometre charge cars/LDV | 40 | 8 |
| | Kilometre charge HGV | 1.5 | 0.3 |
| Rail | Mark-up on existing infrastructure charges | Low | Low |
| Aviation | LTO charges | Low | Low |
| Inland shipping | Kilometre charge | Low | Low |
| Maritime shipping | Harbour charges | Low | Low |
| **Total** | | **41** | **8** |

[59] This has been done for the internalisation scenarios only, so not for scenario 1.

***Scenario 4 - Smart charging***
Since scenario 4a and 4b do not differ with respect to the measures introduced, there will be no differences in implementation costs between both scenarios.

The internalisation measures assumed to be introduced for the various modes in scenario 4 are summarized in Table 14. For the road kilometre pricing a system based on GPS technology is assumed, just as in scenario 3. Such a kind of system is also able to charge on bottlenecks. Therefore, the implementation costs of the road pricing scheme introduced in scenario 4 are equal to the costs in scenario 3. The implementation costs of the internalisation measures assumed for rail and aviation are limited, as are the implementation costs of harbour charges for maritime shipping. For inland shipping we were not able to estimate the implementation costs of the kilometre charge but will in absolute terms be low. Finally, the implementation costs of including maritime shipping in ETS cannot be quantified.

Table 14 Scenario 4: Implementation costs per transport mode

| Mode | Internalisation measure | Investment costs (billion €) | Operating costs (billion €) |
|---|---|---|---|
| Road | Kilometre charge cars/LDV | 40 | 8 |
| | Kilometre charge HGV | 1.5 | 0.3 |
| Rail | Mark-up on existing infrastructure charges, increased fuel duty, ETS | Low | Low |
| Aviation | LTO charges | Low | Low |
| Inland shipping | Kilometre charge | Low | Low |
| Maritime shipping | Harbour charges, ETS | Pm | pm |
| **Total** | | **41 (+ pm)** | **8 (+ pm)** |

***Scenario 5a - Pragmatic - HGV km charging on all roads***
This scenario is the same as scenario 4, with the exception that no kilometre charging is introduced for passenger cars, but only for HGV (on all roads). We assume that such a wide scope for HGV km charging requires a GPS based technology, and for that reason we will estimate the implementation costs of such a system with the help of the cost figures based on cost figures for the HGV charging in Germany. Based on these figures and the number of HGV (9.2 million in 2010, according to TREMOVE 2.5.1) we estimate that the investment costs of HGV km charging on all roads in the EU-29 are equal to € 3.5 billion, and the operational costs are € 2.7 billion.

The GPS-based technology installed in lorries can also be used to charge these vehicles on bottlenecks. For the other road vehicles, a DSRC-based system is assumed. To estimate the implementation costs for passenger cars of applying bottleneck charging in Europe we multiply the costs per user found by Ministry of Transport (2005) by the total number of passenger cars in Europe. In this way we probably overestimate the implementation costs, because not all European passenger cars are confronted with bottleneck charges. Therefore, as a best guess, we assume that 50% all European passenger cars are confronted with bottleneck charges. The implementation costs of the bottleneck charging for passenger cars are then € 9 billion (investments) and € 5 billion (operational costs).

Table 15 Scenario 5a: implementation costs per transport mode

| Mode | Internalisation measure | Investment costs (billion €) | Operating costs (billion €) |
|---|---|---|---|
| Road | Kilometre charges for HGV's,<br>Bottleneck charges for cars/LDV | 3.5<br>9 | 2.7<br>5 |
| Rail | Mark-up on existing infrastructure charges, increased fuel duty, ETS | Low | Low |
| Aviation | LTO charges | Low | Low |
| Inland shipping | Kilometre charge | Low | Low |
| Maritime shipping | Harbour charges, ETS | pm | Pm |
| **Total** | | **12 (+ pm)** | **8 (+ pm)** |

***Scenario 5b - Pragmatic - HGV km charging on motorways only***

This scenario is the same as scenario 5a, with the exception that the kilometre charging for HGV vehicles is only introduced on motorways. For such a road pricing scheme, both a GPS and a DSRC based technology are feasible (see road pricing schemes in Austria, Germany and Switzerland). From Table 12 it is known that the implementation costs of a system based on DSRC technology are lower compared to a GPS based system. Therefore, it was assumed that a kilometre charging based on DSRC technology will be applied. The implementation costs of this type of scheme was estimated € 3.0 billion (investments) and € 0.5 billion (operational costs). Just as in scenario 5a a separate system should be applied for the bottleneck charges on passenger cars. The implementation costs for this scheme are: € 9 billion (investments) and € 5 billion (operational costs).

Table 16 Scenario 5b: implementation costs per transport mode

| Mode | Internalisation measure | Investment costs (billion €) | Operating costs (billion €) |
|---|---|---|---|
| Road | Kilometre charges for HGV's on motorways<br>Bottleneck charges for cars/LDV | 3.0<br>9 | 0.5<br>5 |
| Rail | Mark-up on existing infrastructure charges, increased fuel duty, ETS | Low | Low |
| Aviation | LTO charges | Low | Low |
| Inland shipping | Kilometre charge | Low | Low |
| Maritime shipping | Harbour charges, ETS | Pm | pm |
| **Total** | | **12 (+ pm)** | **6 (+ pm)** |

***Conclusion***

In Table 17 a summary of the total implementation costs for the various scenarios is shown. Unfortunately, due to a lack of information we were not able to estimate the implementation costs of all internalisation measures. Therefore, it is difficult to compare the implementation costs of the different internalisation scenarios. However, for the scenarios 4, 5a and 5b the internalisation measures for which no implementation costs could be estimated are the same, and hence, these scenarios are comparable. Furthermore, notice that the implementation costs are mainly caused by the internalisation measures for road vehicles.

Table 17 Estimation of the total implementation costs per scenario for all modes and EU-29 (billion Euro)

| Scenario | | Investment costs | Operating costs |
|---|---|---|---|
| 2 | Internalisation through fuel and energy taxes | Low | Low |
| 3 | Internalisation through charges | 41 | 8 |
| 4 | Smart charging | 41 + pm | 8 + pm |
| 5a | Pragmatic - HGV km charging on all roads | 12 + pm | 8 + pm |
| 5b | Pragmatic - HGV km charging on TEN-T roads only | 12 + pm | 6 + pm |

Note: The figures presented in this table should be considered as indications of the actual implementation costs of the various scenarios instead of accurate estimations of these costs. The 'pm' costs refer to the costs for internalisation in maritime shipping.

Table 17 shows that the investments are the highest for scenario 3 and 4, which both assume the introduction of a countrywide kilometre charge for all vehicles on all roads. If road kilometre charging is only introduced for HGV's, the investment costs are significantly lower. However, the operational costs of these schemes are higher compared to the operational costs in scenario 3 and 4, which is caused by the relatively high operational costs of DSRC based technology. Finally, the implementation costs for scenario 2 are assumed to be negligible.

## 4.7 Main conclusions from the impact assessment

Table 18 gives an overview of the main results of the impacts and costs of each scenarios.

Table 18 Overview of the main impacts of the various scenarios

| **Scenario** | **2** | **3** | **4A** | **4B** | **5A** | **5B** |
|---|---|---|---|---|---|---|
| Transport volume - all modes | | | | | | |
| Tkm | -3.1% | -3.0% | -4.7% | -4.9% | -4.8% | -0.1% |
| Pkm | -2.5% | -2.3% | -2.8% | -3.1% | -3.0% | -2.6% |
| Emissions (well to wheel) - all modes- *underestimation* | | | | | | |
| $CO_2$ | -4.4% | -4.3% | -4.7% | -4.9% | -4.7% | -2.2% |
| PM | -4.2% | -4.2% | -4.6% | -5.3% | -5.1% | -2.3% |
| $NO_x$ | -5.9% | -5.9% | -6.6% | -6.9% | -6.7% | -1.5% |
| Fatalities- *underestimation* | -0.0% | -3.0% | -2.9% | -2.9% | -0.5% | -0.3% |
| Congestion (interurban roads) - *very rough estimates* | -0.1% | -1.8% | *-50%** | *-50%** | -25%* | -25%* |
| Rough indication of benefits from reduction in external effects (excl. noise) in billion €/year ** | 6 | 10 | 59 | 60 | 33 | 26 |
| Rough indication of implementation costs | | | | | | |
| Initial investments (in billion € ) | Low | 41 | 41+pm | 41+pm | 12+pm | 12+pm |
| Operational costs (in billion €/year) | Low | 8 | 8+pm | 8+pm | 8+pm | 6+pm |

* Congestion reduction in scenario 4 and 5 are based on **a very rough** extrapolation of existing congestion charging schemes and national studies in the UK and Netherlands; not on the TRANS-TOOLS or TREMOVE model results. Congestion reduction in scenario 5 are strong underestimates.

** These benefits are based on very crude assumptions and should be regarded as merely rough indications. Benefits from noise reduction could not be not included.

Note: Impacts on fatalities and congestion from TRANS-TOOLS, other impacts from TREMOVE. Implementation costs own assessment (see section 4.6).

The results of the assessment make clear that the internalisation schemes have considerable effects on the transport market. The main conclusions are listed below:

- The benefits of an internalisation scheme can be considerable. All internalisation scenarios result in lower environmental, congestion and accident costs.
- The highest benefits are to be expected for scenario 4A and B. The highest share in these benefits are from congestion reduction. Scenarios 4A and 4B also have the highest implementation costs. The operational costs for these scenarios are considerably lower than the benefits from the expected reduction of externalities.
- Road freight transport volumes decrease in all scenarios. The biggest freight volume changes are found in scenario 4B and 5A. The largest volume decrease was found for the smaller vehicle types suggesting an increase in transport efficiency (because there is no significant drop in load factors). The results of the network model TRANS-TOOLS indicate that particularly for long distance modal shift to non-road modes (particularly rail and waterborne modes) is likely to occur.

- Passenger transport volumes decrease slightly for all passenger cars. No significant modal shift has been found.
- The model results show only very small changes in load factors and occupancy rates.
- The overall fuel consumption decreases in all scenarios. The largest decrease in fuel consumption can be expected in scenario 2 (at least 10%).
- The highest emissions reductions in the model results are in all scenario 4A, 4B and 5A (5 to 7% in ($CO_2$, $NO_x$ and PM). Results for scenario 5B show much smaller reductions. The results on emissions are an underestimation of the potential impacts on pollutant emissions, particularly for scenario 3, 4 and 5, when charges could be differentiated to region and emission standard.
- With the very simple way of internalising external accident costs, fatalities were reduced by about 3% in scenario 3, 4A, 4B.
- TRANS-TOOLS ands TREMOVE are not able to model many of the impacts from which the main efficiency gains of internalisation are to be expected: congestion reduction in urban areas, impacts of taxes and charges that are differentiated to important cost drivers as Euro standard, noise class, location and time of the day. The modelling work is therefore not able to show the full potential of internalisation strategies. In reality the order of this reduction can be considerably higher than modelled, because of important market responses like shifts to cleaner and more silent vehicles and fuel efficiency improvements. Effects for specific traffic situations and regions such as congested and highly polluted urban areas, specific bottlenecks or sensitive regions can be much higher than shown by the rather aggregated modelling. This is confirmed by the impacts from real life cases like the Swiss HGV charge and various congestion charging schemes. For all these reasons the model results give little guidance in selection of the optimal policy mix.
- Based on various real life examples we can conclude that internalisation of congestion costs by congestion charges can lead to significant reduction of congestion costs up to 50% or even more.
- Both the impacts and the implementation costs are dominated by the internalisation measures for road vehicles.

# 5 Internalisation policy and legal strategies

## 5.1 Introduction

In this chapter we discuss policy and legal strategies to arrive at internalisation of external costs in transport. First we briefly summarize the recommended internalisation approaches per cost category (section 5.2).

The introduction of internalisation measures by Member States is heavily related to the EU policy. With respect to the EU policy and legislation on internalisation, the Commission has various options. The main elements that could be considered as part of a policy are the following:

1 Enabling internalisation by market based instruments (section 5.3 and 5.4).
2 Facilitating internalisation by market based instruments (section 5.5).
3 Binding requirements for market based instruments (section 5.6).
4 Other policies that contribute to internalisation (section 5.7).

## 5.2 Recommended internalisation approaches

The results of the impact assessment presented in the previous chapter show that the internalisation approaches described in chapter 3 can contribute to a reduction of external effects. These approaches, which were based on a assessment of scientific literature, are recommended to take as starting point for the approaches Member States could take to internalise the external costs of transport.

In short, internalisation of external costs can be done by a combination of instruments. The main recommend internalisation approaches are:

- **Climate change costs** can best be internalised by **fuel taxes or ETS**.
- **Air pollution, accident, noise and congestion costs** can be internalised by **differentiated kilometre charges**, differentiated to vehicle characteristics, location, time of the day and for accident costs also driver characteristics. For congestion costs local schemes could be a good alternative, while for accident costs internalisation via insurance companies is to be preferred over a kilometre based charge but first requires further study.

A more detailed discussion on the most appropriate approaches to tackle the various external cost items was yet provided in section 3.2.

### 5.3 Enabling internalisation for road transport

Road transport is responsible for by far the largest share in external costs from transport. Therefore, internalisation policy should start with a strategy for road transport. Differentiated kilometre charges and congestion charges are two key elements in the approaches proposed for road transport. For passenger cars and LDV there exist no legal barriers for implementation of the recommended internalisation approaches. For HGV, however, current legislation does not fully enable internalisation of external accidents, air pollution, noise and congestion costs. In this section, we discuss the options for removing these legal barriers.

#### 5.3.1 Arguments for an amendment to the current Directive

Internalisation of all external costs of road freight transport is not allowed by the existing Eurovignette Directive 2006/38/EC. The principle of cost recovery in the Directive puts a limit to the extent of internalisation that can be achieved. The Directive gives the possibility to add mark-ups in mountainous areas and to levy specific urban traffic charges, congestion charges or regulatory charges to combat environmental impacts, including poor air quality, on any road, notably in urban areas. In addition limited differentiation of charges is allowed. The possibilities are however very restricted and full internalisation of external costs is not possible. Therefore, from the perspective of internalisation of external costs, amendment of the Directive is desirable.

The main arguments for changing the existing Eurovignette Directive are the following:

1. The current charges per km are much lower than the marginal costs related to kilometres driven leading to significant efficiency losses.
2. In cases without congestion, the existing km related charges on motorways for large HGV would need to be much higher in order to cover both infrastructure costs and marginal external costs. In urban areas the situation is even worse because the current system completely lacks charges that reflect marginal costs of air pollution, noise, accidents and in most cases congestion, while these costs are even much higher than on motorways. The level of differentiation currently allowed (lowest charges 50% of highest charges, see section 2.4) is much too limited to reflect the differences in external cost in various traffic situations.
3. Incentives given by fuel taxes are perfect for internalising climate change costs, but fuel taxes can not properly internalise the external costs of air pollution, noise, accidents and congestion.
4. No proper incentives are currently given to transport users for taking these costs into account in their transport decisions.
5. The current legislation is not able to ensure a level playing field between the various transport modes, in particular between road and rail. This holds for the level and the structure of the charges as well as for the possibility of differentiation.
6. An amendment of the current Directive so to explicitly allow Member States to charge HGV for all external costs on top of infrastructure costs could be an important first step towards more efficient pricing. Given that road transport is

the main contributor to external costs of transport, internalisation measures in other modes can hardly be expected as long as for road transport internalisation is not fully enabled. Such an enabling would make it possible for front runner Member States to introduce efficient road charging, based on marginal cost levels.

With the 2006 amendment of the Eurovignette Directive, Member States have more possibilities than before for differentiation of charges to Euro standard or location. To some extent, also mark-ups in sensitive are possible. Since 2006, only few Member States have used these options yet. There are several reasons for this. First of all, the introduction of a new tolling systems or changing an existing scheme is a time-consuming and complex exercise After political agreement, which may in some Member States, already take several years, a whole process of system design, technical and organisational development, tender procedures, testing and implementation are needed. The time span since the 2006 amendment is simply too short for Member States to have walked through all these phases.

A second reason that Member States have not yet applied the full potential of the current Directive can be found in the fact that introducing a differentiated scheme is more sophisticated and more expensive than a scheme with flat charges. Because of the requirement that revenues may not exceed average infrastructure costs, the complexity of a 'smarter' scheme is not reflected in higher revenues. Technological development and experience from other Member States is likely to make that in coming years further charge differentiation will become more and more attractive for Member States to apply.

Although the full potential of the current Directive has not yet been used, it should be noted that the latest schemes that have been introduced as well as the systems that currently under consideration or yet being developed all include differentiation to Euro standards. In addition also other types of differentiation, like to location and time of the day are considered. In addition, Also for taxes and charges other than tolls, the number of differentiations to parameters that relevant from the perspective of Marginal Social Cost Pricing is steadily increasing (see also Annex with data on this from one of the EEA TERM indicators D).

With the technological development, more and more types of charge differentiation may become possible and efficient to implement. There are no reasons why the Commission should prevent Member States to use these options offered by technological innovation as long as it does not end-up in charges that exceed the total marginal cost level. Therefore, we conclude that in the given situation, the most appropriate role of the Commission seems to be the removing of barriers for differentiation rather than on limiting the options offered to Member States. In section 5.5, several suggestion are made for ways the Commission could help to remove these barriers and facilitate.

### 5.3.2 Possible adaptations

Efficient pricing means that charges better reflect the marginal external environmental, accidents and congestion costs and infrastructure costs. This requires higher average charge levels and a higher level of differentiation. Charge levels should not only reflect infrastructure costs but also external costs. In addition it requires much stronger differentiation to various parameters such as axle load (infrastructure costs), Euro standard, vehicles with and without particulate filters, day/night, peak/off peak and location. In particular differentiation between urban and interurban areas is important because of the large difference in marginal cost levels. Potentially a differentiation with regard to vehicle noise emission class could be allowed for. As the Euro standards are tightened, in time a differentiation with respect to Euro standard may no longer be required, since actual emission levels will differ little between vehicles. For the moment however, enabling policies to differentiate on the basis of noise and Euro-standards seems appropriate, given the current air quality and noise exposure levels in many European cities. The current Directive allows yet some differentiation, however the bandwidth is much too small in order to reflect the true differences in external costs[60].

For these reasons it is recommended that the Directive is adapted in the following way:

1 Enable Member States to introduce differentiated charges for marginal external costs of air pollution, noise and accidents on top of infrastructure cost based charge levels, up to a certain level (see discussion in the next section on the definition of a *cap*). An alternative could be to leave accident costs out and opt for internalisation of accident cost via insurance companies.
2 Enable Member States to differentiate the charges for recovering infrastructure costs so that they reflect both marginal infrastructure costs and congestion costs. This means a much stronger differentiation to location, time of the day and vehicle type should be allowed. A precondition that could be set is that other road users notably passenger cars are also subject to congestion charge, where the maximum differentiation between HGV and passenger cars could be based on the PCU[61] (see IMPACT Deliverable 1).
3 Make explicit that the already allowed regulatory charges include additional congestion charges in urban and mountainous areas on top of the charges at average infrastructure cost and air pollution, noise and accidents costs.

Increasing the allowed level of differentiation is an important precondition for charges that better reflect external cost. Various Member States have already differentiated their vignettes or tolls (Switzerland, Germany and Czech Republic) to Euro standard. As discussed in section 4.4.2, these differentiations have significant impacts air pollution, e.g. by affecting fleet composition.

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60 As we saw in section 3.4.2, the marginal external and infrastructure costs of a big Euro 3-truck on a congested motorway can be several times higher than the marginal external and infrastructure costs of a big Euro 5 on a motorway without congestion.

61 PCU = Passenger Car Unit, a measure for the contribution of various vehicle types to congestion, relative to passenger cars (PCU=1). In the IMPACT handbook the following PCU are recommended for HGV: 2 on local streets, 2.5 on trunk roads and urban collectors and 3.5 on motorways.

The use of revenues of internalisation does not need to be determined at EU level. The added value of any type of earmarking is mainly to gain public support. Therefore, it is best to leave decisions on earmarking to Member States and to give only some general conditions or recommendations.

### 5.3.3 EU coordination to avoid overpricing

In the discussions that took place in 2005 and 2006 on the amendment of Directive 1999/62/EC, one important issue was related to the prevention of potential overcharging. When Member States are allowed to price for external costs on top of infrastructure costs, there may be a risk of overpricing. It is important to limit this risk because overcharging may lead to economic inefficiency. Overpricing carries also the risk of undesired traffic deviation and may hamper the smooth functioning of the internal market.

In particular there appeared to be a fear with Member States that are geographically in the periphery of the EU that there is a risk of overpricing the infrastructure use by Member States that are more centrally located. This may result in redistribution effect from peripheral countries to central countries (see also GRACE, 2007).

These risks call for some kind of EU coordination. One option for such coordination would be a certain limit to the level of charges that may be raised by the definition of a cap. The question arises what could be a proper definition for such a cap. It should be noted that a too strict cap carries the risk that Member States are not able to set the most efficient prices.

In general the following option could be considered:
1 No cap.
2 One cap per Member State per type of vehicle for the charge for external environmental and accident costs per vehicle kilometre.
3 A cap for the charge per vehicle kilometre differentiated to vehicle characteristics (e.g. Euro standard), location (e.g. urban/non-urban/metropolitan) and time of the day (e.g. peak/off peak/night).
4 A cap for the charge per vehicle kilometre differentiated to vehicle characteristics (e.g. Euro standard), population density within region, and time of the day (e.g. peak/off peak/night).
5 A cap for the revenues from the charges for external environmental and accident costs, based on the number of vehicle kilometre and an average external costs per vehicle kilometre (this could also be expressed as a maximum to the weighted average charge per vehicle kilometre).
6 A cap for the revenues from the charges for external environmental and accident costs, defined as a percentage of the revenues from average infrastructure costs.

Below we discuss the arguments in favour and against these various options.

The first option has the risks discussed before and would ignore the call for a cap. This option is for that reason not recommended.

The second option has the disadvantage that it would not allow Member States to differentiate the charges according to the most important cost drivers. Since this would make it impossible to introduce charges in line with marginal social costs, this option is also not to be recommended.

The other four options all offer more or less the possibility to Member States to introduce differentiated charges.

A cap for the charge per vehicle kilometre (option 3 and 4) could rely on the handbook on external cost estimates developed within IMPACT. As stated in this handbook, the unit values it provides are exemplary estimations that do not reflect marginal social costs in each specific case. This approach would have the disadvantage that Member States could not diverge from the values recommended. In the handbook it is recommended that Member States calculate their own values based on the methodology and input data provided. Option 3 and 4 for the definition of a cap would not allow Member States to do so and would for that reason still limit Member States in the accuracy of matching their charge levels with marginal social costs. An additional drawback of this option is that it would require to agree on a relatively complicated set of values for all Member States and various types of vehicles, location, time blocks, technologies.

Option 5 means that a cap is set to the revenues raised from the charge for marginal external air pollution, noise and accident costs for HGV. This option has the advantage that the cap is relatively easy because it refers to the revenues of all charges for external costs instead of to the level of the individual charges. It would leave Member States all freedom to introduce fully differentiated charges very much in line with the marginal social cost level if they have the technology and wish to do so. It requires agreement on a much smaller number of caps than in the case of option 3 and 4. The level of the cap could still be based on the estimates for marginal social costs of air pollution, noise and accidents in average situations according to the handbook. The disadvantage of this type of cap could be that it still requires an individual cap for each Member State, unless one European wide cap is defined.

Option 6 is very much like option 5, though it goes one step further in generalisation of the level of the cap over all Member States. It would be a very simple definition of a cap and the level could to some extent still be based on the handbook.

However it also has some important drawbacks:

- The ratio between marginal external costs (of air pollution, noise and accident costs) and the infrastructure costs may vary a lot over countries. Infrastructure costs depend a lot on climate, geographical characteristics (like mountainous areas) in a country. The marginal costs depend a lot on parameters like population density, composition of the fleet mix and accident rates. The two type of costs (external environmental and accident costs on one hand and infrastructure costs on the other).
- Infrastructure cost estimates and the methodology behind it differ a lot between Member States.

From Table 5 at the end of section 3.4.2 we can see that the summarized marginal costs of air pollution, noise and accidents of HGV equal the infrastructure costs of HGV (both 25 billion Euro). This means that a European wide cap for the revenues from internalisation of external costs of HGV could be defined as 100% of the HGV charges for infrastructure costs.

The introduction of a cap is one, but not the only possible EU coordination to avoid overpricing. An alternative approach would be to prescribe the methodology for calculating the external cost, e.g. based on the IMPACT handbook. Such an approach would generally allow Member States more freedom in calculating their charges than by setting a cap. A disadvantage of such an approach could be that that it does not give much guidance on the (maximum) charge level that can be expected.

## 5.4 Enabling internalisation for non-road modes

Internalisation of external costs in road transport is much more relevant than those of other modes as they have by far the biggest impact on society. However, also for the other modes, internalisation of external costs may lead to significant benefits. In size of external costs, maritime shipping and aviation are the most relevant non-road modes, but also for inland shipping and rail transport, the internalisation policy should be further developed.

Enabling full internalisation for road in the short term opens up the way for internalisation strategies in other modes as well, in the medium to long term. For non-road modes, also some legal and other barriers exist for full internalisation of external costs. Below we discuss the main policy approaches and legal barriers per mode.

### 5.4.1 Rail transport

For rail transport, charging for external costs is allowed under the condition that it is done in competing modes as well. In order to fully enable internalisation for rail transport, the rail directive on track pricing could be changed in such a way that internalisation of environmental costs would be allowed without the precondition that the same should happen in the competing modes. Also limiting the precondition to internalisation of environmental costs in road transport only could be an option that is worth to be further assessed.

Other policy initiatives that could foster the internalisation of external costs of rail transport are the following:
- The Commission could encourage Member States to use rail infrastructure charges for giving incentives for emission reduction of diesel trains and in particular noise reduction, e.g. by using charges as part of a package to give incentives to retrofit wagons with low noise brakes.
- The Commission could encourage Member States to make more use of scarcity charging to remove bottlenecks and finance capacity enhancement.

### 5.4.2 Inland shipping

For inland shipping the main legal barriers for market-based instruments are the Mannheim and Danube Conventions (see also Annex B.8.1). Abolishment of this type of legal barrier is an important step to be taken for inland shipping. This would make it possible to internalise external costs and also to charge for (marginal) infrastructure costs, in line with infrastructure charging for road and rail transport. The Commission could investigate the options for removing these barriers, in close co-operation with organisations like the Central Commission for Navigation on the Rhine.

Internalisation of external costs of inland shipping should focus on the costs of air pollution and climate change. A further assessment of the instruments for internalising these costs could be made, with a focus on kilometre charges and harbour dues for internalising air pollution cost and fuel taxes and ETS for climate change costs. In addition, it currently lacks a framework for calculating infrastructure costs of inland shipping. As part of an internalisation strategy, the Commission could come forward with a proposal for such a framework.

### 5.4.3 Maritime shipping

For maritime shipping, the air pollution and climate change costs are the most relevant external costs. For internalisation of the air pollution costs, harbour dues seem the most appropriate instrument. Sea port authorities or national governments can already give incentives for cleaner engines by additional or differentiation of existing harbour dues. However, many ports are reluctant to introduce such a scheme, because they are afraid of losing market share to competing ports. A coordinated initiative by the Commission may help to overcome this type of barrier.

For the internalisation of climate change costs of maritime shipping, further investigation is needed on the various alternatives. Particularly the options for emissions trading are to be explored further, if possible in co-operation with the IMO.

### 5.4.4 Aviation

For aviation, the inclusion in the ETS is an important step. When the emission credits are auctioned and the cap is at a restrictive level, this may be regarded as internalising the climate change costs, except for the impacts of non-$CO_2$ emissions. For the latter, the Commission is currently studying alternatives for $NO_x$ charges. After that further options need to be assessed.

With regard to internalisation of the noise costs of aviation, there already exist some examples of differentiated charges for airlines. Some airports may be afraid for losing market share to competing airports and therefore not introduce such noise elements in their LTO charges. The Commission could take the lead to see how this type of barrier can be abolished.

For the internalisation of air pollution costs, also LTO charges are the most appropriate instrument. The same competition argument may play a role as for noise charges. Therefore also here, the Commission may take the lead to see how this type of barrier can be abolished.

With regard to legal barriers for full internalisation of all external costs of aviation, the most important action would be to take the lead within ICAO to abolish these barriers, e.g. adjustments to the Chicago Convention (for instance to allow fuel taxation).

## 5.5 Facilitating internalisation

More efficient pricing is about restructuring prices in such a way that more incentives are given to reduce the external costs. As stated before, this requires differentiation of charges to various parameters. If many countries implement a differentiated charging scheme, harmonization is important to limit transaction costs for transport users. In order to facilitate internalisation policy by Member States, the Commission could take the lead in the following harmonization:

- Classification of vehicles (including trains, vessels and aircraft) according to environmental characteristics as a base for differentiated charging. For air pollution differentiation to Euro standard (possibly in combination with particulate filters) is the most appropriate. For noise the Commission could investigate possible categorisation (particularly for rail).
- Classification of other parameters for differentiation, like location and time of the day. This type of differentiation could be done by defining certain categories like rural, urban and metropolitan; night, day peak and day off peak (see also the categories used in the IMPACT Handbook). However in some cases local conditions may require other categories, particularly for congestion charging (e.g. shoulder tariffs around peak hours). Therefore this type of coordination by the Commission does not seem to deserve highest priority.
- Pricing systems (technology, design and enforcement), such as a standard for toll and km charging systems. Development of a European standard is desirable to avoid a excessive number of different systems (e.g. based on Galileo and in line with other developments, e.g. with regard to km

registration). Directive 2004/52/EC provides yet a framework for the interoperability of toll collection systems within the EU, which is currently further developed. To ensure that future on-board units are able to capture the main cost drivers, as presented in this report, this framework should include the necessary requirements for charge differentiation, like the ability to differentiate between location, time of the day and Euro-standard.

- Treatment of occasional users and cross-border-enforcement. The development of an electronic toll system faces the problem of how occasional users should be charged. This is particularly related to foreign traffic. The development of an EU-wide approach for this, possibly in combination with some type of register may help to reduce implementation cost. Also, the development of an EU standard for toll systems (see previous point) may contribute to this by ensuring the interoperability of various systems. More in general, fostering the development and implementation of cost efficient and reliable charging and user information technologies help to minimise transaction costs and to enhance the transparency of tariffs and options to users.

An important link has to be made to climate change policy. From an economic point of view, the increase of fuel prices ($CO_2$ taxation) and/or the inclusion of the transport sector in an emission trading system seems a first best solution. For maritime transport and aviation, inclusion in EU ETS is the best way forward; for surface transport, both carbon fuel taxes and ETS could be considered. Globally oriented measures to tackle the $CO_2$ issue and locally oriented measures to tackle local external effects should be distinguished in future internalisation strategies.

Special attention should be paid to the exchange of good practices between Member States. Exchange of experiences would improve the access to information about new solutions and their effects and may thus speed up implementation across Member States.

Introducing market-based internalisation instruments requires an appropriate communication strategy. For the success of any internalisation approach, social acceptance is an essential precondition. This requires a broad and clear understanding of the objectives of the internalisation action. History teaches us that in many cases the efficiency argument has not been convincing enough for the public opinion. Transport users seem more sensitive for arguments related to fairness, like the 'polluter pays principle'. This type of argumentation is also used for the current development of a nationwide km-charging system in the Netherlands.

## 5.6 Binding requirement for market based instruments

The third element that could be part of an EU policy is to apply binding requirements for Member States to come to internalisation by market-based instruments.

An example of such a binding requirement is that each Member State should charge a minimum share (increasing to 100% over time) of marginal external costs per mode (by marginal taxes and charges). Considering the various types of cost drivers, it is recommended to distinguish at least *kilometre based* and *fuel based* costs and taxes/charges. Additional requirements could be that fuel taxes for internalisation of climate change costs should be based on the carbon content of the fuel. An extra requirement for the kilometre based charges could be that they need to be differentiated to at least location (e.g. urban/interurban), emission class, noise class (where possible) and time of the day.

These type of requirements could be applied for road, rail and inland shipping. They can contribute to more harmonized transport pricing in the various Member States. Binding requirements can help to solve the prisoner's dilemma of Member States who want to apply internalisation measures but who wait for neighbouring countries (or modes) to do the same. In addition it may help to move towards a more level playing field both between Member States and modes.

Setting binding requirements requires a clear definition on which taxes and charges may be regarded as internalising which measures. This report could give some guidance. However, the choice on how to assess fuel excise duties is rather a political than a scientific one.

Binding requirements may be hard to apply, because they will interfere with the taxation policy of individual Member States. This might be regarded as conflicting with the principle of subsidiarity. Nevertheless, the way towards binding requirements seems a useful strategy for the long run, in order to harmonise internalisation strategies between Member States. Part of such a strategy could be to start with enabling and facilitating, as discussed in the previous section. When some front runner Member States have experience showing the added value of full internalisation of external costs, it may be easier to come to binding requirements.

For setting binding requirements with regard to aviation and maritime shipping, international legislation may need to be adjusted. However, also within the existing framework, some types of requirements may be possible. The most important options for binding requirements for internalisation of the external costs of aviation are harmonized differentiated mark-ups for noise and air pollution costs. For maritime shipping a uniform system of mark-ups on harbour dues, differentiated to air pollution costs, could be considered.

Internalisation of climate change costs should be regarded as part of an overall climate policy. Both ETS and fuel taxes (if designed to be in line with carbon content of fuel) are in principle excellent instruments to internalise external climate change costs. Including aviation in ETS is a policy proposal and electric rail is already part of the ETS. Other transport modes could be put under the ETS as well. Another option could be to put surface transport under a separate trading system, apart from the existing ETS.

Also fuel excise duties could be used for internalising climate change costs. As stated before, this could be done by a mark-up to existing excise duties or by labelling a part of existing excise duties as $CO_2$ tax. To assess the impacts of these two options is a study in its own. Here we do not recommend one specific approach. Nonetheless, there is a need for more transparency on the way climate change costs are internalised in the various modes. Therefore for each mode a strategy towards either emission trading or a clearly labelled $CO_2$ tax or charge is recommended.

## 5.7 Link with other policies that contribute to internalisation

Besides the policies discussed in the previous sections, the Commission has other options for contributing to internalisation of external costs in transport. The most important options were yet discussed in section 3.2.

First of all various types of non market-based instruments can help to internalise external costs, such as emission and air quality standards that help to reduce exhaust emissions and to reduce air pollution costs. Internalisation policies can never replace these type of very effective instruments, but should be regarded as complementary, providing incentives to increase the effectiveness of technical measures and standards. The best solution is to create a package of instruments representing different types of measures. This improves effectiveness and efficiency of implemented instruments. In the case of noise and air pollution, market-based instruments should be aimed at speeding up the introduction of new vehicles in the fleet and motivating to use most recent technology in critical areas (urban areas, sensitive areas such as alpine transit).

Second, there are also various types of market-based instruments that, in an indirect way, contribute to internalisation of external costs. An important example is the $CO_2$ based differentiation of fixed car taxes (vehicle purchase taxes and circulation taxes), which is part of the passenger car taxation proposal. This type of measure gives specific incentives to influence the vehicle purchasing decision and the supply of fuel efficient passenger cars. Though not being internalisation from the perspective of neoclassic Marginal Social Cost Pricing, it certainly gives incentives to reduce external climate change costs. Therefore, this type of measures is important to be included in an overall policy package. It provides incentives for fuel efficient behaviour by considering different leverage points and decision state: both the decisions of car makers for the supply of fuel efficient cars (specific standards for new cars) and the demand for new cars (differentiation of vehicle taxes or specific taxes/rebates) and thirdly car use (price of fuel).

# 6 Conclusions and recommendations

## 6.1 General conclusions

Internalisation can serve various aims. According to welfare theory, the primary motif for internalisation is a more efficient economy. This is particularly related to influencing behaviour towards a better use of existing resources by providing optimal incentives, which in the neoclassical model is based on Marginal Social Cost Pricing (Marginal Social Cost Pricing). In this project providing optimal incentives is taken as the primary aim of internalisation. The other motives (e.g. equity or fiscal goals) are acknowledged as being politically relevant and have been taken into account, but are considered less central.

From a theoretical point of view and under specific conditions Marginal Social Cost Pricing is a first best approach for more efficient transport pricing. Fiscal constraints (such as the claim to recover infrastructure costs), potentially high implementation and transaction costs, vested interests and political arguments may make it difficult to reach theoretically optimal levels. In addition, pricing structures and levels that are optimal in theory may generate less welfare gains in practice as many requirements of the underlying theory will not be met in reality.

The analysis of cost drivers shows that it is important to distinguish the following types of taxes and charges: fixed ones (not related to transport activity), fuel based taxes and kilometre based charges. Internalisation of external costs is recommended using a combination of instruments. The main recommended internalisation approaches are:
- Carbon content based fuel taxes or inclusion in ETS for internalisation of climate change costs.
- Differentiated kilometre charges for internalisation of air pollution, noise and congestion costs. Preferably charges should be differentiated to vehicle characteristics (including Euro standard and particulate filters) location and time of the day. Accident costs can be internalised by either a kilometre based charge (differentiated to relevant parameters like location, vehicle type and driver characteristics) or via charging insurance companies based on accident rates. The latter option is to be preferred but requires further study. For congestion costs local road pricing schemes can be a good alternative to differentiated kilometre based charges. For aviation and maritime shipping, the number of visits to (air)ports could be taken as charge base.

## 6.2 Existing taxes and charges

For road transport, but also for other modes, current tax and charge structures are generally poorly related to the social marginal cost approach, i.e. to the cost drivers for both external and infrastructure costs. For the non-road modes particularly ETS (for aviation and electric rail transport) is relevant in this perspective. It could be regarded as internalising climate change costs, as long as carbon credits are auctioned and the emission ceiling is in line with the overall $CO_2$ reduction targets, though for aviation only partly since the climate impacts of non-$CO_2$ emissions are not covered.

For road transport the main conclusions on existing taxes and charges are listed below.

**Fixed taxes and charges** (like circulation taxes and vehicle registration taxes) can give some incentives (e.g. to buy a relatively fuel efficient car) but can not be regarded as internalising external costs of transport activity.

**Kilometre charges** and charges that exceed infrastructure cost levels can be regarded as internalising external costs, particularly when differentiated to relevant parameters (see below). Based on a comparison of existing kilometre based charges, marginal external costs and infrastructure costs we conclude:

- There are no kilometre related charges on urban and metropolitan roads, while kilometre related costs in metropolitan areas are much higher than in interurban areas, making the gap between charges and costs highest there.
- In many countries there are no kilometre related charges on motorways, therefore also on motorways transport users do not pay their marginal costs. In countries with motorway tolls (either electronically or with office boxes), their level is generally much lower than the marginal costs in congested areas. On non congested motorways, the existing charges do sometimes cover just part of the infrastructure costs, while in a few exceptions they cover or even exceed the total infrastructure and marginal external costs, particularly for small trucks. Note that these conclusions are based on estimates of infrastructure costs which in same cases were calculated with rather rough extrapolations.
- In heavily congested areas, congestion costs are dominant. In non congested metropolitan areas accidents are generally the highest externality, for HGV together with air pollution costs (and for the largest HGV in some countries marginal infrastructure costs as well). For HGV on motorways air pollution and marginal infrastructure costs are the dominant marginal cost components.

**Fuel taxes** can internalise fuel consumption related external costs, so particularly climate change costs. Fuel taxes can not be regarded as internalising other external costs because fuel consumption is a very weak proxy for the cost drivers of these external costs.

## 6.3 Main conclusions on the impacts of various internalisation scenarios

In this study six scenarios have been designed for internalisation of external costs and one baseline scenario. The internalisation scenarios consist of changes in taxation and charging structures and levels compared to the baseline. The scenarios have been subject to model exercise[62] (TRANS-TOOLS and TREMOVE) in order to assess their impacts.

The model results show that road freight transport volumes decrease in all scenarios. The largest volume decrease was found for the smaller vehicle types suggesting an increase in transport efficiency (because there is no significant drop in load factors). Passenger transport volumes decrease with 2 to 3% for all passenger cars. The results of the network model TRANS-TOOLS indicate that both for freight and passenger transport particularly for long distance modal shift to non-road modes (particularly rail and waterborne modes) is likely to occur.
The overall fuel consumption decreases in all scenarios. The largest decrease in fuel consumption (at least 10%) can be expected in scenario 2, internalisation by fuel taxes only.

Model results show emission reductions of 5 to 7% for most scenarios. These results are an underestimation of the potential impacts on pollutant emissions. Charges differentiated to region and emission standard would result in significantly higher reductions.

Even with the fairly simple way of internalising external accident costs, fatalities were reduced with about 3%.

All internalisation scenarios result in lower environmental and accident costs. Overall the reduction of fatalities, emission reduction and welfare gains are highest in the scenarios that are closest to the recommended internalisation approaches. In these scenarios the benefits from congestion reduction are dominant.

The implementation costs of these scenarios are estimated in the order of 40 billion for the whole EU (for all modes except maritime shipping)[63]. The operational costs are estimated at roughly 10 billion a year. In scenario 5, where no kilometre charging system for passenger cars was included, the costs are much lower (implementation costs in the order of 10-15 billion and operational costs in the order of 5-10 billion a year). About 70% of these costs in scenario 5 are for the local DSRC-based congestion charging that are part of this scenario; the remaining costs are for the HGV kilometre charging schemes. In all scenarios, the implementation costs are mainly caused by the internalisation measures for road vehicles.

[62] The modelling was carried out outside of the IMPACT project by LAT Thessaloniki and the JRC in Seville.
[63] About 4% of the costs are for HGV.

Based on various real life examples we conclude that internalisation of congestion costs by congestion charges can lead to significant reduction of congestion costs up to 50% or even more.

In this project no full cost benefit analyses has been carried out. In other studies this has been done, showing that in most cases the overall benefits of internalisation by market-based instruments exceed the costs. Earlier studies showed welfare gains from efficient pricing for all modes of inland transport over € 30 billion per year[64], alone for Germany, France and the UK (ECMT, 2003).

## 6.4 Recommended internalisation strategies

Internalisation of external costs requires further differentiation of taxes and charges to parameters that are good proxies for the external costs. These are for example type of location, time of the day, Euro standard, vehicle with and without particulate filters or noise standard. Kilometre-based charges will allow a more differentiated charging scheme than fuel excise duties can provide. The introduction of kilometre charges based on marginal costs and considering congestion, safety and environmental issues is an appropriate way to come to internalisation, in particular for road transport. A special focus should be given to traffic in urban areas and sensitive areas such as Transalpine freight traffic, since marginal costs are higher in these areas.

Internalisation policy should always be designed in the context of other environmental and transport policy. It should not replace effective non market-based instruments, such as emission and air quality standards, but should at first be regarded as complementary, aimed at speeding up the introduction of new vehicles in the fleet and motivating to use most recent technology in critical areas.

Successful pricing measures show that for introducing them it is important to ensure that people can opt out of the taxed transport activity or have reasonable alternatives (for acceptability and efficiency reasons}. This may include technological alternatives with low external costs (like particulate filters, alternative fuels, etc.) or sufficient provision of public transport alternatives. For these reasons, policy packaging is the recommended approach for internalisation.

Internalisation of climate change costs should be embedded in an overall climate change strategy not only covering the transport sector. Climate change costs can be internalised by fuel taxes or $CO_2$ emission trading (for transport this could be within or apart from the existing ETS). In this study we did not analyse the specific impacts of the ETS option. For road, incentives for purchasing more fuel efficient cars (e.g. passenger car taxation proposal) are very important as well.

[64] The gain in welfare recorded is a net gain: it is what remains after subtracting the welfare losses at various points - in particular, the reduction in the consumer surplus currently enjoyed by motorists who are undercharged - from the sum of the various elements of welfare gain, including the increase in revenues, the reduction in travel time for motorists and freight traffic in the newly decongested roads, the reduction in the real cost to society represented by pollution and accidents, and so on.

Internalisation of up- and downstream costs, such as external costs of refining and electricity production and car vehicle disposal respectively, can best be done by internalisation measures for these sectors themselves (electricity producers and refineries) than indirectly through measures tackling transport.
Below, we list the recommended internalisation approaches for the various transport modes. Next, the policy and legal recommendations are listed.

**Road**
For road, Marginal Social Cost Pricing can be approached most closely by a combination of fuel taxes (climate change costs), differentiated kilometre charges (for other environmental costs, accident costs, and marginal infrastructure costs), congestion charges at bottlenecks and cordon charges for congested urban areas. A special focus should be given to traffic in urban areas and sensitive areas such as Transalpine freight traffic, since marginal costs are higher in these areas. This could be combined with a reduction of existing fixed taxes, in particular circulation taxes and vignettes.

Pricing only certain parts of the road network can have the risk of undesired shift to other non-tolled parts of the network. This is particular the case for motorway tolls. Evidence from the German HGV toll shows that the significance of a shift to the secondary roads depends a lot on local circumstances and can in some cases in the long run be very small.

The external part of accident costs can be internalised by a well differentiated kilometre charge or, preferably, by an alternative approach via insurance companies. It is hard to design price structures that give proper incentives, because external accident costs have many cost drivers. Therefore, the recommended approach is to charge insurance companies for external accident costs. They are the experts in how to charge these costs to the users and how to give them the best incentives. These charges should be differentiated as much as possible to the external accident costs per insurance company (e.g. based on statistics on fatalities and injured). This approach for accident costs is also recommended for the other modes and it is suggested as an issue for further study.

Urban road pricing deserves special attention in internalisation policy, because in urban areas current marginal taxes and charges are much lower than the marginal costs, which are much higher than in other areas.

Congestion pricing in congested areas leads to a significant reduction of congestion levels and can be an efficient way of tackling the problem of congestion. The level of efficiency depends on the design and the operation costs of the charging system and on urban sprawl effects that are to be expected. In order to avoid overpricing, congestion charges could be introduced as differentiations of existing cost recovery based infrastructure charges to time of the day and location. Particularly in urban and mountainous areas additional charges appear more appropriate.

An important question with regard to road transport is how excise duties should be assessed when designing an internalisation strategy. Except climate change costs, fuel excise duties can not internalise marginal external and infrastructure costs as the system lacks incentives for reducing these costs. Internalisation of climate change costs with extra charges on top of existing fuel taxes may be appropriate. However there are also good arguments to state that climate change costs of road transport are yet internalised by the existing fuel taxes. Based on pure scientific arguments it is currently not possible to decide between these two approaches. Existing fixed taxes (such as circulation taxes or registration taxes) could be lowered to compensate for the introduction of (kilometre based) charges for internalisation of external costs.

**Non-road modes**

For rail transport, marginal external costs can relatively easily be internalised by mark-ups on the existing infrastructure charges. The most efficient way of internalising the external costs of rail transport are differentiated mark-ups, with a focus on noise costs and, for diesel powered trains, air pollution costs. Climate change costs of electric trains can be regarded as internalised by the ETS. Air pollution costs of electric trains are preferably internalised upstream, within the energy sector. For diesel trains, fuel taxes (or a transport wide ETS) are regarded as the proper way to internalise climate change costs.

For aviation internalisation of external costs can be done by differentiated mark-ups on LTO charges, based on external noise, accidents and air pollution costs. Climate change costs of $CO_2$ emissions by aviation are expected to be internalised soon by the ETS. The climate impacts of other aircraft emissions that contribute to climate change (including contrails) will not be internalised by ETS and deserve special attention.

For inland shipping, there are very few existing charges that could be taken as levy point. Kilometre charges, comparable with what is present in rail transport would give incentives that are closest to marginal social costs. Possibly, some legal barriers to river and channel charges exist, notably the Mannheim and Danube Conventions. An alternative could be to introduce mark-ups on harbour dues. For internalising climate change costs of inland shipping, fuel taxes are regarded as the most proper way, but also ETS may be considered.

For maritime shipping harbour dues are the most appropriate levy point for internalisation of air pollution costs. Climate change costs could be internalised by including maritime shipping in the ETS.

For all non-road modes, an effective and efficient way to tackle scarcity costs is by local pricing measures. For rail this could be done by scarcity mark-ups on track pricing, for shipping by mark-ups on harbour dues and for aviation on slots. These type of mark-ups should always be differentiated to the scarcity level. Scarcity costs however are difficult to measure. Therefore a demand oriented approach by allocating scarce tracks according to willingness to pay of potential users may be intensified.

## 6.5 Recommendations with respect to policy and legal strategy

A more explicit enabling for Member States to charge HGV for external air pollution, noise and accidents costs on top of infrastructure costs would be an important first step towards more efficient pricing. An alternative could be to leave accident costs out and opt for internalisation of accident cost via insurance companies. In addition enabling much stronger differentiation is recommended, including differentiation the charges for recovering infrastructure costs so that they reflect both marginal infrastructure costs and congestion costs. Finally, it is recommended to make more explicit that the already allowed regulatory charges include additional congestion charges in urban and mountainous areas on top of the charges at average infrastructure cost and air pollution, noise and accidents costs. The handbook, presented in Deliverable 1 of IMPACT, could serve as common framework for external cost estimation.

Amendment of the current Eurovignette Directive could follow the internalisation approaches proposed in this report. An important issue is the definition of a cap, to prevent overpricing. Also a decrease of existing taxes and charges not in line with the use of infrastructure (such as fixed charges) could be envisaged. A cap for charging external costs may help gaining support, particularly from peripheral countries that fear a redistribution effect from peripheral countries to central countries. The most appropriate definition appears a cap on the weighted average charge per vehicle kilometre based on the weighted average external air pollution, noise and accident costs. Alternatively, a cap on the extra revenues, defined as a percentage of the revenues from average infrastructure costs could be used. The design of a cap should leave as much flexibility as possible, otherwise it carries the risk that Member States can not introduce the most efficient charge levels.

The internalisation of marginal costs in road transport is much more relevant than in other modes as they have by far the biggest impact on society. However, also for other modes, the Commission could contribute to steps towards further internalisation of external costs.

For rail transport, the Commission could encourage Member States to give incentives for emission reduction of diesel trains and in particular noise reduction, e.g. by using charges as part of a package to give incentives to retrofit wagons with low noise brakes. Member States could also be encouraged to make more use of scarcity charges.

For inland shipping the main legal barriers for market-based instruments are the Mannheim and Danube Conventions. The Commission could investigate the options for removing these barriers, in close co-operation with organisations like the Central Commission for Navigation on the Rhine. A further assessment could be made of kilometre charges and harbour dues for internalising air pollution cost and fuel taxes and ETS for climate change costs. In addition, the Commission could develop a framework for calculating, and at the longer term charging, infrastructure costs of inland shipping.

For the internalisation of climate change costs of maritime shipping, further investigation is needed on the various alternatives, particularly emissions trading. Many ports are reluctant to introduce incentives for cleaner engines by differentiated harbour dues, because they are afraid of losing market share to competing ports. A coordinated initiative by the Commission may help to overcome this type of barrier. In aviation similar barriers seem to exist for the introduction of noise and air pollution elements in LTO charges. Therefore also here, the Commission could take the lead.

In order to facilitate internalisation policy by Member States, the Commission could take the lead in the following harmonization:
- Classification of vehicles according to environmental characteristics as a base for differentiated charging.
- Pricing systems (technology, design and enforcement), such as a standard for toll and km charging systems in line with he framework provided by Directive 2004/52/EC on interoperability of toll collection systems within the EU.

In addition, it currently lacks a framework for calculating infrastructure costs of inland shipping. As part of an internalisation strategy, the Commission could come forward with a proposal for such a framework.

For road, rail and inland shipping, requirements could be set for the minimum share of marginal infrastructure plus external costs that need to be charged, per mode. Also the way this should be done could be defined to some extent, as long as it respects the various tax systems of Member States.

The most important options for binding requirements for internalisation of the external costs of aviation are harmonized differentiated mark-ups for noise and air pollution costs. For maritime shipping a uniform system of mark-ups on harbour dues, differentiated to air pollution costs, could be considered.

The use of revenues of internalisation does not need to be determined at EU level. The added value of any type of earmarking is mainly to gain public support. Therefore, it is best to leave decisions on earmarking to Member States and to give only some general conditions or recommendations (e.g. for urban traffic). For public support, the revenues collected for external effects should be decoupled from budgetary constraints. E.g. an overall increase in the environmental friendliness of vehicle fleets should be associated with lower transport taxes and charges.

Internalisation of climate change costs should be regarded as part of an overall climate policy approach. Internalisation of the external climate change costs of transport, should be embedded in a overall climate policy. For each transport mode a strategy towards either emission trading or a clearly labelled $CO_2$ tax is recommended.

We recommend to start with more stringent legislation for those situations where externalities or the gap between costs and taxes/charges is largest, where travel alternatives exist or can be improved, where other measures are limited and, consequently, where public acceptability for price changes will be highest. Typical cases are roads in urban and sensitive areas, congestion charging and HGV charging.

To keep track of the success or of adverse effects of charging systems, it may be appropriate to regularly check the need for charge adjustments as technical or behavioural parameters of the pricing system will change over time. This could also include periodic evaluation of the level and structure of mark-ups for external costs and the comparison with existing charges in the Member States.

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**CE Delft**
**Solutions for environment, economy and technology**

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

# Internalisation measures and policy for the external cost of transport

Produced within the study
Internalisation Measures and Policies for all external cost of Transport – Deliverable 3

Annexes

**Report**

**Delft, June 2008**

Author(s): H.P. van Essen, B.H. Boon, A. Schroten, M. Otten (CE Delft)
M. Maibach and C. Schreyer (INFRAS)
C. Doll (Fraunhofer Gesellschaft - ISI)
P. Jochem (IWW)
M. Bak and B. Pawlowska (University of Gdansk)

# A Good practices

## A.1 Introduction

This annex very briefly describes a number of good practice measures for internalisation of external effects. Because the good practices for internalisation relate to different externalities, cost effectiveness across measures could not be compared.

The next section gives a brief overview of good practices. Section A.3 to 0 provide a fact sheet per good practice. The fact sheets address the issue of costs and effects of particular policy measures. We have not included a category cost effectiveness of efficiency. The reason is that the different fact sheets relate to different external effects, a category 'cost effectiveness' or 'efficiency' may therefore be confusing, in the sense that these cannot be compared if the aims of the measures differ, as they generally do.

## A.2 Overview of good practices

In 2003, a *congestion charge* of 5 pounds per day for road passenger vehicles was introduced in London City. The aim of the charge is to reduce congestion in the inner city. At the time of introduction, substantial investments were made in the public transport system, to offer people an alternative. The congestion charge has decreased traffic volumes by 15%, reducing congestion by up to 30%. In addition, emissions of pollutants and $CO_2$ has gone down by about 20%.

Since 2001 a distance-, weight- and emission based *heavy goods vehicles toll* (HGV toll) is applicable on the entire Swiss road network. The aim of the scheme is to internalize the external costs of road transport, limit the growth of heavy goods vehicles traffic, and finance new railway infrastructure. Simultaneously to the introduction of the HGV toll, the weight limit of vehicles was increased. Due to these measures, vehicle kilometres decreased by 8% and the replacement of old vehicles was accelerated. As a consequence, emissions decreased by 6-8%.

Heavy goods vehicles are subject to a compulsory toll (*Maut)* on German motorways since 2005. Like the Swiss scheme, the charge level is based on the distance travelled, the emission class and the number of axles of the vehicle. The aims of the scheme are to finance infrastructure expenditures, to charge the real costs, to promote efficient use of HGVs and innovative techniques, and to stimulate a shift of road freight transport to other modes. Due to this scheme the number of empty runs decreased by approximately 15%, while the number of containers carried by rail increased by about 7%.

At 19 Swedish airports *emission based landing fees* are levied. The emission charge is based on the engines' actual emission of $NO_x$ and HC during the Landing and Take Off cycle (LTO cycle). The charge level per kg of emission is based on an estimate of the external costs. Nonetheless the scheme is revenue neutral, because simultaneously infrastructure charges have been reduced. The charge is to stimulate airlines to purchase and operate aircraft with lower engine emissions. LTO emissions per trip decreased in the first years after the introduction of the charge. However, since 2004 LTO emissions per trip are rising again.

In Norway a *$CO_2$ tax* applies to fuel used for domestic aviation. The measure was introduced simultaneously with a lowering of the passenger tax, so to green the tax structure. The impact on fuel efficiency of the tax is very low because the charge levels are modest. Nonetheless, it can be regarded as a first step in the right direction, changing charge structures to reflect external effects.

On several tolled motorways in France, *toll levels are differentiated* so to spread returning holiday traffic more evenly over the day. Tariffs in peak hours are increased, whereas in shoulder hours a reduction applies. Experiences from the US indicate that such differentiation may reduce congestion considerably, also when targeting commuter traffic. There, a differentiation of 50% in bridge toll levels diverted 20% of the traffic from peak to shoulder periods.

In 1998 20 to 25 Swedish ports have introduced a *differentiated port due* with respect to $SO_x$ and $NO_x$ emissions of the ships. The aim of this charge is to provide ship owners/operators an incentive to reduce emissions of sulphur and nitrogen oxides. Simultaneously to the introduction of the differentiated port dues also differentiated fairway dues were introduced. Together these measures reduced $NO_x$ emissions by a little less than 10%, while $SO_x$ emissions were reduced by about 30%.

Italy has a *congestion and scarcity charge* for rail infrastructure. The infrastructure charge depends both on the time of the day and the speed profile of the train, so to optimize the capacity of the track. For each route standard speed profiles are designed to optimize the line. Higher prices are charged on trains which speed diverges from the norm for the route in question because this will stall other traffic and reduce capacity. In addition, there is a charge per node that varies with the implicit amount of congestion at the node by categorizing nodes according to traffic levels.

At many airports in Europe, the general *landing and takeoff charges are differentiated* with respect to the noise emissions of the aircraft and the time of day. The purpose is to incentivise the use of quieter aircraft and to reduce night noise. At Frankfurt airport this differentiation is rather sophisticated. Moreover, at Frankfurt an additional noise surcharge is levied for the financing of a noise abatement program.

Many countries apply *differentiations in registration or circulation taxes* for passenger vehicles, so to incentivise the purchase of fuel efficient cars. In some countries the differentiation is very rough, whereas other countries have a more sophisticated differentiation. In the Netherlands, the registration taxes are dependent on the vehicles relative efficiency compared to cars that have more or less the same size. Providing an incentive on purchase may be more effective because at that time, consumers make a choice that will partly determine their long time emissions of $CO_2$.

In the UK, the company car taxation scheme has been adapted to incentivise the purchase of fuel efficient cars. The company car tax is an additional tax paid by owners of a company car that use the car for private purposes. A certain percentage of the list price of the car is added to the taxable income, depending on the fuel efficiency of the car. Due to the revenue neutral scheme, the average fuel efficiency of company cars has improved by 15 g/km.

## A.3 London congestion charge

| **London Congestion Charge** | | | **Road** |
|---|---|---|---|
| Aim | The key aim of the congestion charge is reducing congestion in London inner city. In addition, also improvements of journey time reliability for car users, bus services and efficiency of the distribution of goods and services are pursued. Finally, it generates net revenues to support the Mayor's Transport Strategy more generally. | | |
| **Description of the system** | | | |
| Year of introduction | 2003 | Geographical scope | London inner city |
| Revenues (£/year) | 190 million | Costs (£/year) | 90 million |
| Charge level | Until July 2005, the congestion charge was a £ 5 daily charge for driving or parking a vehicle on public roads within the congestion charging zone between 07:00 and 18:30, Mondays to Friday, excluding weekends and public holidays. In July 2005 the daily charge has been increased to £8.<br><br>Certain categories of vehicle, notably taxis, London licensed private hire vehicles, motorcycles, pedal cycles and vehicles with more than 9 seats are exempted form the charge. Certain categories of vehicle users can register for discounts. For example, residents of the congestion charging zone can register for a 90% discount, and disabled persons holding a Blue Badge and certain alternative fuel vehicles are eligible for a 100% discount. | | |
| Collection of charges | Charges can be paid either in advance or on the day of travel before, during or after the journey or by midnight the following charging day. In the last case, the charge will be £ 10 instead of £ 8. It is possible to pay for more than one day at a time, up to 90 days in advance. By paying the vehicle registration mark is registered on a database for journeys within the Congestion Charging Zone. As a vehicle enters the Congestion Charging zone his registration mark is read by cameras and checked against the database. Charges can be paid in different ways: online, at selected shops, petrol stations and car parks, by post, by telephone, by SMS, or at BT Internet kiosks. | | |

| | |
|---|---|
| Revenues and costs | Total charge and penalty charge payments, based on the £ 5 charge, typically amounted to £ 190 million per year (no figures based on the £ 8 charge are available yet).<br><br>The operating costs, which includes among other things administrative, supervising and monitoring costs, are estimated to be £90 million per year. In addition, the costs of the provision of extra public transport capacity to cater for car occupants who switch to this kind of transport are estimated £ 20 million. However, there are also additional public transport fares generated by those transferring to bus, underground and rail services. These are estimated of the order of £ 15 million per year. So, the net costs of extra public transport are £ 5 million per year. |
| Earmarking | By law, the net revenues of the congestion charge are spent on London transport facilities. |
| Enforcement | At midnight the following charging day, all photographic images of vehicles that did pay the congestion charge are deleted. The vehicle registration mark of vehicles that should have paid but have not done so, are kept by the computer. These registration marks are checked manually, and a Penalty Charge Notice (PCN) of £ 100 is imposed on the registered keeper of the vehicle. This payment will be reduced to £ 50 for prompt payment within 14 days. Failure to pay the PCN within 28 days results in an increase of the penalty to £ 150. Failure to pay this penalty can result in further (legal) action. |
| Acceptance | TFL (2004) studied the social impacts of the congestion charge. The main conclusions were:<br>– A majority of the people say that the scheme has actually made no difference to them.<br>– Especially people with higher incomes, without cars, and those making work trips say they have personally gained from the charging scheme.<br>– People who say they have personally lost are those who drive in the zone, and from lower income households.<br>– People from outer London are less likely to report any impact from the charging scheme.<br><br>In addition, the opinions of businesses with regard to the congestion charge were studied in TFL (2006):<br>– The majority of charging zone businesses recognise that decongestion had created a more pleasant working environment and easier journeys for employees using public transport for travel to work. Amongst businesses in the charging zone there were more supporters of the congestion charge than opponents.<br>– London businesses outside the charging zone were broadly supportive of congestion charging and did not report any significant negative effects. |
| Legislation | |
| **Effects** | |
| Transport demand | In 2005, traffic entering the charging zone was reduced by 17% in relation to equivalent pre-charging figures in 2002. The reduction in cars entering the charging zone was even larger: 31%. However, little or no change in number of trips to the central area was registered. 50 to 60% of the travellers moved to public transport, 20-30% diverted round the charging zone, and 15-25% made other adaptations. The introduction of the congestion charge had also significant impact on the number of vehicle kilometres driven within the inner city of London: -16% for all traffic and - 21% for cars, both in relation to 2002. |

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| | The increase in charge level from £ 5 to £ 8 in July 2005 had significant impact on transport demand. The number of cars decreased by 4%, while total traffic figures are 2% lower compared to the figures just before July 2005. |
| External effects | – Congestion in the charging zone is reduced by 30% compared to pre-charging congestion levels in 2002. Also congestion on radial routes approaching or leaving the charging zone has decreased.<br>– Due to the lower traffic volumes in the charging zone, also the number of accidents is decreased. It is estimated that within the charging zone 40 to 70 accidents with personal injury are saved each year.<br>– Between 2002 and 2004, total emissions of $NO_x$ from road traffic sources in the charging zone are estimated to have reduced by ca. 18%. Equivalent reductions for $PM_{10}$ were approximately 22%.<br>– $CO_2$ emissions have been reduced by 19% between 2002 and 2004.<br>– No evidence was found for an effect of the congestion charge on ambient noise. |

**Alternative systems**

- From January to July 2006 a congestion tax trial was conducted in Stockholm. Also this trial shows good results with regard to decreasing transport volumes (-22%) and emissions (8 to 14%). In addition, 5% to 10% reduction in accidents involving personal injuries are registered, while journey times have considerably fallen (Stockholmförsöket, 2006).
- From 1998, charges for entry into a limited zone in the centre of Rome have to be paid. The charging system has reduced traffic in the controlled zone by 20%. Also significant reductions in pollutant emissions have been recorded (ECMT, 2004).
- Six Norwegian cities have electronic toll rings, which were introduced to raise revenues for new infrastructure investments, mainly road tunnels (ECMT, 2004).

**Additional remarks**

The introduction of the congestion charge had a broadly neutral impact on overall business performance in the charging zone. No overall impact on employment, number of businesses, turnover, commercial rents or profitability were found.

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## A.4 Heavy vehicle charging system in Switzerland

| **Heavy vehicle charging system in Switzerland** | | | **Road** |
|---|---|---|---|
| Aim | – Internalisation of external costs.<br>– Financing new railway infrastructure.<br>– Limiting heavy goods vehicles (HGV) traffic growth.<br>– Diverting HGV to rail traffic in transalpine traffic. | | |
| **Description of the system** | | | |
| Year of introduction | 2001 | Geographical scope | Switzerland |
| Revenues (€/year) | 1,350 million (2007) | Costs (€/year) | 35 million |
| Charge level | Since 2001, all heavy good vehicles with a total admissible weight of more than 3.5 tons are subject to a charge, including foreign vehicles driving through or into Switzerland. The charge is applicable on the entire road network of Switzerland.<br><br>The charge level depends on the highest authorized total weight and emission category of the vehicle, and the distance travelled on Swiss roads:<br>Charge level = distance travelled in Switzerland * weight of vehicle * tariff rate.<br><br>There are three steps according to the bilateral treaty with the European Union. The introduction of the charge was in parallel to an increase of the weight limit of HGV (from 28 to 34 tonnes). 2005 the tariffs have been increased with a parallel increase of the weight limit from 34 to 40 tonnes. A final increase of the tariffs has taken place 2008. The rates are dependent on the emission class of the vehicle.<br><br>**Euro class** **Tariff**<br>Euro 2/1/0 and older 0.0307 CHF/tkm<br>Euro 3 0.0266 CHF/tkm<br>Euro 4,5 and younger 0.0226CHF/tkm<br><br>These tariffs were derived on the following basis. First, the uncovered costs of heavy traffic were calculated. These consist of uncovered road infrastructure costs, air pollution, noise and accidents caused by HGVs. Second, total transport performance was estimated. Finally, the tariffs were estimated by relating the uncovered costs to the transport performance. | | |
| Collection of charges | The kilometres travelled are recorded by an On-Board-Unit (OBU). Further information is stored directly in the OBU (e.g. weight, emission category). The operator who is subject to the fee registers the data each month on a chipcard, which he can send to the Federal Customs Administration, either by post or electronically (by Internet). For vehicles without an OBU, an identification card, issued on the first entry into Switzerland, is used to record data. The driver inserts the card into a terminal on entry into Switzerland and declares the current mileage. The fee must be paid at the latest on leaving Switzerland (Are, 2004). | | |
| Revenues and costs | The operating costs of the Swiss HGV toll system are € 35 million per year, while the fee income equals € 1,35 billion per year (2007). Due to the final increase 2008, an income of 1,45 billion CHF is expected for 2009. In addition, the one time investment costs are approximately € 200 million (Oehry, 2006). | | |
| Earmarking | The largest part of the revenues (up to 2/3) are to be used for projects in public transport. The remaining 1/3 goes to the cantons where it is used mainly for road purposes (Nash, 2004). | | |

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| Enforcement | The functioning the OBU can be checked by 12 control stations spread throughout Switzerland. Vehicles not equipped with an OBU are subject to periodic check.<br><br>For intentional breaking of the rules, a fine of 5 times the regular fee is charged on the offender. For unintentional offenders this is equal to 3 times the regular fee. In any case, the minimum fine is CHF 100. |
| Acceptance | The Swiss heavy vehicle charging system was introduced after a national referendum at which the Swiss population voted for introduction of a distance based, electronically collected road toll for heavy good vehicles.<br>Balmer (2003) states that three reasons have been decisive for the political implementation of the charge system:<br>– The HGV charge system was introduced simultaneously with a raise in the weight limit of trucks, as a consequence of which the competitiveness of road transport remains stable.<br>– The HGV charge system was linked to the polluter pays principle.<br>– The revenues of the system were reinvested in transport infrastructure in road and public transport. |
| Legislation | The conditions under which user charges and tolls may charged for road use by heavy goods vehicles are defined in the so called 'Eurovignette Directive' (European Commission, 1999; 2006/38/EC). |
| **Effects** | |
| Productivity Effects | Together with the increase of the weight limit, the average load factor has been increased by 10.6% between 2001 and 2005 (ARE, 2007). |
| Transport demand | In the first four years of the toll system, an absolute reduction of 6.4% in vehicle kilometres was observed resulting in a traffic volume that is 23% lower than the forecasts for the business as usual scenario (ARE, 2007). This reduction was caused by the combination of the charge and the increase in the maximum allowed weight of HGV's (from 28 to 34 tons in 2001, and to 40 tons in 2005).<br><br>Despite the strong reduction in vehicle kilometres, the transport by road (in ton kilometres) was about the same as in the business as usual. The number of tonne kilometres by rail in 2005 was about 8% higher than the business as usual scenario. Together this resulted in a small increase in the overall transport volume. So, the advantage for the road sector caused by the higher weight limit was counterbalanced by the kilometre charge. Overall the effect of the charge was thus a considerable modal shift. The other main effect of the HGV toll was its incentive for fully exploiting the logistic potential to optimise utilisation of the vehicle fleet and especially avoiding empty runs.<br><br>According to ARE (2004), the effect of the HGV toll was somewhat stronger than that of the higher weight limits. |
| External effects | In the first four years of the toll system, an absolute reduction of 6.4% in vehicle kilometres was observed resulting in a traffic volume that is 23% lower than the forecasts for the business as usual scenario (ARE, 2007). This reduction was caused by the combination of the charge and the increase in the maximum allowed weight of HGV's (from 28 to 34 tons in 2001, and to 40 tons in 2005). |
| **Alternative systems** | |
| – In 2004 a HGV charging system was introduced in Austria, mainly aimed to finance the extension and operation of the motorway network. The system is less sophisticated than the Swiss and German ones, since charges are not differentiated to emission classes.<br>– A similar HGV charging system is in place in Germany (see fact sheet 'Heavy vehicle charging system in Germany'). | |

| **Additional remarks** |
|---|
| – On balance the HGV toll system resulted in an increase in transport costs of about 6%. Due to the small ratio of transport costs in total production costs, there is a negligible effect on prices (0,1% at most, according to ARE (2004)). |
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## A.5 Heavy vehicle charging system in Germany

| **Heavy vehicle charging system in Germany** | | | **Road** |
|---|---|---|---|
| Aim | – Financing extension and operation of motorway network.<br>– Charging the real costs: 'the user pays' principle.<br>– Promoting the efficient use of Heavy Goods Vehicles (HGV) and creating an incentive for a shift of freight transport to other modes, like rail and inland shipping.<br>– Promoting innovative technologies. | | |
| **Description of the system** | | | |
| Year of introduction | 2005 | Geographical scope | Germany |
| Revenues (€/year) | 3,000 million | Costs (€/year) | 620 million |
| Charge level | Since 1 January 2005, German and foreign HGV's with a maximum permissible weight of 12 tonnes or more have been subject to a compulsory toll *(Maut)* on German motorways. The charge level depends on the distance traveled, the number of axles, and the emission class of the vehicle. Based on their emission class, vehicles were assigned to one of three categories as follows:<br><br>(see table below)<br><br>Based on the number of axles, the charge levels for the various categories are:<br><br>(see table below) | | |

| | Category A | Category B | Category C |
|---|---|---|---|
| Until 30-9-2006 | Euro 4/5, EEV | Euro 2/3 | Euro 0/1 |
| From 1-10-2006 to 30-9-2010 | Euro 5, EEV | Euro 3/4 | Euro 0/1/2 |
| From 1-10-2010 | EEV | Euro 4/5 | Euro 0/1/2/3 |

| | Up to three axles | Four or more axles |
|---|---|---|
| Category A | € 0.09 | € 0.10 |
| Category B | € 0.11 | € 0.12 |
| Category C | € 0.13 | € 0.14 |

| | |
|---|---|
| Collection of charges | Automatic tracking and charging is done with a GPS On-Board-Unit (OBU) which sends the travel data through a GSM mobile unit to the (private) company responsible for charging, Toll Collect, which subsequently charges the user for the covered distance. Vehicles without OBU can pay manually before embarking on the trip at any of the *Maut* terminals which are placed at petrol stations and other sites near entries to the German motorway network. Payment is also possible via internet or telephone. |
| Revenues and costs | The operating costs of the German HGV toll system are € 620 million per year, while the fee income equals € 3 billion per year (Oehry, 2006). |
| Earmarking | Revenues generated by the toll will be spent on infrastructure projects for roads, railways and waterways. |
| Enforcement | Toll enforcement and the punishment of violations are the responsibility of the Federal Office for Goods Transport (BAG). With the aid of special technology, BAG can determine if a vehicle has an obligation to pay toll and if it has met this obligation fully, partially, or not at all. The control system distinguishes between automatic enforcement through control bridges, enforcement by stationary and mobile teams, and company-level enforcement. If it is determined that toll has not been paid, the fee for the distance travelled will be collected after-the-fact and an administrative fine may be imposed. If the actual distance travelled cannot be determined, a toll will be collected for a distance of 500 km. |
| Acceptance | By earmarking the revenues generated by the toll for improving transport infrastructure (especially road infrastructure) acceptance of HGV charging was increased. |
| Legislation | The conditions under which user charges and tolls may charged for road use by heavy goods vehicles are defined by Directives 1999/62/EC and 2006/38/EC (European Commission, 1999; 2006). |
| **Effects** | |
| Transport demand | – The share of empty rides decreased slightly from 11.5 in 2004 to about 10.2% in the first months of 2007 However this is just continuation of a trend which was also going on before the introduction of the charge.<br>– The number of containers carried by rail increased by about 7%. |
| External effects | |
| **Alternative systems** | |
| – In 2004 a HGV charging system is introduced in Austria, mainly aimed to finance the extension and operation of the motorway network. The system is less sophisticated than the Swiss and German ones, since charges are not differentiated to emission classes.<br>– A similar HGV charging system is in place in Switzerland (see fact sheet 'Heavy vehicle charging system in Switzerland'). | |
| **Additional remarks** | |
| | |

**Literature**


BGL (2007b): website www.bgl-ev.de.

CE Delft (2005), *Technology for pricing policy – experiences with current schemes*, Delft.

European Commission (1999), *Directive 1999/62/EC of the European Parliament and of the Council, on the charging of heavy goods vehicles for the use of certain infrastructures*, Brussels.

European Commission (2006), *Directive 2006/38/EC of the European Parliament and of the Council*, *amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures*, Brussels.

Oehry, B. (2006), *Charging technology and cost effectiveness* (presentation), Basel.

Swiss Customs Authority (2006), Bern, http://www.zoll.admin.ch.

Schulz, G. (2006), *HGV tolls in Germany based on satellite and mobile communications technology: innovative, environmentally friendly and fair* (presentation), Federal Ministry of Transport, Building and Urban Affairs, http://www.cemt.org/topics/taxes/Paris06/Schulz.pdf.

## A.6 Emission based landing fees at Swedish airports

| **Emission based landing fees at Swedish airports** | | | **Air** |
|---|---|---|---|
| Aim | Providing an incentive to airlines to purchase and operate aircraft with lower engine emissions. | | |
| **Description of the system** | | | |
| Year of introduction | 1998 | Geographical scope | All 19 Swedish airports |
| Revenues (€/year) | Revenue neutral | Costs (€/year) | |
| Charge level | In 1998 emission based landing fees were introduced at 9 Swedish airports. In 2000 this program was extended to all 19 Swedish airports. The emission charge is applied for all aircraft with a maximum take off weight over 5.7 tonnes. The emission charge is based on the engines' actual emission of $NO_x$ and HC in the LTO cycle. It was originally based on the external cost estimate of emissions, and set at 50 SEK per kg of $NO_x$. It was introduced simultaneously with a decrease of infrastructure charges, so the scheme would be revenue neutral.<br><br>At least for Arlanda Airport (Swedish largest airport), the charge structure has been changed in 2006 and is now as follows.<br><br>**Average LTO Emissions**<br>**(in g/kN)Landing Fee Increase**<br>**(In %)**<br>HC > 19 *or* $NO_x$ > 80 — 30<br>≤ 80 $NO_x$ — 25<br>≤ 70 $NO_x$ — 20<br>≤ 60 $NO_x$ — 15<br>≤ 50 $NO_x$ — 10<br>≤ 40 $NO_x$ — 5<br>≤ 30 $NO_x$ — No supplement | | |
| Collection of charges | The emission surcharge are due for immediate payment to the airport. Agreement can be made on periodic debiting, provided the owner or user of an aircraft carries on regular or extensive traffic. However, respite for payment must not exceed 30 days. | | |
| Revenues and costs | The emission charge was revenue neutral to the airports. The landing charge was reduced by 12%, which was offset by the revenues of the emission charge. | | |
| Earmarking | The revenues generated by emissions fees at Swedish airports are used to support an environmental fund that has helped finance emissions reduction measures at the airports. These airport-related emission reduction measures were historically paid through general airport revenues. | | |
| Enforcement | Late payments will result in interest of overdue payment with 15.5%. | | |
| Acceptance | | | |
| Legislation | | | |

| **Effects** | |
|---|---|
| Transport demand | |
| External effects | The direct impact of the emission based landing fees has not been evaluated. However, the Swedish governments reports aircraft LTO emissions from 19 airports (Luftfartsverket, 2004; Swedish Civil Aviation Administration, 2001). From this data it becomes clear that emissions have diminished in the first years after the introduction of the emission surcharge, while on the same time the number of aircraft movements increased. However, since 2004 LTO emissions rose faster than air traffic. This may be due to longer flights and the use of larger aircrafts. |
| **Alternative systems** | |
| – At Zurich Airport and Geneva Airport similar emissions based fee programs to the ones instituted in Sweden are implemented in 1997/1998. These airports have added an emissions surcharge (directed on $NO_x$ and HC emissions) to the landing fee based on the engine characteristics of the planes (NESCAUM, 2003)<br>– Heathrow and Gatwick have introduced revenue neutral $NO_x$ emission charges, albeit at much lower incentive levels. | |
| **Additional remarks** | |
| | |
| **Literature** | |
| Heathrow Airport (2005), *Conditions of Use,* http://www.lhr-acc.org/documents/HACC422.pdf<br>Luftfartsverket Arlanda airport (2006), *Product Catalogue,* Stockholm https://www.arlanda.lfv.se/upload/Flygplatser/Arlanda/PDF/ProductCatalogue_eng_0306.pdf.<br>Luftfartsverket (2001), Annual Report 2001, http://www.lfv.se/upload/Tjanster/Dokumentbank/ar04_eng.pdf.<br>NESCAUM (Northeast States for Coordinated Air Use Management) (2003), *Controlling Airport-related air pollution* http://www.ccap.org/pdf/2003-June--Controlling_Airport-Related_Air_Pollution.pdf.<br>Swedish Civil Aviation Administration (2001), *Swedish Civil Aviation Administration Annual Report 2000.*<br>Swedish Civil Aviation Administration (2005), *Luftfartstyrelsen*, Norrköping. | |

## A.7 $CO_2$ charge domestic aviation in Norway

<table>
<tr><th colspan="3">$CO_2$ charge domestic aviation in Norway</th><th>Air</th></tr>
<tr><td>Aim</td><td colspan="3">– Greening the taxation scheme.<br>– Internalisation of external costs.</td></tr>
<tr><th colspan="4">Description of the system</th></tr>
<tr><td>Year of introduction</td><td>January 1999</td><td>Geographical scope</td><td>All domestic Norwegian flights</td></tr>
<tr><td>Revenues (€/year)</td><td>An estimated NOK 180 mio/year (about € 20 million), but other taxes were lowered simultaneously.</td><td>Costs (€/year)</td><td></td></tr>
<tr><td>Charge level</td><td colspan="3">The charge level is 0.53 NOK per litre of kerosene, which is around € 0.06. Simultaneously, the tax on passenger seats was reduced by an equivalent amount.</td></tr>
<tr><td>Collection of charges</td><td colspan="3"></td></tr>
<tr><td>Revenues and costs</td><td colspan="3">The revenues are about € 20 million annually. Because simultaneously the passenger seat tax was reduced, the measure was budget neutral.</td></tr>
<tr><td>Earmarking</td><td colspan="3">The kerosene charge is not earmarked</td></tr>
<tr><td>Enforcement</td><td colspan="3">The tax can be avoided by tankering abroad. No measures have been implemented to control this. However, the effect is expected to be limited. There are costs connected to tankering abroad, since the weight of the aircraft increases, resulting in a considerable increase in fuel usage which would reduce the net savings. Moreover, it is considered unlikely that the airlines will start using the same aircrafts for domestic and international traffic (OECD, 2005).<br><br>In the Netherlands, tankering abroad has been overcome. Operators that principally perform domestic flights were liable to pay the tax while fuelling, for all their flights, and were then refunded for their international flights. Conversely, largely international operators were not charged while fuelling, but were liable to pay tax on fuel used for their domestic flights .</td></tr>
<tr><td>Acceptance</td><td colspan="3">The Association of Norwegian Airlines has repeatedly stated its opposition to the aviation fuel tax.</td></tr>
<tr><td>Legislation</td><td colspan="3"></td></tr>
<tr><th colspan="4">Effects</th></tr>
<tr><td>Transport demand</td><td colspan="3">No effect expected. The shift from passenger seat tax to kerosene taxation did not affect ticket prices.</td></tr>
<tr><td>External effects</td><td colspan="3">The tax also had little or no apparent effect on operational measures to reduce fuel use, or on new aircraft design. There was also little increase in ‘tankering’. Thus, the tax appears to have had very little environmental impact overall (Cottrel, 2005).</td></tr>
<tr><th colspan="4">Alternative systems</th></tr>
<tr><td colspan="4">$CO_2$ charge for domestic aviation in the Netherlands, 2005 (€ 0.21/l). Several States in the USA tax kerosene.</td></tr>
<tr><th colspan="4">Additional remarks</th></tr>
<tr><td colspan="4">Although the effects are limited, it is a good example of greening the taxation scheme by changing the tax structures. The charging scheme now fits the external cost driver, fuel consumption/$CO_2$ emissions.</td></tr>
</table>

## A.8 Road toll differentiated with respect to congestion levels

| **Tolls differentiated with respect to congestion level** | | | **Road** |
|---|---|---|---|
| Aim | To reduce congestion by spreading traffic in time | | |
| **Description of the system** | | | |
| Year of introduction | 1992 | Geographical scope | Selected French motorways |
| Revenues (€/year) | | Costs (€/year) | |
| Charge level | Surcharging for congestion costs has been introduced in France on the A1 (Paris-Lille) motorway in weekends and on the major links with the South (A26, A5/A6) at the time of important movements for the summer holidays. Tolls on an urban section near Marseille are also increased in peak hours.<br>On some sections of the A1 motorway, tariffs in shoulder periods (from 14.30 to 16.30 and from 20.30 to 23.30) are reduced by 25%, whereas tariffs in the peak period in between are increased by 25%. This holds for traffic in the direction of Paris, on every Sunday, and some holiday Mondays and Tuesdays. The purpose is to spread the passenger cars returning to Paris from the South from holidays more evenly over the day. | | |
| Collection of charges | As the general toll collection. | | |
| Revenues and costs | Few costs as the infrastructure for the general toll collection can be used. No information on revenues has been found, but note that the peak hour surcharge is complemented with a shoulder period charge reduction. The effect may be fairly budget neutral. | | |
| Earmarking | | | |
| Enforcement | As the general toll collection. | | |
| Acceptance | | | |
| Legislation | | | |
| **Effects** | | | |
| Transport demand | | | |
| External effects | No data have been found. Based on the introduction in 1992 and its existence today, one may assume that charge differentiation indeed has some success in spreading traffic. | | |
| **Alternative systems** | | | |
| In the US there are examples of highways on which some lanes are tolled, and others are not, with charge levels being adapted every six minutes based on the actual congestion level. Such a system requires flexibility for the driver to switch between lanes periodically (US FHA, 2006).<br>In Florida, for some bridges tolls were lowered during shoulder periods by 50%. Traffic volumes increased by 20% with corresponding drops in the peak period (US FHA, 2006). | | | |
| **Additional remarks** | | | |
| From the US evidence, toll differentiation appears a potentially strong instrument to spread traffic over time. | | | |
| **Literature** | | | |
| World Bank, 2000, Louis Berger SA, Review of French experience with respect to public sector financing of urban transport, draft final report, July 2000.<br>http://www.sanef.com/autoroute/tarif-peage-autoroute.htm (Consulted January 8th, 2007).<br>US FHA (2006), Congestion pricing; a primer, US Department of Transportation, Federal Highway Administration, December 2006, FHWA-HOP-07-074. | | | |

## A.9 Differentiated harbour dues in Sweden

| **Differentiated port dues in Sweden** | | | **Shipping** |
|---|---|---|---|
| Aim | Establishing an incentive for ship owners to reduce emissions of sulphur and nitrogen oxides. | | |
| **Description of the system** | | | |
| Year of introduction | 1998 | Geographical scope | 20–25 Swedish ports |
| Revenues (€/year) | 0 | Costs (€/year) | |
| Charge level | Based on a tripartite agreement between the Swedish Maritime Administration, the Swedish Ship Owners Association and the Swedish Ports' and Stevedores' Association, 20 to 25 Swedish ports have differentiated their port dues with respect to $SO_x$ and $NO_x$ emissions of the ships. Together with the differentiated harbour dues also fairway dues are differentiated to environmental performances of ships. The charged harbour due is port dependent. For example, the port of Göteborg granted a reduction in the vessel harbour dues in accordance with the following scale (Port of Göteborg, 2006):<br><br>Emission level ($NO_x$ – kWh in grams) per unit of the ship's gross tonnage — Reduction in SEK<br>11.99–6.01 — SEK 0.05 per GT<br>6.00–2.01 — SEK 0.10 per GT<br>2.00 or less — SEK 0.20 per GT<br><br>The Swedish Maritime Administration's certificate in accordance with the proclamation of the Swedish Administration is valid as a condition for the reduction. | | |
| Collection of charges | In accordance with general port due collection. | | |
| Revenues and costs | The overall adaptation of the charging scheme, combining port harbour and fairway dues, is aimed to be revenue neutral. | | |
| Earmarking | Not relevant. | | |
| Enforcement | In accordance with general port due collection. | | |
| Acceptance | The measure is the outcome of a tripartite agreement. The sector was thus involved in the process and has accepted the measure. | | |
| Legislation | | | |
| **Effects** | | | |
| Transport demand | The revenue neutral scheme is not expected to have had any effect on transport demand. | | |
| External effects | No estimates of emission reductions directly related to differentiated port dues are known. However, NERA (2004) reports substantial decreases of maritime emissions of $NO_x$ and $SO_x$ of the differentiated charging system for Swedish fairways *and* ports. Eliminating the effect of traffic growth the reduction of $NO_x$ was estimated at a little less than 10%, while $SO_x$ emissions are estimated to be reduced by about 30%. | | |
| **Alternative systems** | | | |
| – Harbour fee reduction for crude oil and product tankers with Green award in various ports (including ports in the Netherlands, Spain, Portugal and the UK)<br>– The port of Mariehamn in Finland has adopted differentiated charges for $NO_x$ and $SO_2$. | | | |
| **Additional remarks** | | | |
| | | | |

| Literature |
|---|
| NERA (2004), *Evaluation of the feasibility of alternative market-based mechanisms to promote low-emission shipping in European Union Sea Areas, a report for the European Commision, Directorate-General* Environment, London.<br>Port of Göteborg (2006), *Port tariff for the port of Göteborg*, http://www.portgot.se/ prod/hamnen/ghab/dalis2.nsf/vyFilArkiv/Port_Tariff_2006.pdf/$file/Port_Tariff_2006.pdf. |

## A.10 Italian rail infrastructure charges differentiated with respect to congestion

| **Italian rail infrastructure charges differentiated with respect to congestion** | | | **Rail** |
|---|---|---|---|
| Aim | Efficient use of rail infrastructure | | |
| **Description of the system** | | | |
| Year of introduction | | Geographical scope | Italy |
| Revenues (€/year) | | Costs (€/year) | |
| Charge level | Italy has a congestion and scarcity charge for rail infrastructure. This charge depends on the time of the day and on traffic demand. For each route standard speed profiles are designed to optimize the line. Higher prices are charged on trains which speed diverges from the norm for the route in question (whether it is above or below the norm). In addition, there is a charge per node that varies with the implicit amount of congestion at the node by categorizing nodes according to traffic levels. | | |
| Collection of charges | In accordance with general rail infrastructure charges | | |
| Revenues and costs | | | |
| Earmarking | The general infrastructure charges need to cover the costs of traffic management (wholly) and infrastructure manager's salary costs and pension liabilities (partly). | | |
| Enforcement | In accordance with general rail infrastructure charges. | | |
| Acceptance | | | |
| Legislation | In Directive 2001/14 on allocation of railway infrastructure capacity and levying of charges a detailed framework for railway infrastructure charging is established. It allows for higher charges for scarce infrastructure. | | |
| **Effects** | | | |
| Transport demand | | | |
| External effects | | | |
| **Alternative systems** | | | |
| In nine Member States, the infrastructure manager applies charges that are based on scarcity levels. Other examples are Belgium (rail user charge depends on traffic density), the capacity charge in the UK and the increased charges in the Netherlands for stretches that have been declared congested. | | | |
| **Additional remarks** | | | |
| | | | |
| **Literature** | | | |
| Nash, C. (2005), Rail Infrastructure charges in Europe, University of Leeds, http://www.hhs.se/NR/rdonlyres/FC18D020-1E0C-4F12-8DAA-C10B937207BB/0/Nash_Rail_Infrastructure_Charges_in_Europe.pdf<br>Network statement Italy<br>TERM 26 fact sheet | | | |

## A.11 Differentiated noise charges at Frankfurt airport

<table>
<tr><th colspan="3">Differentiated noise charges at Frankfurt airport</th><th>Air</th></tr>
<tr><td>Aim</td><td colspan="3">To reduce aircraft noise impact, by:<br>– Giving airlines a greater incentive to serve the airport with the quietest and most modern aircraft.<br>– Discouraging loud aircraft, especially at night.<br>– Diverting night time flights to daytime.</td></tr>
<tr><th colspan="4">Description of the system</th></tr>
<tr><td>Year of introduction</td><td>2001/2002</td><td>Geographical scope</td><td>Frankfurt Airport</td></tr>
<tr><td>Revenues (€/year)</td><td></td><td>Costs (€/year)</td><td></td></tr>
<tr><td>Charge level</td><td colspan="3">Seven classes of aircraft are distinguished, based on the average takeoff noise level of aircraft. The noise charges per class are differentiated, with additional payments for night time flights. The charge structure and levels (in €) are as follows:
<table>
<tr><th>Noise class, LAX in dB(A)</th><th>General noise charge</th><th>Additional charge 22.00-22.59 and 05.00-05.59</th><th>Additional charge 23.00-04.59</th></tr>
<tr><td>< 69.9</td><td>0</td><td>33</td><td>34,50</td></tr>
<tr><td>70-73.9</td><td>21</td><td>84</td><td>87</td></tr>
<tr><td>74-76.9</td><td>47</td><td>153,50</td><td>158</td></tr>
<tr><td>77-79.9</td><td>150</td><td>288</td><td>300</td></tr>
<tr><td>80-82.9</td><td>335</td><td>1.020</td><td>1.100</td></tr>
<tr><td>83-85.9</td><td>3.800</td><td>11.100</td><td>12.300</td></tr>
<tr><td>> 86</td><td>8.000</td><td>23.500</td><td>26.500</td></tr>
</table>
In addition to these noise charges, separate noise surcharges are levied for the financing of a passive noise abatement program. The noise surcharges are levied per passenger (€ 0.40), per 100 kgs of cargo or mail (€ 0.20) and according to the noise category of the aircraft and time of day as follows:
<table>
<tr><th>Noise class, LAX in dB(A)</th><th>General noise surcharge</th><th>Additional surcharge 22.00-05.59</th></tr>
<tr><td>< 69.9</td><td>5</td><td>12,50</td></tr>
<tr><td>70-73.9</td><td>10</td><td>20</td></tr>
<tr><td>74-76.9</td><td>15</td><td>27,50</td></tr>
<tr><td>77-79.9</td><td>20</td><td>35</td></tr>
<tr><td>80-82.9</td><td>25</td><td>42,50</td></tr>
<tr><td>83-85.9</td><td>250</td><td>500</td></tr>
<tr><td>> 86</td><td>500</td><td>1.000</td></tr>
</table></td></tr>
<tr><td>Collection of charges</td><td colspan="3">The landing and takeoff charges and noise surcharges (as well as all other charges) are payable prior to take off.</td></tr>
<tr><td>Revenues and costs</td><td colspan="3">The revenue of the standard noise charges was about € 15 million annually in 2005, ca. 3.3% of total airport charges (Becker, 2005). The total (instead of annual) expenditures on the passive noise program, to be fully retrieved by the noise surcharges, amount to approximately € 76 million over a five year period.</td></tr>
<tr><td>Earmarking</td><td colspan="3">Revenues from the noise surcharges are earmarked for the passive noise abatement program, under which insulation and other measures are carried out. If this program is finished and all expenses are covered, the noise surcharge will be revoked. The general noise charge is a differentiation of the landing and takeoff charges and are used to cover the general costs of providing runway capacity.</td></tr>
<tr><td>Enforcement</td><td colspan="3"></td></tr>
</table>

| | |
|---|---|
| Acceptance | The current differentiation of the noise charges is the outcome of a political process involving airport, local authorities and airlines. This is expected to contribute to the acceptance by the airlines. |
| Legislation | |
| **Effects** | |
| Transport demand | According to OKÖ/DIW (2004), the noise charges per passenger are relatively low for the aircraft currently in use (the first 5 classes). They therefore do not expect any significant reductions in transport volumes. |
| External effects | According to OKÖ/DIW (2004), the noise charge differentiation is too small to incentivise the use of more quiet aircraft. Clearly, insulation carried out under the passive noise abatement program may be expected to have reduced noise nuisance. |
| **Alternative systems** | |
| In over 15 Member States airport charges are differentiated with respect to either the noise characteristics of the aircraft or the time of day. | |
| **Additional remarks** | |
| The noise classification used is based on measurements and the airport states it is more in touch with time then the ICAO classification of aircraft (Fraport website, 2007). It may well be that the noise surcharges will be revoked soon, with all expenses on the passive noise abatement program financed. The costs for the airport are expected to be low, since the infrastructure for the collection of general airport charges can be used. | |
| **Literature** | |
| Becker (2005), Thorsten Becker, airport charges department, personal communication, 2005.<br>Fraport (2006), Airport charges; Charges for central ground handling infrastructure, Frankfurt airport - effective as of January 1, 2006.<br>http://www.fraport.com/cms/products_services/dokbin/77/77796.flughafenentgelte_2006@de.pdf<br>Fraport website, 2007, consulted February 15th, 2007,<br>http://www.fraport.com/cms/environment/rubrik/3/3007.noise_abatement.htm.<br>OKÖ/DIW (2004), Economic measures for the reduction of the environmental impact of air transport; noise related landing charges, Berlin, 2004. | |

## A.12 Differentiated vehicle registration taxes with respect to $CO_2$ emissions

| **Differentiated vehicle registration taxes with respect to $CO_2$ emissions** | | | **Road** |
|---|---|---|---|
| Aim | To reduce the average fuel consumption of new passenger cars. | | |
| **Description of the system** | | | |
| Year of introduction | 2006 | Geographical scope | Netherlands |
| Revenues (€/year) | 0 (budget neutral) | Costs (€/year) | |
| Charge level | | | |

The basis for the vehicle registration tax (VRT) differentiation is the vehicle labelling system as enforced via Directive 1999/40. Vehicles are categorised on the basis of their ground surface. A fuel efficiency label is subsequently allocated on the basis of the relative fuel consumption within the vehicle size class. The VRT on new vehicles is either increased or reduced, depending on this fuel efficiency label. Below the rebates and surcharges are tabled:

| Rebates/surcharges on registration tax (per car) | Fuel efficiency class | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G |
| Situation until 1-1-2006 | | | | | | | |
| Hybrid | -€ 9,000 | x | x | x | x | x | x |
| Non-hybrid | x | x | x | x | x | x | x |
| 1-1-2006 until 1-7-2006 | | | | | | | |
| Hybrid | -€ 9,000 | -€ 3,000 | x | x | x | x | x |
| Non-hybrid | x | x | x | x | x | x | x |
| As of 1-7-2006 | | | | | | | |
| Hybrid | -€ 6,000 | -€ 3,000 | x | € 135 | € 270 | € 405 | € 540 |
| Non-hybrid | -€ 1,000 | -€ 500 | x | € 135 | € 270 | € 405 | € 540 |

| | |
|---|---|
| Collection of charges | Via the existing VRT. This tax is channelled to the government via car dealers. |
| Revenues and costs | The system costs are limited, as it is a transformation of an existing taxation scheme. The differentiated top of the VRT charge is budget neutral, so there are no additional revenues. |
| Earmarking | Vehicle registration taxes are not earmarked |
| Enforcement | The national vehicle authority allocates vehicles to a fuel efficiency class. |
| Acceptance | |
| Legislation | Fiscal incentives to improve passenger car fuel efficiency is one of the pillars of the agreement to reduce new car fuel consumption with the car industry. |
| **Effects** | |
| Transport demand | |
| External effects | It is estimated that $CO_2$ emissions are reduced by 0,1-0,2 Mton/year (MNP,2006; ECN, 2005). |
| **Alternative systems** | |
| Similar systems are in place in several Member States. Some schemes are related to the registration taxes (Austria, France), others to the annual circulation taxes (e.g. UK, Sweden, Denmark). Alternatively in many other countries taxes are related to vehicle weight, or engine capacity. A link with $CO_2$ emissions is most direct. Whereas the Dutch scheme is relative, relating to a car's fuel efficiency within its class, other systems directly relate to $CO_2$ emissions. | |
| **Additional remarks** | |
| The new cabinet has the plan to further differentiate the VRT between fuel efficient and high fuel consuming cars. | |

| Literature |
| --- |
| CE Delft, 2005<br>Cool cars, fancy fuels, A review of technical measures and policy options to reduce $CO_2$ emissions from passenger cars, CE Delft, The Netherlands, www.ce.nl.<br>ECN, 2005<br>$CO_2$-differentiatie BPM<br>http://www.ecn.nl/fileadmin/ecn/units/bs/Optiedoc_2005/factsheets/co2-tra-05.pdf.<br>MNP, 2006<br>Beoordeling Maatregelenpakket Toekomstagenda Milieu, Milieu- en Natuurplanbureau (MNP), Bilthoven, mei 2006, MNP-publicatienummer 500085002/2006. |

## A.13 Differentiated company car taxation with respect to $CO_2$ emissions

| **Company car tax in the United Kingdom** | | | **Road** |
|---|---|---|---|
| Aim | To stimulate the purchase of fuel efficient company cars | | |
| **Description of the system** | | | |
| Year of introduction | October 2002 | Geographical scope | United Kingdom |
| Revenues (€/year) | | Costs (€/year) | Revenues of the tax have gone down by £120 million a year, although is was designed to be revenue neutral. In part, this foregone revenue is compensated by additional income taxes. |
| Charge level | The company car tax is an additional tax paid by owners of a company car that use the car for private purposes. A certain percentage of the list price of the car is added to the taxable income, depending on the fuel efficiency of the car.<br><br>The old system of company car taxation held an perverse incentive to drive more kilometres, as the higher the business miles driven, the less tax was levied. The new system gives an incentive to buy a fuel efficient company car. The measure was introduced within a broader framework addressing climate emissions.<br><br>The tax rate starts at 15% of the car's list price, for a small car emitting 140 g/km $CO_2$ or less, then rises in 1% steps for every additional 5g/km over 140g/km up to a maximum of 35% of the car's list price at 240 g/km.<br><br>The lower threshold of 140 g/km has been lowered each year, starting from 165 g/km in 2002. It is frozen at 140 g/km for until 2008.<br><br>Diesel cars incur a 3% supplement to the percentage charge to reflect that they often produce higher levels of harmful local air pollutants such as particulates and nitrous oxides with a maximum of 35%. Alternatively fuelled cars get a discount (CNG, hybrid, LPG, electric).<br><br>Income tax is paid at the normal rate (40%, 22% or 10%, depending on someone's overall earnings) on what is called the 'car benefit'. | | |
| Collection of charges | Via income tax | | |
| Revenues and costs | The system has been designed as revenue neutral, compared to the previous system. However, the number of company cars has decreased (possibly due to reduced attractiveness) and the fuel efficiency of company cars has been improved, the total revenues have gone down substantially. | | |
| Earmarking | The tax is not earmarked | | |
| Enforcement | | | |
| Acceptance | | | |
| Legislation | | | |

| Effects | |
|---|---|
| Transport demand | Several effects have been estimated (HM, 2006):<br>– The number of company cars has reduced to around 1.2 million in 2005, compared with around 1.6 million in 2001.<br>– Fuel for private use is no longer free. This has resulted in a reduction of 70-100 million private miles with cars in 2005. This is less than 0.1% of the total amount of mileage done in cars in the UK in 2005. |
| External effects | – Average $CO_2$ emissions figures from company cars were around 15g/km lower in 2004 than would have been the case if the reform had not taken place.<br>– The total $CO_2$ emission reduction is estimated at around 0.4-0.9 Mtonnes.<br>– Despite the 3% supplement, the share of diesel cars has increased more strongly for company cars than for the vehicle stock as a whole. Apparently, the benefit from better fuel efficiency outweighs the penalty for higher emission of local pollutants. The share of company cars running on diesel was around 50-60% at the end of 2004 from around 33% in 2002. |
| **Alternative systems** | |
| | |
| **Additional remarks** | |
| Cars on the second hand car market will have also lower $CO_2$ emissions, as most company cars are typically replaced every 3-4 years. | |
| **Literature** | |
| HM, 2006<br>Report on the Evaluation of the Company Car Tax Reform: Stage 2, Her Majesty's Revenue & Customs, 22 March 2006. | |

# B Legal background

## B.1 Introduction

In this section, an overview is provided of the legal background for internalisation in the various modes. If focuses on prevailing EU directives, but attention will also be given to current proposals from the European Commission, and to other current international arrangements that may either enable or restrict internalisation of external effects. Specific national laws are not addressed.
The purpose of this overview is to provide a general background on the legal possibilities for internalisation. This current state of affairs serves as a point of departure for the internalisation scenarios to be developed in this project. However, it is not the intention that all internalisation scenarios put forward adhere to current legislation. Some adaptations may be proposed.
The overview provided here is not meant to be exhaustive. In particular, legislation with regard to fuel quality has not been included. Special attention has been be paid to legislative requirements on charge levels and earmarking.
The structure of this section is as follows. We will first discuss several horizontal directives, that apply to all modes. Next, we discuss in turn legislation that applies to road, rail, aviation and shipping. A distinction will further be made between EU directives and other international arrangements.

## B.2 Horizontal directives

There are several horizontal directives that are of relevance. Directive 2002/49/EC is about the assessment and management of environmental noise. Directive 2003/96/EC relates to the taxation on energy products and electricity.

***Directive 2002/49/EC***
This directive prescribes which noise indicators should be applied by Member States, inter alia for the assessment of noise emitted by means of transport, road, rail and air traffic. By 30 June 2007 Member States have to have made strategic noise maps for all major roads which have more that six million vehicle passages a year, for major railways which have more that 60,000 trains passages annually and for major airports within their territories. The directive furthermore requires Member States to draw up action plans for places near these road and railways. Several actions that could potentially be included in the action plan are listed, including regulatory and economic measures or incentives. The action plan should include cost effectiveness and cost benefit assessments of the measures proposed.

***Directive 2003/96/EC***
This directive regulates inter alia the minimum levels of taxation on motor fuels. The 'level of taxation' is defined as the total charge levied in respect of all indirect taxes (except VAT) calculated directly or indirectly on the quantity of energy products. So any form of carbon charge on fuel would fall under this definition. Member States which introduce a system of road user charges for motor vehicles for the carriage of goods by road may apply a reduced rate on gas oil used by such vehicles. In contrast, no particular mentioning is made of more general road uses charges that apply to passenger vehicles as well.
Regarding aviation, jet fuel is to be exempted from the minimum tax levels as set in the Directive. Energy products for private pleasure flying may be taxed. Similarly, fuel for navigation in Community waters is to be exempted. Member States may limit these exemptions to international and intra-Community transport. In addition, in case of bilateral agreements, exemptions may also be waved. In such cases, a level of taxation below the minimum level set out in the Directive may be applied.
Energy products and electricity used for the carriage of goods and passengers by rail, metro, tram and trolley bus may also be exempted. Also, energy produces used as fuel for inland navigation may be exempted. Finally, the Directive makes it also possible for Member States to grant tax reductions/exemptions in favour of biofuels, under certain conditions.

Table 19 Minimum levels of taxation applicable to motor fuels

| | 1 / 1 / 2004 | 1 / 1 / 2010 |
|---|---|---|
| Leaded petrol (in € / 1,000 l) | 421 | 421 |
| Unleaded petrol (in € / 1,000 l) | 359 | 359 |
| Gas oil (in € / 1,000 l) | 302 | 330 |
| Kerosene (in € / 1,000 l) | 302 | 330 |
| LPG (in € / 1,000 kg) | 125 | 125 |
| Natural gas (in € per gigajoule gross calorific value | 2,6 | 2,6 |

Source: 2003/96/EC.

## B.3 Road

First we discuss the legislation that applies to both freight and passenger transport. Then we discuss directive 1999/62/EC and its amendment 2006/38/EC which apply specifically to freight transport, and subsequently we address (proposals for) directives that are aimed at passenger cars only.

***Euro standards***
Regulation of pollutants from road vehicles by Euro Standards has been very successful. Emission regulation for new light duty vehicles were first specified in Directive 70/220/EEC. Over the years new standards and amendments have been implemented. Recently the emission levels for Euro 5 (applicable from 1 September 2009) and Euro 6 (applicable from 1 September 2014) have been adopted by the European Parliament. Emission standards generally differ by fuel type and weight category of the passenger car or light duty vehicle. Standards for

heavy duty vehicles (all vehicles with a technically permissible maximum laden mass over 3,500 kgs) were originally proposed in Directive 88/77/EEC. The Euro 5 standards will hold as of 2008, for heavy duty vehicles including busses.
Member States are free to introduce fiscal incentives to reduce emission beyond the levels prescribed by the Euro standards. These incentives may not surpass the additional costs of meeting the standards (including installation costs). The standards themselves are technology neutral. National authorities may not, on grounds relating to emissions or fuel consumption of motor vehicles, prohibit the registration, sale or entry of vehicles that comply with EU regulations. That means that requiring specific technologies to be installed, such as diesel particle filters, is not allowed at national level.

## B.4 Freight

At the heart of this study are Directives 1999/62/EC and 2006/38/EC relating to charging heavy goods vehicles for the use of infrastructure. Below briefly the main points of these directives are highlighted.

Directive 2006/38/EC amending 1999/62/EC regulates the charging of heavy good vehicles for the use of infrastructure. It defines tolls as payments for the use of a specific stretch of infrastructure, to be based on the distance travelled and the type of vehicle. User charges are payments conferring the right to use infrastructure for a given period. Tolls and user charges may not both be imposed at the same time for a single road section. However, tolls may be imposed on the network where user charges are levied for the use of bridges, tunnels and mountain passes. 2006/38/EC applies to all vehicles with a maximum permissible laden weight of over 3.5 tonnes, although Member States may choose to exempt vehicles between 3.5 and 12 tonnes.

Tolls need to be based on the principle of the recovery of infrastructure costs only. These include the costs of operating, maintaining and developing the infrastructure network concerned. Costs of infrastructure or infrastructure improvements may include any specific expenditures on infrastructure designed to reduce nuisance related to noise or to improve road safety and actual payments made by the infrastructure operator corresponding to environmental elements such as protection against soil contamination. These means that mitigation measures related to the infrastructure can already be financed by infrastructure charges.
Variation of toll rates is allowed for purposes such as combating environmental damage, tackling congestion, minimising infrastructure damage, optimising the use of the infrastructure concerned or promoting safety, provided that it is not designed to generate additional revenues. Toll rates may be varied according to:

- Euro emission class:
  - Provided that no toll is more that double the toll charged for equivalent vehicles meeting the strictest emission standards.
- Time of day, type of day or season:
  - Provided that no toll is more that 100% above the toll charged during the cheapest period.

- Where the cheapest period is zero rated, the penalty for the most expensive period is no more than 50% of the level of toll that would otherwise be applicable.

Member states are generally required to vary toll rates with respect to Euro class as of 2010. Mark-ups in mountainous regions may be allowed for road sections that are subject to acute congestion and/or where vehicles cause significant environment damage, inter alia on condition that:
- The revenue from the mark-up is invested in priority projects.
- The mark-up does not exceed 15% of the weighted average toll rate (or if the revenues are invested in cross border priority projects: 25%).

Other forms of variation of toll rates are only allowed in exceptional cases.

Member States are not restricted in their freedom to provide appropriate compensation for tolls and/or user charges introduced. Nor shall the directive prevent:
- Levying of registration taxes.
- Levying of specific urban traffic charges.
- Introduction of regulatory charges to combat time and place related traffic congestion.
- Introduction of regulatory charges to combat environmental impacts, including poor air quality.

on any road, notably in urban areas.

Members States may determine the use to be made of revenue from charges for the use of road infrastructure.

The Directive applies to tolls and user charges on the transeuropean network, and leaves open the possibility for introducing tolls and charges on other roads.

## B.5 Passenger cars

In 2005 the Commission published a proposal for adaptation of passenger car related taxes (COM(2005) 261 final). It proposes that by 2008, at least 25% of the total revenue from annual circulation taxes and registration taxes shall come from a carbon dioxide based element in the tax structure. For 2012 this should hold for 50% of the total revenue, thus providing a strong financial incentive to purchase more fuel efficient vehicles. Furthermore, registration taxes are to be abolished by the beginning of 2016 to eliminate double taxation.

## B.6 Rail

Directive 2001/14/EC lays down the requirements for the allocation of railway infrastructure capacity and the levying of charges for use. The marginal cost oriented pricing approach is considered as a basis for track pricing.

The Directive specifically allows for a charge which reflects the scarcity of capacity of the identifiable segment of the infrastructure during periods of congestion.

The infrastructure charge may also be modified to take account of the cost of the environmental effects caused by the operation of the train. Such a modification shall be differentiated according to the magnitude of the effect. Charging of environmental costs which results in an increase in the overall revenue accruing to the infrastructure manager shall however be allowed only if such charging is applied at a comparable level to competing modes of transport. In the absence of any comparable level of environmental charging in those modes, such modification shall not result in any overall change in the revenue to the infrastructure manager[65].

If a comparable level of charging of environmental costs has been introduced for rail and competing modes of transport and that generates additional revenue, it shall be for the Member States to decide how the revenue shall be used.

In addition to this, Directive 2004/26/EC regulates the emissions from non-road vehicles, including railroad locomotive engines and marine engines used for inland shipping. Engines of new locomotives need to meet specific emission requirements.

## B.7 Aviation

### B.7.1 EU legislation

There are a number of EU (proposals for) Directives that address the environmental impact of aviation. Directive 2002/30/EC lays down requirements on operating restrictions at airports. In general, it requires that Member States shall adopt a balanced approach in dealing with noise problems at airports in their territory, as also required by ICAO (to be discussed below).

In December 2006, the European Commission put forward a proposal for the inclusion of the aviation sector in the EU ETS (COM(2006) 818). Airlines would be required to purchase allowances for any emission above the number of allowances initially allocated to them. It is proposed to base the initial allocation on a combination of benchmarking and auctioning. The total number of allowances allocated to the sector would be equal to the average historical emissions for 2004-2006.

Recently, the Commission published a proposal for a directive on airport charges[66]. Airport charges are defined as levies collected for the benefit of the

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[65] In fact, the Directive allows Member States to introduce time-limited compensation schemes for the use of railway infrastructure for the demonstrably unpaid environmental, accident and infrastructure costs of competing transport modes in so far as these costs exceed the equivalent costs of rail.

[66] http://ec.europa.eu/transport/air_portal/airports/doc/2007_proposal_directive_airports_charges_en.pdf.

airport managing body and paid by the airport users and/or air passengers with a view to recovering all or part of the costs of facilities and services which are exclusively provided by the airport management body and which are related to landing, takeoff, lighting and parking of aircraft, and processing of passengers and freight. As such, this directive does not contain any reference to the introduction of charges related to internalising external effects.

A proposal for a directive on the establishment of a Community Framework for noise classification of civil subsonic aircraft for the purpose of calculating noise charges has been withdrawn a few years ago.

### B.7.2 Other international arrangements

International aviation is very much influenced by the International Civil Aviation Organisation (ICAO). The Chicago Convention by ICAO prohibits the taxation of fuel already on board of aircraft on arrival, and retained on board on leaving. The ICAO Council of 14 December 1993 confirmed that not only goods already on board the aircraft, but also fuel embarked on aircraft shall be exempt of excise duties and other consumption taxes. All EU Member States are members of ICAO and have to abide by this regulation. In addition, many bilateral air service agreements between States explicitly prohibit the taxation of fuel taken on board.

The status of environmental charges under ICAO is not fully clear. It is for example disputed whether an emission tax related to $CO_2$ emissions is allowed for. In general, ICAO does not prohibit environmental charges, which are used to finance mitigation measures. Nonetheless, ICAO resolutions urge States to refrain from unilateral environmental measures that would adversely affect the orderly development of international civil aviation. Moreover, States that do impose such charges are advised to use the revenues for mitigation expenses or scientific research into environmental effects.

In practice, noise charges in place at EU airports are often introduced for the financing of insulation or other mitigation schemes. In addition, airports differentiate landing charges with respect to noise emissions, without net revenue. This also holds for the very few examples of charges related to the emission of pollutants.

Similar to the status of environmental charges, it is disputed whether the emission trading scheme proposed by the European Commission can indeed be enforced on non-EU carriers.

Under ICAO, emission may be regulated by standards. ICAO has developed both noise and $NO_x$ certification standards for new aircraft.

## B.8 Shipping

### B.8.1 Inland waterways

For inland waterways, the Mannheim Convention is very relevant. In addition, there are emission standards.

***Mannheim Convention and the CCR***

The Central Commission for Navigation on the Rhine (CCR) is the oldest intergovernmental organisation in the world. It was set up by the 1868 Mannheim Convention, and has the task of guaranteeing freedom of navigation on the Rhine and promoting the prosperity of navigation on the Rhine, while guaranteeing a high level of safety of navigation on the Rhine and on other rivers in the Rhine estuary. The CCR is made up of Belgium, France, Germany, the Netherlands and Switzerland.

The articles 1 and 3 of the Mannheim Convention are the most relevant articles with regard to the legal feasibility of implementing economic incentives such as emissions charges or an emission trading system on inland shipping on the Rhine. Article 1 states that on the Rhine and other rivers that fall under the CCR jurisdiction, the only restrictions that can be imposed on shipping must be aimed at ‘general security’. Article 3 states that ships sailing on the Rhine and the other rivers will be free of duties that are exclusively based on shipping. In contrast, market based incentives levied at ports and locks are possible within the Mannheim convention.

Furthermore, the Mannheim convention does not seem to explicitly forbid a levy on $NO_x$ emissions. $NO_x$ emissions are not directly related to inland shipping, since in principle the emissions can be reduced to zero by technical means, although such a reduction would be very costly. However, whether or not such a levy will hold in court, remains subject of discussion.

A levy on distance sailed will be hard to introduce if it is only applied to ships. However, when such a levy is also imposed on trucks, like for example in Germany, it can be argued that the levy is not exclusively based on shipping. In that case, it may be possible to introduce such an incentive. In the end, the legitimacy of a distance duty will probably have to be decided in court.

In 1952, an additional protocol was added to the Mannheim Convention. This protocol states explicitly that fuels used in inland shipping shall be free of taxes, duties and levies. An economic incentive based on fuels seems therefore not to be feasible under the current law. However, it may be possible to circumvent this problem by signing a new treaty. This has been done in 1996, when a new convention was signed on the Collection, Depositing and Reception of Waste (see section 2.4). This convention includes a duty on diesel sold at bunkers by vessels. Member States avoided possible incompatibility with article 3 of the Mannheim Convention, by signing a *new* Convention on Waste. As long as all member States are included in the new Convention, it will prevail over an old one.

The Establishment of a Convention on Waste independent from the Mannheim Convention shows the political will in the Member States is the most important factor in introducing economic measures for inland shipping. Therefore, also incentives that are not legitimate under the current law, and incentives whose legitimacy is questionable, will still be analysed in this study. When they appear to be the best incentives, it may be better to try to amend the Mannheim Convention than to implement a suboptimal duty.

***Emission standards***

Directive 2004/26/EC regulates gaseous and particle emissions from internal combustion engines to be installed in non-road mobile machinery. In contrast to previous EU regulation, this includes engines in vessels for inland shipping.

Apart from the EU standards, the CCR has also implemented engine emission standards. EU emission standards are not exactly compatible with CCR standards. The CCR standards regulate $NO_x$ emissions as such, while the EU standards regulate combined emissions of nitrogen oxides and hydrocarbons.

## B.8.2 Maritime transport

As international transport by air is regulated in part by ICAO, the International Maritime Organisation was set up to ensure safety by sea.

There are also clearly major political barriers to implement a maritime bunker fuel charge. The United Nations Convention on the Law of the Sea (UNCLOS) guarantees the right of innocent passage for foreign ships in the territorial sea without being subject to any charges, except for services received.

Annex VI of the Marpol convention sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions from ozone depleting substances. It furthermore introduces requirements on the sulphur content of fuel used for shipping.

# C Scenarios

Table 20 Overview of internalisation measures in scenario 2

| **Scenario 2** | *Climate* | *Air Pollution* | *Noise* | *Other* | *Accidents* | *Congestion and scarcity* | *Changes to existing taxes and charges* |
|---|---|---|---|---|---|---|---|
| *Road passenger cars* | Assumed to be internalised by minimum fuel excise duties | Fuel tax, in TRANS-TOOLS differentiated to petrol/diesel cars | Fuel tax | - | Fuel tax | - | Fuel excise duties to minimum levels |
| *Road HGV* | Assumed to be internalised by minimum fuel excise duties | Fuel tax | Fuel tax | - | Fuel tax | - | Fuel excise duties to minimum level |
| *Rail* | For diesel: $CO_2$ shadow price based fuel tax<br>For electric: ETS | Diesel: Fuel tax<br>Electric: Energy tax | Fuel tax | - | Fuel tax | - | - |
| *Inland shipping* | $CO_2$ shadow price based fuel tax | Fuel tax | - | - | - | - | - |
| *Maritime shipping* | $CO_2$ shadow price based fuel tax | Fuel tax | - | - | - | - | - |
| *Aviation* | ETS | Fuel tax | Fuel tax | - | Fuel tax | - | - |

Table 21 Overview of internalisation measures in scenario 3

| **Scenario 3** | *Climate* | *Air Pollution* | *Noise* | *Other* | *Accidents* | *Congestion and scarcity* | *Changes to existing taxes and charges* |
|---|---|---|---|---|---|---|---|
| *Road passenger cars* | Assumed to be internalised by minimum fuel excise duties | Charge per km, in TRANS-TOOLS also differentiated to type of road | Charge per km, in TRANS-TOOLS also differentiated to type of road | - | Charge per km, in TRANS-TOOLS also differentiated to type of road | Flat charge on all roads at average congestion cost (TRANS-TOOLS only) | Fuel excise duties to minimum levels |
| *Road HGV* | Assumed to be internalised by minimum fuel excise duties | Same as cars | Same as cars | - | Same as cars | Same as cars | Fuel excise duties to minimum level |
| *Rail* | For diesel: $CO_2$ shadow price based harbour due For electric: ETS | Charge per km, in TRANS-TOOLS also differentiated to electric/diesel | Charge per km, in TRANS-TOOLS also differentiated to electric/diesel | - | Charge per km | | - |
| *Inland shipping* | $CO_2$ shadow price based kilometre charge | Charge per km | - | - | - | - | - |
| *Maritime shipping* | $CO_2$ shadow price based charge per harbour visit | Charge per harbour visit | - | - | - | - | - |
| *Aviation* | ETS | Charge per LTO | Charge per LTO | - | Charge per LTO | - | - |

Table 22 Overview of internalisation measures in scenario 4

| **Scenario 4** | *Climate* | *Air Pollution* | *Noise* | *Other* | *Accidents* | *Congestion and scarcity* | *Changes to existing taxes and charges* |
|---|---|---|---|---|---|---|---|
| *Road passenger cars* | Assumed to be internalised by minimum fuel excise duties | Charge per km, in TRANS-TOOLS also differentiated to type of road | Charge per km, in TRANS-TOOLS also differentiated to type of road | - | Charge per km, in TRANS-TOOLS also differentiated to type of road | Congestion charge, differentiated to location, not to time of the day (TRANS-TOOLS only) | 4A: Fuel excise duties to minimum levels<br>4B: -<br>4A&4B: replacement of existing tolls by charges at marginal infrastructure cost level |
| *Road HGV* | Assumed to be internalised by minimum fuel excise duties | Same as cars | Same as cars | - | Same as cars | Same as cars | 4A: Fuel excise duties to minimum level<br>4B: - |
| *Rail* | For diesel: $CO_2$ shadow price based fuel tax<br>For electric: ETS | Charge per km, in TRANS-TOOLS also differentiated to electric/diesel | Charge per km, in TRANS-TOOLS also differentiated to electric/diesel | - | Charge per km | - | - |
| *Inland shipping* | $CO_2$ shadow price based fuel tax | Charge per km | - | - | - | - | - |
| *Maritime shipping* | $CO_2$ shadow price based fuel tax | Charge per harbour visit | - | - | - | - | - |
| *Aviation* | ETS | Charge per LTO | Charge per LTO | - | Charge per LTO | - | - |

Table 23 Overview of internalisation measures in scenario 5

| **Scenario 5** | *Climate* | *Air Pollution* | *Noise* | *Other* | *Accidents* | *Congestion and scarcity* | *Changes to existing taxes and charges* |
|---|---|---|---|---|---|---|---|
| *Road passenger cars* | Assumed to be internalised by fuel excise duties | Mark-up on circulation taxes (TREMOVE only) | Mark-up on circulation taxes (TREMOVE only) | - | Mark-up on circulation taxes (TREMOVE only) | - | - |
| *Road HGV* | Assumed to be internalised by minimum fuel excise duties | Charge per km, in TRANS-TOOLS also differentiated to type of road (5A all roads, 5B motorways only) | Charge per km, in TRANS-TOOLS also differentiated to type of road (5A all roads, 5B motorways only) | - | Charge per km, in TRANS-TOOLS also differentiated to type of road (5A all roads, 5B motorways only) | Congestion charge, differentiated to location, not to time of the day (TRANS-TOOLS only) | Fuel excise duties to minimum level (except for UK[67]) Replacement of existing tolls by charges at marginal infrastructure cost level |
| *Rail* | For diesel: $CO_2$ shadow price based fuel tax For electric: ETS | Charge per km, in TRANS-TOOLS also differentiated to electric/diesel | Charge per km, in TRANS-TOOLS also differentiated to electric/diesel | - | Charge per km | - | - |
| *Inland shipping* | $CO_2$ shadow price based fuel tax | Charge per km | - | - | - | - | - |
| *Maritime shipping* | $CO_2$ shadow price based fuel tax | Charge per harbour visit | - | - | - | - | - |
| *Aviation* | ETS | Charge per LTO | Charge per LTO | - | Charge per LTO | - | - |

[67] Excise duties for trucks are lowered with the increase of the total revenues of all other taxes and charges but not below the minimum fuel tax levels.

# D Existing differentiations of taxes and charges to environmental effects

| Non-fuel related tax and charges | | AT | BE | BG | CY | CZ | DE | DK | EE | ES | FI | FR | GB | GR | HU | IE | IS | IT | LI | LT | LU | LV | MT | NL | NO | PL | PT | RO | SE | SI | SK | TR | EU total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air pollution/Euro-class | Road - pass. | ✓ | | | | | ✓ | | | ✓ | | | | ✓ | ✓ | | | | | | | | | ✓ | | | | ✓ | | | | | 7 |
| | Road - vans | | | ✓ | | ✓ | ✓ | | | | | ✓ | | -- | ✓ | | | ✓ | | | | | | ✓ | | ✓ | | | ✓ | | | | 9 |
| | Road - frei. | | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | | -- | ✓ | | | ✓ | | | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | | | | 14 |
| | Rail | | | | | ✓ | | | | | | | | | | | | | | | | | | | | ✓ | | | ✓ | | | | 3 |
| | Air | | | | | | | | | | | | ✓ | | | | | | | | | | | | | | | | ✓ | | | | 2 |
| | Water | | ✓ | | | | | | | ✓ | ✓ | | ✓ | | | | | | | ✓ | | | | ✓ | | ✓ | ✓ | | ✓ | | | | 9 |
| Climate change/fuel consumption/$CO_2$ emission | Road - pass. | ✓ | ✓ | | ✓ | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | -- | | | ✓ | | + | + | | | | | | 14 |
| | Road - frei. | | | | ✓ | | | | | | | ✓ | ✓ | | | | | ✓ | | | | | | | | ✓ | | | | | | | 5 |
| | Rail | | | | | | | | | | | | | | | | | | | | | | | | | ✓ | | | | | | | 1 |
| | Air | | | | | | | | | | | | | | | | | | | | | | | | ✓ | | | | | | | | 1 |
| | Water | | | | | | | | | | | | | | | | | | | | | | | | ✓ | ✓ | | | | | | | 2 |
| Noise | Road - pass. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Road - frei. | ✓ | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| | Rail | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Air - dB | ✓ | ✓✓ | | ✓ | ✓ | ✓ | | | | ✓✓ | ✓ | ✓ | | ✓ | | | ✓ | | | ✓✓ | | | ✓ | +✓ | + | | | ✓ | | | | 14 |
| | / night charges | | | | | | ✓ | | | | | ✓ | ✓ | | ✓ | | | | | | | | | ✓ | | + | | | | | | | 11 |
| | Water | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Congestion | Road | | | | | | | | | | | ✓ | ✓ | | | | | | | | | | | | | | | | | | | | 2 |
| | Rail | ✓ | ✓ | | | | ✓ | ✓ | | | | ✓ | ✓ | | | | | ✓ | | | ✓ | | | ✓ | | | | | | | | | 9 |
| | Air | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Water | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Distance related charging | Road - pass. | ✓ | | | | | | | | ✓ | | ✓ | ✓ | ✓ | | | | ✓ | | | | | | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | 11 |
| | Road - frei. | ✓ | | | | | ✓ | | | ✓ | | ✓ | ✓ | ✓ | | | | ✓ | | | | | | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | 12 |
| Urban charging | Road | | | | | | | | | | | | ✓ | | | | | ✓ | | | | ✓ | | | ✓ | | | | + | | | | 5 |

| Non-fuel related tax and charges | AT | BE | BG | CY | CZ | DE | DK | EE | ES | FI | FR | GB | GR | HU | IE | IS | IT | LI | LT | LU | LV | MT | NL | NO | PL | PT | RO | SE | SI | SK | TR | EU total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fuel related** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tax break low sulphur | + | ✓ | | | | ✓ | -- | | | -- | | ✓ | | | | | | | | | | | | ✓ | | | | ✓ | | | | 6 |
| Carbon tax | | | | | | ✓ | | | | | | | | | | | -- | | | | | | | ✓ | | | | ✓ | + | | | 4 |
| **Total number of measures** | 8 | 7 | 2 | 3 | 4 | 11 | 3 | 0 | 6 | 3 | 10 | 12 | 4 | 6 | 1 | 0 | 9 | 0 | 1 | 4 | 1 | 0 | 8 | 10 | 12 | 4 | 1 | 9 | 3 | 0 | 2 | 144 |

Note: A tick in the above table means - with the exception of the categories 'urban charging' and 'distance based charging' that the charges are *directly* linked with the specific external effect. It does not necessarily mean that this external cost is fully internalised. Reduced excise duty on bio fuels is not taken into account, but mentioned in the tables at the end of this fact sheet. Tax reductions for hybrid vehicles receive a tick in the category 'Climate change'. Ticks do not provide information on the absolute charge level or its revenues and on its appropriateness. For more detailed information on tax and charging structures, see the tables at the end of this fact sheet. A green 'plus' (new measure) and green total number of measures means an advancement in internalisation, a red 'minus' (removed measure) and red total number of measures means a decay in internalisation. Green and red ticks hold their colour for one year. A black colour of the total numbers means no change.

Detailed information on fuel tax levels, structures and trends is provided in the fact sheet TERM 21 EU - Fuel prices and taxes. More information on external costs is provided in fact sheet TERM 25 EU - External costs of transport. Due to recent EEA membership, Switzerland is not yet included in this table.

*Source:* Boeing, 2006; ACEA, 2004, 2005, 2006, Infras, 2000, TRL, 2002, Climate change database, IEA, ECMT 2004, Questionnaire 2004.

Source: EEA TERM fact sheet: TERM 26 EEA 31- Progress in charge structures and internalisation policies.

# E Road pricing schemes

There are presently several road pricing schemes existing in European countries and beyond. They range from the basic access fee for the city centre of London to the countrywide kilometre charge for lorries in Switzerland. Especially the latter category pricing schemes is interesting for this study. For that reason we will discuss in this annex the pricing schemes for heavy vehicles in Austria, Germany and Switzerland. In addition, we will pay attention to studies after the implementation costs of possible countrywide road pricing schemes in the Netherlands and the UK.

Before we discuss the various road pricing schemes, we will briefly discuss the possible technologies available for road pricing, since the implementation costs heavily depends on the choice of technology. Based on this discussion and the description of the schemes in the different countries, we will discuss which technologies are most appropriate for the rather sophisticated pricing schemes proposed in this study.

## E.1 Available technologies for road pricing

Different technologies for detecting vehicles, determining the charge to apply and detecting offenders can be applied in road pricing schemes. In this section we will discuss the main technologies available:
- Cash tolling.
- Paper licences.
- Tachograph.
- Automatic Number Plate Recognition (ANPR).
- Dedicated Short-Range Communications (DSRC).
- Global Positioning System (GPS).

*Cash tolling*
A proven technology for road pricing is cash tolling. It requires manned or automatic collection facilities at each entry point. This technology may be appropriate for small areas or those that are lightly trafficked. For large or heavily trafficked areas, however, this technology is less suitable. In addition, differentiation to environmental characteristics is hardly possible.

*Paper licences*
Paper licenses can be issued to provide authorisation either to be within a charged area (area licensing) or to enter one (entry permit). A main advantage of this instrument is that it can be set up relatively quickly and has relatively low implementation costs. However, paper licenses also have some significant drawbacks. First, charging per kilometre is not possible. In addition, the price cannot be differentiated to time. Finally, the reliability of the system is rather low.

*Tachograph*

Registration of the number of kilometres travelled is possible with the tachograph. This instrument has rather low implementation costs, but has also some important drawbacks: differentiation to time of day or location is not possible, monitoring and enforcement is difficult, and it provides some administrative tasks for the user.

*Automatic Number Plate Recognition (ANPR)*

With ANPR, cameras take digital photographs of vehicle number plates, which are then read by the system to identify the person liable for the charge. Since ANPR based systems are compatible with differentiation to location, time and environmental characteristics of the vehicle, they can be used for rather sophisticated road pricing schemes. However, if the scheme is implemented on all roads in Europe, the implementation costs will be high due to the large number of roadside equipment needed.

An important advantage of ANPR is that it relatively easily accommodates occasional users since there is no need for installing any onboard equipment. A limitation of ANPR based systems is the high rate of failure to read automatically a number plate, as a result of which a large number of pictures should be analysed manually, which is quite labour intensive. In addition, photographing cars has lead to some concerns over privacy.

*Dedicated Short-Range Communications (DSRC)*

DSRC is based on communications (usually microwave) between a (relatively simple) onboard transponder (tag) and roadside equipment installed at the charge point. This triggers a charge transaction, which is either recorded in the onboard unit or in an off vehicle central accounting system. In the end, this recorded data will be send to an back office, where it will be processed. For monitoring and enforcement, ANPR based technology can be used.

Like ANPR based technology, DSRC technology is appropriate for rather sophisticated pricing schemes; differentiation to time, location and environmental characteristics of the vehicle is possible. However, the implementation costs will be high for schemes with a large (geographical) scope, since a large amount of roadside infrastructure is needed.

*Global Position systems (GPS)*

With GPS based technology, all vehicles are provided with an on board unit (OBU) which can determine the location of the vehicle with the help of satellite based positioning systems, such as GPS. The OBU communicates (through GSM, DSRC technology or portable media like smart cards) relevant data to a central back office. Calculating the payable charge can be done in the back office, but also in the OBU. For monitoring and enforcement, ANPR based technology can be used.

Due to the high costs of the vehicle equipment (e.g. the OBU's) GPS based systems are not appropriate for small scaled road pricing schemes. However, for countrywide road charging systems, GPS-based systems are appropriate, especially since relatively little roadside equipment is needed.

## E.2 Kilometre charges in the Netherlands

The Dutch government intends to introduce a different form of payment for mobility (Ministry of Transport, 2004); not vehicle ownership will be the basis for payment, but use of a vehicle. This intention should lead to the introduction of a countrywide price per kilometre on all roads, differentiated by time, place and environmental characteristics of the vehicle.

Since 2004 the Dutch government has executed two studies after the implementation costs of an introduction of a price per kilometre. In the first study from 2005 estimations of the implementation costs of a broad range of road pricing scenarios are presented (Ministry of Transport et al., 2005). Here, we will only discuss the scenarios which are relevant for this study. In Table 24 an overview of the relevant scenarios is given.

Table 24 Relevant scenarios from Ministry of Transport (2005)

| Scenario | | Description |
|---|---|---|
| a | Kilometre charging | Kilometre charging for all vehicles on all roads in the Netherlands. Differentiation on vehicle characteristics like mass, sales price and environmental characteristics. |
| b | Kilometre charging heavy vehicles | Kilometre charging for HGV vehicles (> 12 ton) on motorways. |
| c | Kilometre charging + congestion charging | Kilometre charging for all vehicles on all roads in the Netherlands. In addition, a mark-up on the charges during rush hours. |
| d | Toll charging | Toll charging on six locations. |

The investment and operating costs of the four scenarios are given in Table 25 and Table 26. The DSRC technology is used in the scenarios with a relatively limited scope. In the scenarios where road pricing is introduced countrywide a GPS system is assumed. For scenario B both the implementation costs of using DSRC and GPS systems are estimated.

For all scenarios different cost components are distinguished: vehicle equipment (including installation), roadside equipment (portals, etc.), data transfer and register occasional users (costs of transferring data, additional registering systems for occasional users, etc.), invoicing and payment (processing data, costs related to invoice and payment), control and enforcement (monitoring systems, periodically testing of vehicle equipment, etc.), and other costs. The costs for the various scenarios are estimated using traffic figures for 2005.

The results show that countrywide road pricing for all vehicles have significantly lower implementation costs compared to a scheme for HGV's only. This can be explained by the variance in number of users of the schemes to which the fixed implementation costs can be allocated. As expected, the investment costs of a local road pricing scheme (scenario D) are lower than for a countrywide scheme. Furthermore, it can be seen that the implementation costs for scenario B are significantly lower when a GPS based technology is applied instead of a DSRC based technology. Finally, the main cost components for GPS based schemes are vehicle equipment and control & enforcing. For DSRC based schemes, on the other hand, the costs of roadside equipment are the most important ones.

Table 25 Investment costs for different road pricing scenarios

| | Scenario A | Scenario B1 | Scenario B2 | Scenario C | Scenario D |
|---|---|---|---|---|---|
| **General assumptions** | | | | | |
| Technique used | GPS | GPS | DSRC | GPS | DSRC |
| Number of vehicles | 7,499,000 | 220,000 | 240,000 | 8,000,000 | 1,395,785 |
| Number of roadside equipments | - | - | 1,283 | - | 35 |
| **Investment cost components (in mln. €)** | | | | | |
| Vehicle equipment | 1,800-3,200 | 99-200 | 12-14 | 1,870-3,485 | 49-63 |
| Roadside equipment | - | - | 237-284 | - | 27-35 |
| Data transfer, register occasional users | 40-80 | 9-18 | 9-11 | 44-82 | 5-7 |
| Invoicing, payment | 40-80 | 2-4 | - | 44-82 | - |
| Control, enforcement | 120-240 | 61-125 | 24-29 | 132-246 | 5-7 |
| Other | 100-200 | 9-18 | 18-22 | 110-205 | 14-18 |
| **Total investment costs** | | | | | |
| Total investments (in mln. €) | 2,100-3,800 | 180-365 | 300-360 | 2,200-4,100 | 100-130 |
| Investments per user (€) | 280-507 | 818-1,660 | 1,250-1,500 | 275-513 | 72-93 |

Source: Ministry of Transport, 2005.

Table 26 Operating costs for different road pricing scenarios

| | Scenario A | Scenario B1 | Scenario B2 | Scenario C | Scenario D |
|---|---|---|---|---|---|
| **General assumptions** | | | | | |
| Technique used | GPS | GPS | DSRC | GPS | DSRC |
| Number of vehicles | 7,499,000 | 220,000 | 240,000 | 8,000,000 | 1,395,785 |
| Number of roadside equipments | - | - | 1,283 | - | 35 |
| **Operating cost components (in mln €)** | | | | | |
| Vehicle equipment | 140-385 | 10-26 | 0,2-0,5 | 170-374 | 1-2 |
| Roadside equipment | - | - | 17-46 | - | 2-6 |
| Data transfer, register occasional users | 60-165 | 5-13 | 5-13 | 75-165 | 5-15 |
| Invoicing, payment | 56-154 | 2-6 | 2-6 | 65-143 | 23-74 |
| Control, enforcement | 116-319 | 15-38 | 29-78 | 155-341 | 24-76 |
| Other | 28-77 | 3-7 | 6-16 | 35-77 | 5-17 |
| **Total operating costs** | | | | | |
| Total operating costs (in mln €) | 400-1,100 | 35-90 | 60-160 | 500-1,100 | 60-190 |
| Operating costs per user (€) | 53-147 | 159-409 | 250-667 | 63-138 | 43-136 |

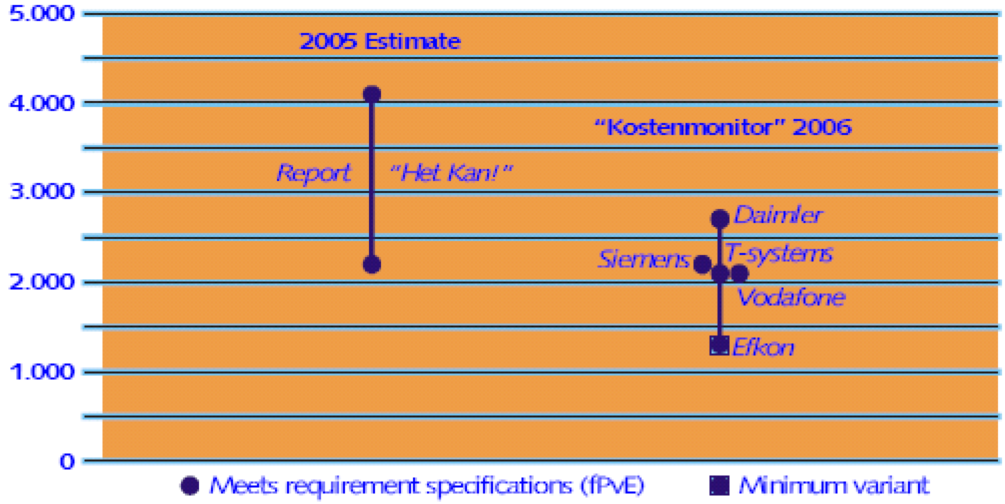
Source: Ministry of Transport, 2005.

In 2006 the Ministry of Transport conduct a second study after the implementation costs of road pricing in the Netherlands (Ministry of Transport et al., 2006). In this study a road pricing scheme comparable to scenario C from the 2005 study - a kilometre price for all vehicles on all roads in the Netherlands, which is differentiated to time, location and environmental characteristics of the vehicle - was investigated.

The market has been involved in this study intensively through an open, transparent process of market consultation. Different market parties are asked to present a system for road pricing in the Netherlands based on some preconditions. Next to the preconditions mentioned before - the scheme must apply to all vehicles on all roads in the Netherlands and should allow differentiation to time, location and environmental characteristics of the vehicles - another important precondition was that the scheme should apply a GPS based technology. This technology was recommended by a majority of the consulted market parties, possibly with additional technology to improve reliability and reduce fraudulent behaviour. The main reason for the choice for satellite navigation above DSRC based technology is the broad geographical scope of the intended kilometre price. The large number of roadside equipment needed to cover all roads in the Netherlands will be an important barrier for a DSRC based system. Four market parties have researched a integral road pricing system based on GPS technology. One other party has been commissioned to investigate cheaper alternative systems.

Figure 24 shows the investments estimated by the market parties in relation to the 2005 estimations. According to this figure, the investments could be lower than the average in the 2005 estimate. The investment costs of the five market parties range from € 1.3 to € 2.7 billon. Per user the investment costs are equal to € 163 - € 338. Notice that the minimum variant does not meet all requirement specifications.

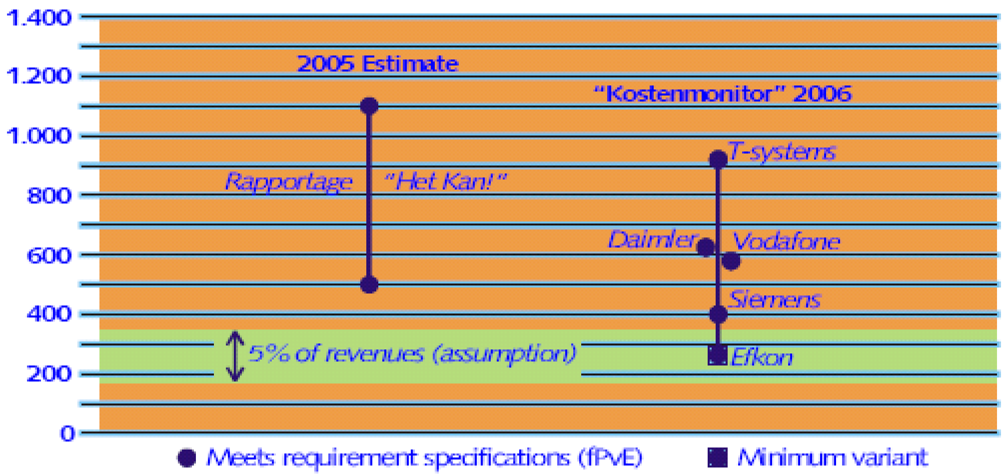
Figure 24 Investment cost (in million €) estimated by five market parties in relation to the 2005 estimates




Source: Ministry of Transport, 2006b.

In Figure 25 the estimates of the operating costs per year are shown. According to two market parties the operating costs could be substantially lower compared to the 2005 estimates. The other three parties find operating costs which lie within the 2005 range. Overall, the operating costs found by the five market parties range from € 250 to € 925 million per year (€ 31 - €119 per user per year).

Figure 25 Operating cost (in million € per year) estimated by five market parties in relation to the 2005 estimates




Source: Ministry of Transport, 2006b.

Figure 26 and Figure 27 show the decomposition of the estimated implementation costs by the five market parties and the 2005 estimates. The investment costs are still heavily dependent on the costs of the vehicle equipment, although all market parties anticipate a downward trend (from € 180 per OBU in 2005 to about € 100 in 2006). The costs related to communication between OBU and back office, facilities for customer relations management and the costs of any additional system for incidental users are higher than the 2005 estimates. These differences are largely due to a different allocation of costs to the main categories. Since a lower control intensity was considered necessary, the costs of enforcement are significantly lower than in 2005.

Because the investment costs of the vehicle equipment is estimated lower, the operating costs as a result of replacement, repair and new users is lower for all users. Most noticeable in Figure 27 are the costs of communication. These costs are estimated much higher compared to the 2005 estimates, with considerable differences between the various market parties. The most important difference lies in the estimates of the subscription costs for mobile data communication (ranging from € 7.50 to € 36 per user per year). Some parties (DaimlerChrysler and Efkon) do not use mobile communication, but rather the exchanging of a data carrier or DSRC communication at petrol stations. This involves no cost for mobile communication, but it does involve expenses for managing a special infrastructure to exchange the data.

Figure 26 Decomposition of investments estimated by five market parties in relation to the 2005 estimates

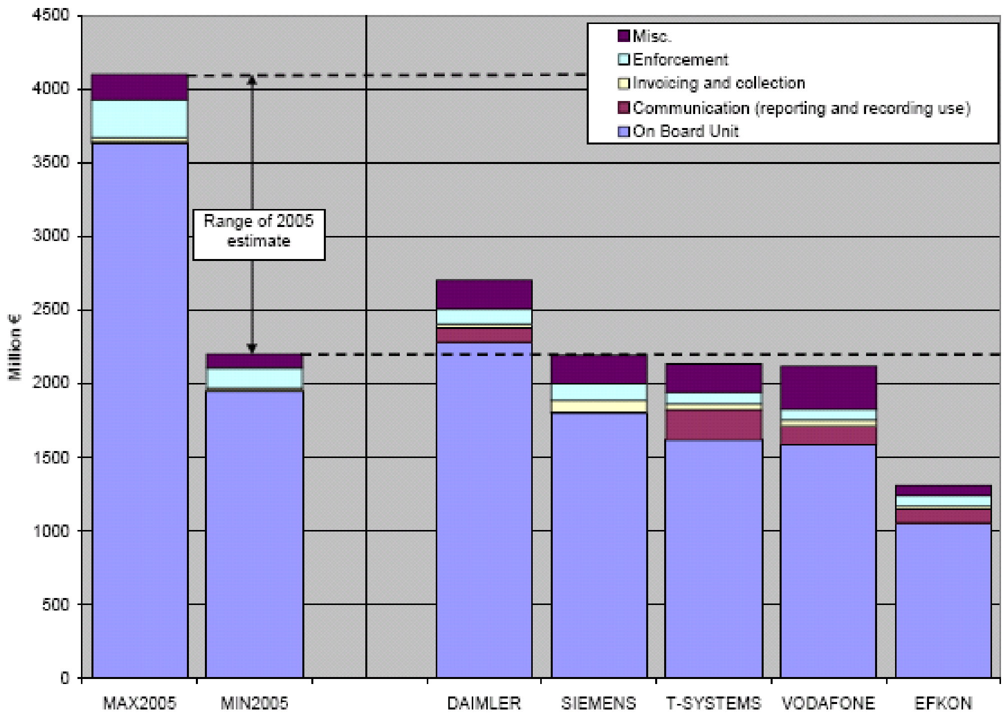
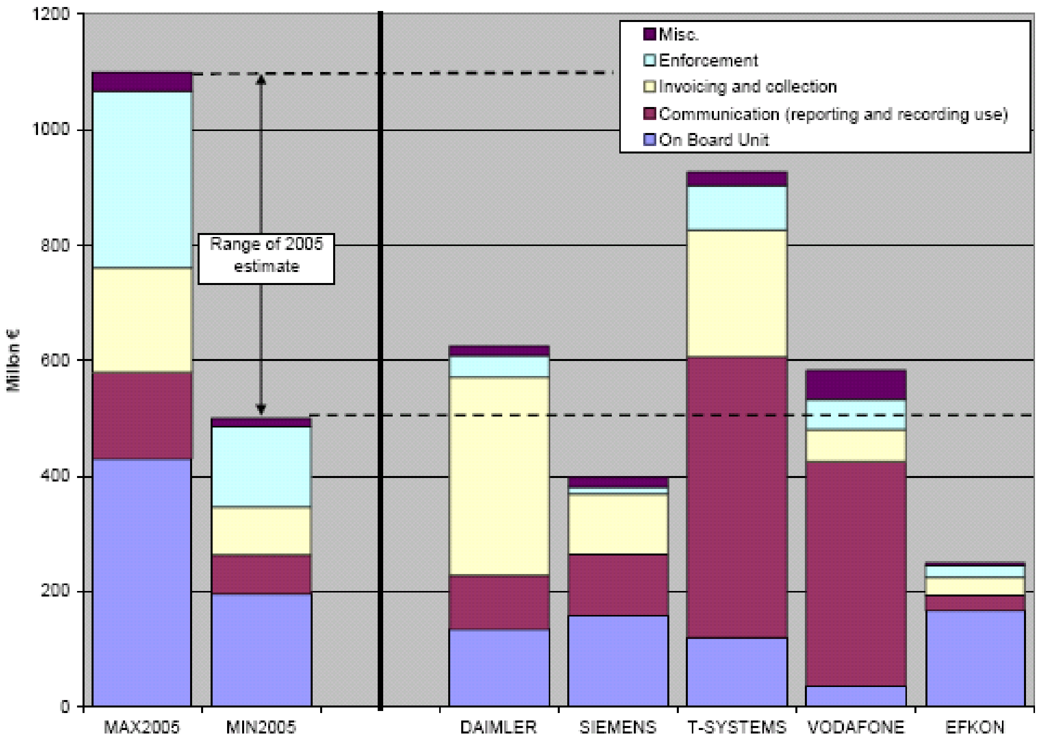


Figure 27 Decomposition of annual costs estimated by five market parties in relation to five market parties




## E.3 Kilometre charges in the UK

The Department for Transport (DfT) investigated 10 potential scenarios for the implementation for road user charges in the UK (DfT, 2004). One of these scenarios examine a road pricing scheme for all vehicles on all UK roads. It is assumed that all road users would be required to obtain a on board unit which employs GPS technology such that charging is carried out according to actual distance travelled. The implementation costs estimated for this scenario are interesting for this study and hence will be discussed in this section.

Table 27 shows the estimated investment and operational costs for road pricing on all UK roads.

Table 27 Estimated implementation costs for road pricing on all UK roads

| | |
|---|---|
| Total investments | € 15 - € 91 billion |
| Investments per user | € 662 - € 4,925 |
| Total annual operational costs | € 2,9 - € 8,0 billion |
| Annual operational costs per user | € 128 - € 433 |

The investment costs depend on a large extent on the costs of OBU's. Due to the uncertainty in the costs of these vehicle equipment a range of OBU costs is considered: € 150 - € 775. This explains the large bandwidth in the estimates of total investments. If the OBU costs are compared to the costs estimated in the

Dutch studies, they seem too high. Hence, we expect that the upper limit of the estimated implementation costs of road pricing in the UK is also too high.

Just as investment costs depend heavily on the OBU costs, so the operating costs of this scheme depends to a large extent on the cost of the communications between the OBU and the back office. It was assumed that this communication would be done by mobile telephony. The estimated annual costs per user could be in the range of € 18 - € 53, which is on average significantly higher than the annual costs per user of € 7,50 - € 36 estimated in the Dutch studies.

## E.4 Heavy vehicle charging in Austria, Germany and Switzerland

Since a couple of years a kilometre charge for heavy vehicles is in place in Austria, Germany and Switzerland. In Austria heavy vehicles have to pay per kilometre on all motorways and some express ways. The kilometre charge is differentiated to the number of axles and the emission class of the vehicle. Every time the vehicle passes under one of the 420 toll gantries, a DSRC signal is sent to the tag indicating the position which is subsequently used to calculate the distance travelled. For enforcement, the authorities relies on ca. 100 gantries equipped with ANPR, and about 30 mobile units. Both prepay and post pay are possible. For a description of the schemes in Germany and Switzerland we refer to Annex A, where for both schemes a fact sheet is presented.

In Table 28 the implementation costs of the three charging schemes are presented.

Table 28 Implementation costs of HGV charging in Austria, Germany and Switzerland

| | HGV Maut Austria | HGV Maut Germany | LSVA Switzerland | Czech Republic |
|---|---|---|---|---|
| **Total implementation costs** | | | | |
| Investments | € 250 - € 370 mln. | € 700 - € 1,200 mln. | € 160 - € 200 mln. | € 95 mln. |
| Investments per user | € 417 - € 617 | € 500 - € 1,000 | € 450 - € 565 | € 320 |
| Annual operational costs | € 35 mln. | € 550 - € 610 mln. | € 35 mln. | unknown |
| Annual operational costs per user | € 58 | 393-508 | € 100 | unknown |

Source: CE Delft, 2005; Oehry, 2006; Ministry of Transport et al., 2005; Bartl, 2008.

## E.5 Concluding remarks

Based on the discussion in this annex we can conclude that in general three technological options are available for a wide range road pricing scheme: ANPR, DSRC and GPS based technologies. The implementation of systems using ANPR or DSRC based technologies on all roads in a country causes extremely high cost, especially due to the large number of roadside equipment needed. For scenarios proposing a kilometre charge on all roads a GPS based technology

seems the most preferred option. However, if the kilometre charge is introduced on a part of the total road network only, DSRC based technologies are also a viable option. ANPR based technology seems especially appropriate to be used in combination with other technologies, to ensure enforcement.
Table 29 shows an overview of the implementation costs per user found by the various studies. A distinction is made between road pricing schemes for all vehicles, schemes for HGV vehicles only and local road pricing schemes.

Table 29 Overview of implementation costs per user found by various studies

| | Investments per user | Operating costs per user |
|---|---|---|
| **Road pricing for all road vehicles on all roads** | | |
| Ministry of Transport, 2005 (km charging) | 280-507 | 53-147 |
| Ministry of Transport, 2005 (km charging + congestion charging) | 275-513 | 63-138 |
| Ministry of Transport, 2006 (km charging) | 163-338 | 31-119 |
| DfT (2004) | 662-4,925 | 128-433 |
| **Road pricing for HGV** | | |
| Ministry of Transport, 2005 (GPS) | 818-1,660 | 156-409 |
| Ministry of Transport, 2005 (DSRC) | 1,250-1,500 | 250-667 |
| Austria | 417-617 | 58 |
| Germany | 500-1,000 | 393-508 |
| Switzerland | 450-565 | 100 |
| Czech Republic | 320 | unknown |
| **Local road pricing schemes** | | |
| Ministry of Transport, 2005 (toll charging) | 72-93 | 43-136 |

Note: The gray labelled data has been used for the implementation cost estimates in this report.

The implementation costs found for road pricing schemes for all vehicles differ widely. There are several reasons for these differences. First, the figures presented in Table 29 do refer to different kind of pricing schemes. Second, some figures are older than other ones. Since the technology needed for road pricing is still developing, recent studies show in general lower implementation costs compared to older studies. This may be an important reason for the relatively high costs estimates for DfT (2004). The most recent figures available are from Ministry of Transport et al. (2006). Therefore, we propose to use these figures to estimate the implementation costs of kilometre charging for all vehicles on all roads.

For HGV charging, both figures from actual pricing schemes (Austria, Germany and Switzerland) and from implementation studies (Ministry of Transport, 2005) are available. Since the former are more reliable, we will use these figures to estimate the implementation costs of the various internalisation scenarios. For pricing schemes based on DSRC-technology the cost figures from the Czech system are used for investments and from the Austrian scheme for operational costs. If a GPS-based scheme is assumed, figures based on cost estimates for Germany are used.

# F Model description of TRANS-TOOLS and TREMOVE

## F.1 TRANS-TOOLS

TRANS-TOOLS is a European transport network model covering passenger and freight, as well as intermodal transport, which overcomes the shortcomings of current European transport network models. The following clear innovations are obtained from TRANS-TOOLS:

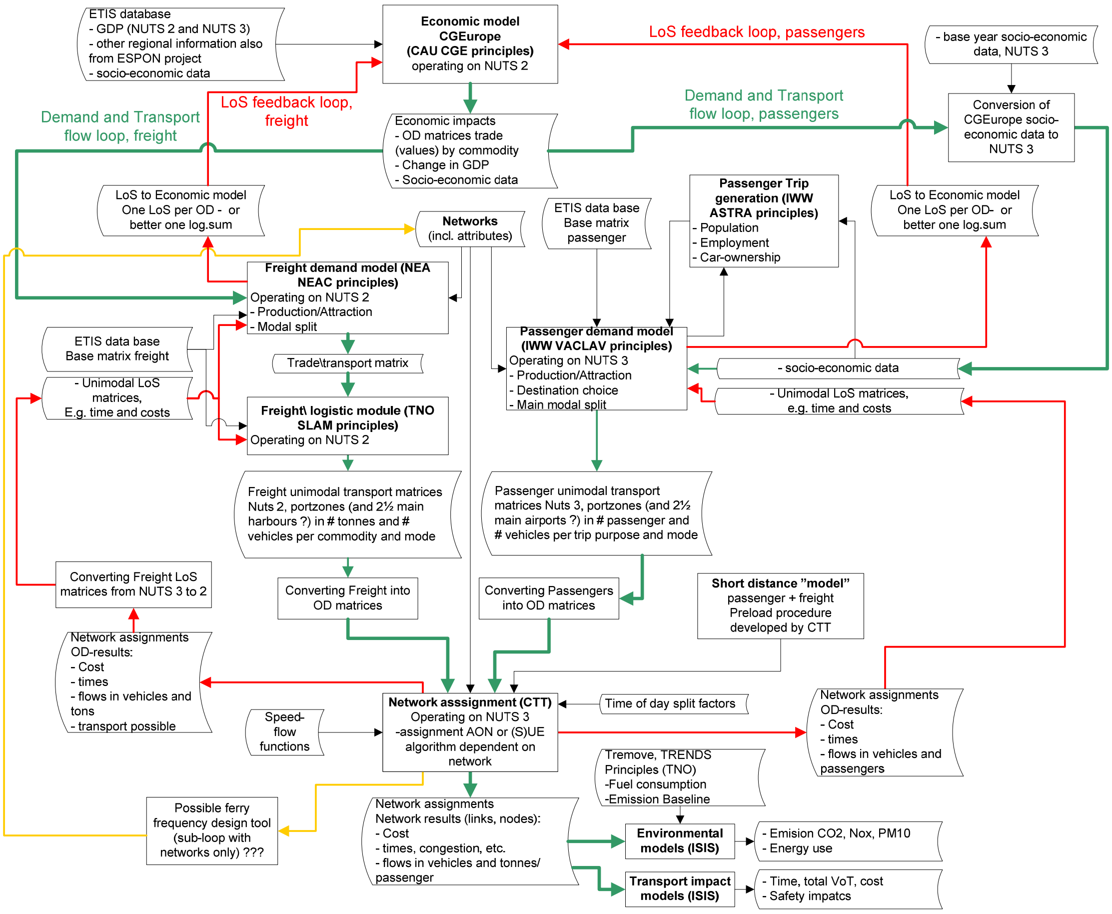
- New set up of a supply and demand model.
- Intermodality for passenger/freight (as National and European transport policies seek to promote intermodality through different measures).
- Inclusion of intercontinental flows (mainly for freight), as some models do not cover this segment.
- Full coverage of Central and Eastern Europe (Accession Countries and the countries at the borders of the enlarged European Union).
- Integration of the new Member States at a level similar to those of EU-15.
- Feedback infrastructure development economy (as the question of indirect effects in the economy and on network level is important, especially where investment has a substantial influence - notably for Accession Countries).
- Logistics/freight chain explicitly included.
- Coupling method with local traffic in order to address the effect of congestion on long distance traffic.
- The consortium provides access to all relevant experience concerning EU and national modelling.
- A software approach is chosen which results in a software modelling tool on network level.

The TRANS-TOOLS model, which reference data comes from the ETIS database, is made of different modules, as it can be seen by the blueprint in Figure 28. These model components exchange information according to a sequential approach (i.e. the origin/destination matrix produced by the passenger model is transferred to the modal split model, etc.), although feed back effects are taken into account (i.e. transport costs and times produced by the assignment model are fed back to the modal split model). In brief, the model works in the following way (using a modelling step of 1 year):

- The freight/logistics model (based on NEAC and SLAM principles) produces the freight unimodal transport modal matrices for the 10 NST/R commodity groups on the basis of the NUTS-2 zoning system.
- The passenger model (based on ASTRA and VACLAV principles) simulates the generation and distribution of trips and produces origin/destination matrices by trip purpose and by mode at regional level (NUTS3 zoning system).
- Main inputs for these two models are the transport network, the socioeconomic data and the transport Level of Service (cost and times); the latter is produced by the TRANS-TOOLS assignment model.

- The freight and passenger trip matrixes enter in the assignment stage. Freight matrixes have to be brought on the level of NUTS-3, a level which is appropriate to describe congestion.
- From the assignment module the transport costs will enter (in log sum) into the SCGE model, which is based on CG Europe principles. The change in transport costs/accessibility is a driving force for indicating the indirect effects (change in regional GDP), which are then fed in the freight and passenger model.

Figure 28 Overview of TRANS-TOOLS modules




## F.2 TREMOVE

TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector. The model estimates the transport demand, the modal shifts, the vehicle stock renewal, the emissions of air pollutants and the welfare level. The model can be applied for environmental and economic analysis of different policies as road pricing, public transport pricing, emission standards, subsidies for cleaner cars, etc.

TREMOVE models both passenger and freight transport, and covers the period 1995-2020.

TREMOVE is in fact 2 models: a land transport model, and a maritime model. The maritime model has not been used for IMPACT since it is not able to model the impacts of pricing policies. The land transport model has been set up to model all transport within one country. The TREMOVE modelling used for IMPACT covers 19 countries: the EU-15 plus Czechoslovakia, Hungary, Poland and Slovenia.

The TREMOVE model has been developed by Transport & Mobility Leuven and the K.U. Leuven, for the European Commission, DG Environment.
The first version of the model dates 1997-1998. At that time, the model covered nine countries and focussed on road transport. The K.U. Leuven and DRI developed the first model as an analytical underpinning for the European Auto-Oil II programme.

TREMOVE consist of twenty-one parallel country models. Each country model consists of three interlinked 'core' modules: a transport demand module, a vehicle turnover module and an emission and fuel consumption module, to which a welfare cost module and a well-to-tank emissions module has been added.

The **transport demand module** describes transport flows and the users' decision making process when it comes to making their modal choice. Starting from the baseline level of demand for passenger and freight transport per mode, period, region, etc., the module describes how the implementation of a policy measure will affect the user's and company's choice between these 240 different transport types. The key assumption here is that the transport users will select the volume of transport and their preferred mode, period, region etc. based on the generalized price for each mode: cost, tax or subsidy and time cost per km travelled. The output of the demand module consists of passenger kilometres (pkm) and ton kilometres (tkm) that are demanded per transport type for a given policy environment. The pkm and tkm are then converted into vehicle kilometres.

The **vehicle stock turnover module** describes how changes in demand for transport or changes in vehicle price structure influence the share of age and type of vehicles in the stock. The output of the vehicle stock module is twofold: both the total fleet and the number of km for each year according to vehicle type and age.

The **fuel consumption and emissions module** is used to calculate fuel consumption and emissions, based on the structure of the vehicle stock, the number of kilometres driven by each vehicle type and the driving conditions.

Outputs from the vehicle stock and fuel consumptions and emissions modules are fed back into the demand module. As fuel consumption, stock structure and usage influence usage costs, they are important determinants of transport demand and modal split.

In addition to the three core modules, the TREMOVE model includes a well-to-tank emissions and a welfare cost module.

The **well-to-tank emissions module** enables to calculate emissions during production of fuels and electricity.

The **welfare cost module** has been developed to compute the cost to society associated with emission reduction scenarios in European urban and non-urban areas. The welfare effect of a policy change is calculated as the discounted sum of changes in utility of households, production costs, external costs of congestion and pollution and benefits of tax recycling. These benefits of tax recycling represent the welfare effect of avoiding public funds to be collected from other sectors, when the transport sector generates more revenues.

# G Background information on scenario results

## G.1 Changes in the level of taxes and charges in the various scenarios

The scenarios affect the prices transport users pay in various ways: some taxes or charges introduced or increased, while at the same time others are decreased or even abolished. To get an idea of the net impact of the price changes on the total taxes and charges users need to pay, the changes in taxes and charges per mode have been summarized for each of the scenarios. The results of this are given in Table 30 and Table 31. The changes have been calculated for TREMOVE. For TRANS-TOOLS runs, the changes are different because intra NUTS-3 traffic is not included and congestion charges are included in scenario 3-5.

These overviews show the impact of the scenarios on the average total of taxes and charges transport users pay, if they would not change their transport behaviour. Note that the overviews do NOT show the changes in overall revenues, since they are based on the traffic volumes in the baseline. The introduction of internalisation measures changes the traffic patterns and so, also the revenues of taxes and charges. The impact of the scenarios on the revenues is to be expected as modelling output, though not yet available.

Table 30 Summarized changes in total taxes and charges for freight transport, per mode, per scenario

| TOTAL INCREASE CHARGES/TAXES *EU-19, 2010, (billion Euro)* | FREIGHT | | | |
|---|---|---|---|---|
| Scenario | Rail | Road | IWW | Total freight transport |
| **2** | **1** | **29** | **1** | **31** |
| Excise duties to minimum levels | 0 | -5 | 0 | -5 |
| Fuel taxes for internalisation | 1 | 34 | 1 | 37 |
| **3** | **1** | **29** | **1** | **31** |
| Excise duties to minimum levels | 0 | -5 | 0 | -5 |
| Charges for internalisation | 1 | 34 | 1 | 37 |
| **4A** | **1** | **51** | **1** | **54** |
| Excise duties to minimum levels | 0 | -5 | 0 | -5 |
| Taxes/charges for internalisation external cost | 1 | 34 | 1 | 37 |
| Abolishment existing tolls & Eurovignettes | 0 | -9 | 0 | -9 |
| Tolls at marginal infra cost levels | 0 | 31 | 0 | 31 |
| **4B** | **1** | **56** | **1** | **59** |
| Taxes/charges for internalisation external cost | 1 | 34 | 1 | 37 |
| Abolishment existing tolls & Eurovignettes | 0 | -9 | 0 | -9 |
| Tolls at marginal infra cost levels | 0 | 31 | 0 | 31 |
| **5A** | **1** | **53** | **1** | **55** |
| Taxes/charges for internalisation external cost | 1 | 34 | 1 | 37 |
| Abolishment existing HGV tolls & Eurovignettes | 0 | -9 | 0 | -9 |
| HGV tolls at marginal infra cost levels | 0 | 31 | 0 | 31 |
| **5B** | **1** | **4** | **1** | **6** |
| Taxes/charges for internalisation external cost | 1 | 12 | 1 | 15 |
| Abolishment existing HGV motorway tolls & Eurovignettes | 0 | -9 | 0 | -9 |
| HGV motorway tolls at marginal infra cost levels | 0 | 13 | 0 | 13 |

Source: Summarized modelling input data (based on TREMOVE 2.44 fleet and mileage data for 2010, EU-19).

Remark: These data do NOT show changes in overall revenues, since they are based on traffic volumes in the baseline. Taxes or charges for internalisation include costs of air pollution, noise and accidents (for road), air pollution, noise, accidents and climate change (for diesel rail), air pollution, accidents and noise (for aviation and electric rail), air pollution and climate change (for inland waterways transport). For TREMOVE runs, so not including congestion charges.

For the non-road modes, the changes in the level of the sum of all taxes and charges are the same in all scenarios.

For road transport, the levels differ a lot over the scenarios, mainly because of differences in the changes in the existing taxes and charges when internalisation measures are introduced. The lowest increase in overall taxes and charges for HGV is given in scenario 5B, while the highest increase, which is almost seven times higher, is in scenario 4B and 5A. For road passenger transport, the overall level of taxes and charges varies from a modest decrease in scenario 4A to an increase of 100 billion per year in scenario 5. For comparison, in IMPACT Deliverable 2, the overall revenues of taxes and charges from road transport (both freight and passenger transport) for the same set of countries (EU-19) are estimated at 312 billion. The increase in the overall tax and charge level of road transport varies from about 28% in scenario 4A to 50% in scenario 5A.

Table 31 Summarized changes in total taxes and charges for passenger transport, per mode per scenario

| TOTAL INCREASE CHARGES/TAXES *EU-19, 2010, (billion Euro)* | PASSENGER | | | |
|---|---|---|---|---|
| Scenario | Aviation | Rail | Road | Total passenger |
| **2** | **1** | **2** | **60** | **63** |
| Excise duties to minimum levels | 0 | 0 | -36 | -36 |
| Fuel taxes for internalisation | 1 | 2 | 96 | 99 |
| **3** | **1** | **2** | **60** | **63** |
| Excise duties to minimum levels | 0 | 0 | -36 | -36 |
| Charges for internalisation | 1 | 2 | 96 | 99 |
| **4A** | **1** | **2** | **30** | **33** |
| Excise duties to minimum levels | 0 | 0 | -36 | -36 |
| Taxes/charges for internalisation external cost | 1 | 2 | 96 | 100 |
| Abolishment existing tolls & Eurovignettes | 0 | 0 | -14 | -14 |
| Abolishment existing circulation taxes | 0 | 0 | -28 | -28 |
| Tolls at marginal infra cost levels | 0 | 0 | 11 | 11 |
| **4B** | **1** | **2** | **66** | **69** |
| Taxes/charges for internalisation external cost | 1 | 2 | 96 | 100 |
| Abolishment existing tolls & Eurovignettes | 0 | 0 | -14 | -14 |
| Abolishment existing circulation taxes | 0 | 0 | -28 | -28 |
| Tolls at marginal infra cost levels | 0 | 0 | 11 | 11 |
| **5A** | **1** | **2** | **96** | **100** |
| Taxes/charges for internalisation external cost | 1 | 2 | 0 | 3 |
| Additional circulation taxes for internalisation cars/LDV/MC | 0 | 0 | 96 | 96 |
| **5B** | **1** | **2** | **96** | **100** |
| Taxes/charges for internalisation external cost | 1 | 2 | 0 | 3 |
| Additional circulation taxes for internalisation cars/LDV/MC | 0 | 0 | 96 | 96 |

Source: Summarized modelling input data (based on TREMOVE 2.44 fleet and mileage data for 2010, EU-19).

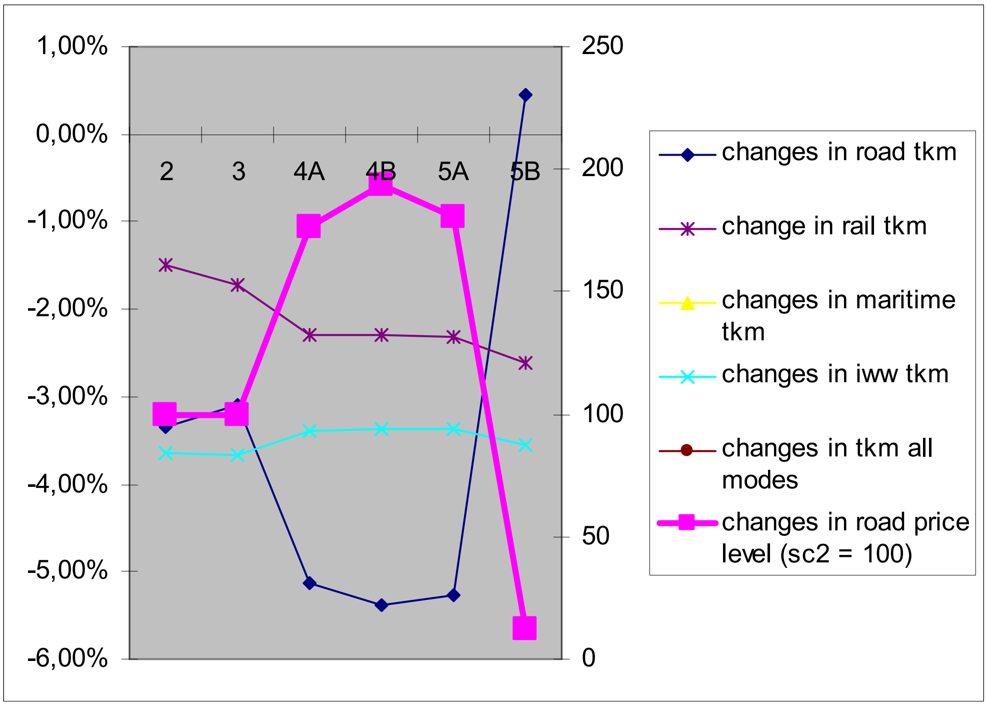
Remark: These data do NOT show changes in overall revenues, since they are based on traffic volumes in the baseline. For TREMOVE runs, so not including congestion charges.

## G.2 Comparison of volume changes and changes in the level of taxes and charges in the various scenarios

For the analysis of the changes in transport volume from TREMOVE, the changes in price levels resulting from the relevant changes in taxes and charges and the changes in transport volumes have been plotted in the same graph.

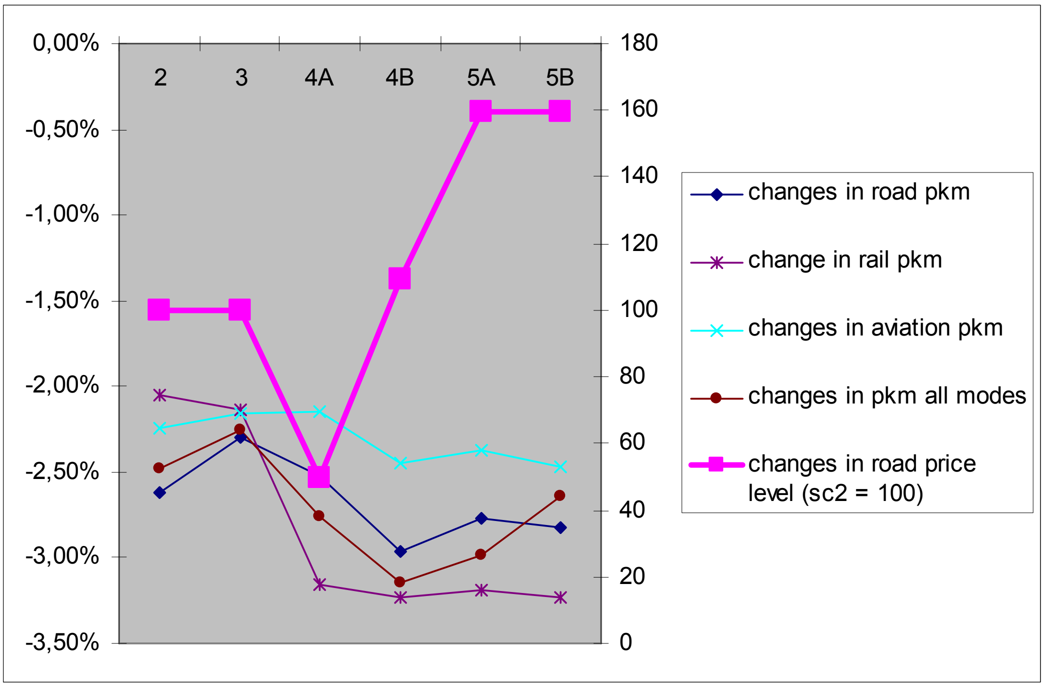
The changes in non-road tkm for TREMOVE seem almost insensitive for the changes in road pricing.

Figure 29 Changes in tkm compared with overall price changes (TREMOVE)




Just like for freight we plotted the price changes and impacts on volumes in one graph, see Figure 30 (TREMOVE).

Figure 30 Changes in pkm compared with overall price changes (TREMOVE)



## G.3 Revenues from congestion charges in TRANS-TOOLS

The revenues from the congestion charges in TRANS-TOOLS are shown in Table 32.

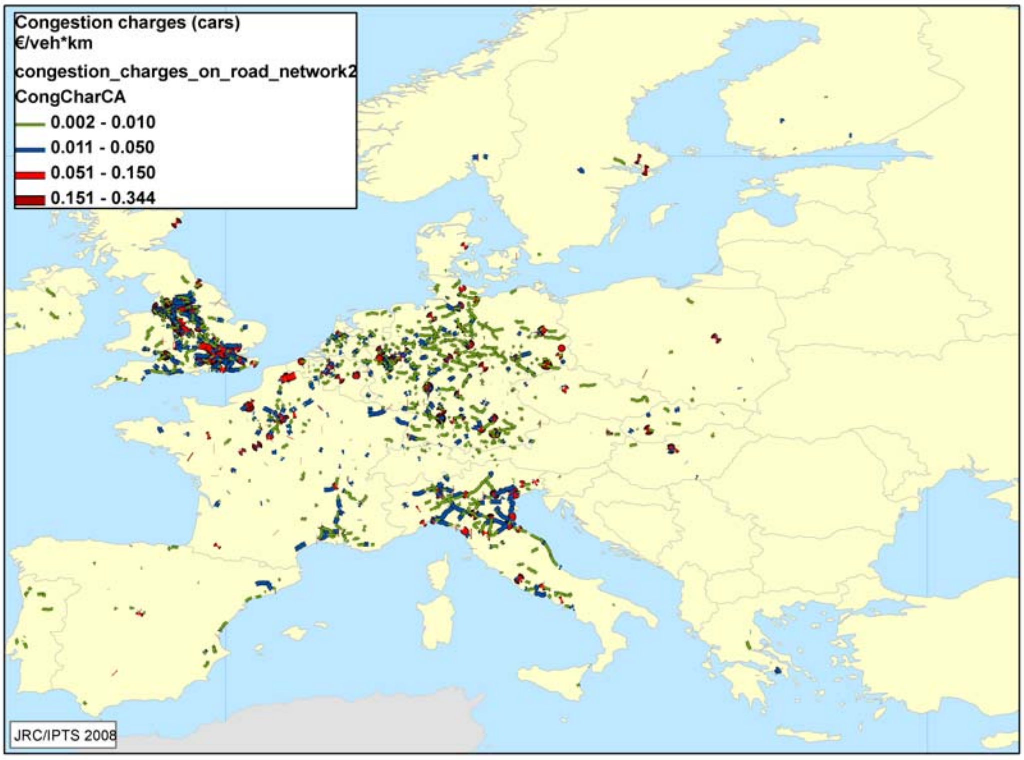
Table 32 Total revenues from the congestion charges in TRANS-TOOLS (scenario 4B)

| **Country** | **Revenues (Million €/year)** |
|---|---:|
| Austria | 25.9 |
| Belgium | 134.9 |
| Czech Republic | 33.3 |
| Denmark | 5.4 |
| Finland | 3.1 |
| France | 766.6 |
| Germany | 1,505.0 |
| Greece | 40.2 |
| Hungary | 46.6 |
| Ireland | 4.4 |
| Italy | 1,128.1 |
| Luxembourg | 6.6 |
| Netherlands | 221.2 |
| Poland | 34.1 |
| Portugal | 7.3 |
| Slovenia | 0.1 |
| Spain | 133.0 |
| Sweden | 63.6 |
| United Kingdom | 6,190.1 |
| *Total EU-19* | *1,593,823* |

# H Maps from TRANS-TOOLS modelling results

## H.1 Map showing the congestion charges applied in TRANS-TOOLS scenario 4

The map below shows the congestion charges modelled with TRANS-TOOLS in scenario 4.



# I Estimates for revenues from marginal cost based road charges for 2000, 2010 and 2020

Table 33 Comparison of revenues from existing and marginal costs based taxes and charges for road transport (EU-19, for **2000** in billion € 2,000)

| Billion Euro | Cars | LDV | HGV | Bus | Motorcycles | All road vehicles |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Marginal kilometre-related costs** | **93** | **15** | **50** | **20** | **8** | **184** |
| Variable infrastructure | 5 | 0.4 | 22 | 16 | 0.1 | 44 |
| Air pollution | 24 | 6 | 18 | 3.1 | 0.5 | 52 |
| Noise | 7 | 3 | 3 | 0.4 | 0.3 | 13 |
| Accidents | 56 | 6 | 5 | 1.2 | 7 | 75 |
| Congestion | | | | | | (100) |
| **Kilometre charges/tolls** | **5** | **3** | **14** | **0.1** | **0.5** | **22** |
| **Cost coverage. excl. congestion** | **5%** | **20%** | **28%** | **0%** | **6%** | **12%** |
| | | | | | | |
| **Marginal fuel-related costs** | **24** | **3** | **7** | **0.9** | **0.3** | **30** |
| Climate change | 10 | 1.2 | 3 | 0.4 | 0.1 | 10 |
| Well to tank emissions | 14 | 1.4 | 4 | 0.5 | 0.2 | 19 |
| Security of supply | | | | | | |
| **Fuel taxes** | **161** | **19** | **29** | **3** | **2** | **214** |
| **Cost coverage** | **679%** | **735%** | **414%** | **368%** | **516%** | **718%** |
| | | | | | | |
| **Fixed costs** | **132** | **13** | **21** | **3** | **2** | **172** |
| Fixed infra costs | 119 | 12 | 15 | 2 | 2 | 151 |
| Other external costs | 13.1 | 1.4 | 6.1 | 0.7 | 0.4 | 22 |
| **Fixed taxes/charges** | **58** | **3** | **5** | **1.4** | **6** | **73** |
| **Cost coverage** | **44%** | **25%** | **24%** | **45%** | **242%** | **42%** |
| | | | | | | |
| **Total costs. excl. congestion** | **249** | **31** | **78** | **24** | **11** | **386** |
| **Total costs. incl. congestion** | | | | | | **486** |
| **Total taxes and charges** | **223** | **25** | **48** | **5** | **8** | **309** |
| **Cost coverage excl. congestion** | **90%** | **81%** | **61%** | **20%** | **74%** | **80%** |
| **Cost coverage incl. congestion** | | | | | | **64%** |

Note: Calculated with data on vehicle kilometres, fuel consumption and emissions from TREMOVE (version 2.5.1) and valuation of external costs from IMPACT Deliverable 1. Revenues and infrastructure costs from IMPACT Deliverable 2. Total external costs are higher than shown here since the marginal costs are in some cases lower than the average costs. Note that the data on revenues and infrastructure costs are based on estimations and extrapolation of data for a limited number of countries (from IMPACT D2). Over time the revenues from marginal cost based charges for climate change strongly increase, while for air pollution revenues tend to decrease. Data for other years calculated by scaling variable revenues and external accident and noise costs with vehicle kilometre of the TREMOVE baseline; climate change costs use the different valuations from IMPACT D1, air pollution the TREMOVE emission factors for 2000.

Table 34 Comparison of revenues from existing and marginal costs based taxes and charges for road transport (EU-19, for **2010** in billion €-2,000)

| Billion Euro | Cars | LDV | HGV | Bus | Motor-cycles | All road vehicles |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Marginal kilometre-related costs** | **91** | **13** | **48** | **19** | **9** | **180** |
| Variable infrastructure | 6 | 0.5 | 26 | 17 | 0.2 | 49 |
| Air pollution | 12 | 3 | 13 | 1.2 | 0.4 | 29 |
| Noise | 8 | 3 | 4 | 0.4 | 0.4 | 15 |
| Accidents | 65 | 6 | 6 | 1.2 | 8 | 86 |
| Congestion (rough estimate) | | | | | | (100) |
| **Kilometre charges/tolls** | **5** | **3** | **18** | **0.1** | **0.5** | **27** |
| **Cost coverage. excl. congestion** | **6%** | **24%** | **37%** | **0%** | **6%** | **15%** |
| | | | | | | |
| **Marginal fuel-related costs** | **28** | **3** | **10** | **1.0** | **0.4** | **42** |
| Climate change | 14 | 1.7 | 5 | 0.5 | 0.2 | 22 |
| Well to tank emissions | 14 | 1.5 | 5 | 0.4 | 0.2 | 21 |
| Security of supply | | | | | | |
| **Fuel taxes** | **190** | **20** | **35** | **4** | **2** | **250** |
| **Cost coverage** | **678%** | **637%** | **358%** | **377%** | **442%** | **592%** |
| | | | | | | |
| **Fixed costs** | **132** | **13** | **21** | **3** | **2** | **172** |
| Fixed infra costs | 119 | 12 | 15 | 2 | 2 | 151 |
| Other external costs | 13.1 | 1.4 | 6.1 | 0.7 | 0.4 | 22 |
| **Fixed taxes/charges** | **58** | **3** | **5** | **1.4** | **6** | **73** |
| **Cost coverage** | **44%** | **25%** | **24%** | **45%** | **242%** | **42%** |
| | | | | | | |
| **Total costs. excl. congestion** | **251** | **29** | **79** | **23** | **12** | **395** |
| **Total costs. incl. congestion (rough estimate)** | | | | | | **495** |
| **Total taxes and charges** | **253** | **27** | **58** | **5** | **8** | **350** |
| **Cost coverage excl. congestion** | **101%** | **90%** | **73%** | **22%** | **70%** | **89%** |
| **Cost coverage incl. congestion (rough estimate)** | | | | | | **71%** |

Note: Calculated with data on vehicle kilometres, fuel consumption and emissions from TREMOVE (version 2.5.1) and valuation of external costs from IMPACT Deliverable 1. Revenues and infrastructure costs from IMPACT Deliverable 2. Total external costs are higher than shown here since the marginal costs are in some cases lower than the average costs. Note that the data on revenues and infrastructure costs are based on estimations and extrapolation of data for a limited number of countries (from IMPACT D2). Over time the revenues from marginal cost based charges for climate change strongly increase, while for air pollution revenues tend to decrease. Data for other years calculated by scaling variable revenues and external accident and noise costs with vehicle kilometre of the TREMOVE baseline; climate change costs use the different valuations from IMPACT D1, air pollution the TREMOVE emission factors for 2010.

Table 35 Comparison of revenues from existing and marginal costs based taxes and charges for road transport (EU-19, for **2020** in billion €-2,000)

| Billion Euro | Cars | LDV | HGV | Bus | Motorcycles | All road vehicles |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Marginal kilometre-related costs** | **97** | **12** | **50** | **19** | **10** | **186** |
| Variable infrastructure | 7 | 0.5 | 30 | 16 | 0.2 | 55 |
| Air pollution | 5 | 1 | 8 | 0.7 | 0.3 | 15 |
| Noise | 9 | 3 | 4 | 0.4 | 0.4 | 17 |
| Accidents | 75 | 7 | 7 | 1.2 | 9 | 99 |
| Congestion | | | | | | (100) |
| **Kilometre charges /tolls** | **6** | **3** | **21** | **0.1** | **0.6** | **31** |
| **Cost coverage. excl. congestion** | **6%** | **28%** | **43%** | **0%** | **6%** | **17%** |
| | | | | | | |
| **Marginal fuel-related costs** | **39** | **5** | **16** | **1.3** | **0.6** | **61** |
| Climate change | 23 | 2.8 | 10 | 0.8 | 0.4 | 37 |
| Well to tank emissions | 16 | 1.7 | 6 | 0.5 | 0.2 | 25 |
| Security of supply | | | | | | |
| **Fuel taxes** | **219** | **22** | **42** | **4** | **2** | **250** |
| **Cost coverage** | **564%** | **484%** | **265%** | **291%** | **341%** | **409%** |
| | | | | | | |
| **Fixed costs** | **132** | **13** | **21** | **3** | **2** | **172** |
| Fixed infra costs | 119 | 12 | 15 | 2 | 2 | 151 |
| Other external costs | 13.1 | 1.4 | 6.1 | 0.7 | 0.4 | 22 |
| **Fixed taxes/charges** | **58** | **3** | **5** | **1.4** | **6** | **73** |
| **Cost coverage** | **44%** | **25%** | **24%** | **45%** | **242%** | **42%** |
| | | | | | | |
| **Total costs. excl. congestion** | **268** | **30** | **87** | **23** | **13** | **420** |
| **Total costs. incl. congestion** | | | | | | **520** |
| **Total taxes and charges** | **283** | **29** | **68** | **5** | **8** | **354** |
| **Cost coverage excl. congestion** | **106%** | **96%** | **79%** | **22%** | **64%** | **84%** |
| **Cost coverage incl. congestion** | | | | | | **68%** |

Note: Calculated with data on vehicle kilometres, fuel consumption and emissions from TREMOVE (version 2.5.1) and valuation of external costs from IMPACT Deliverable 1. Revenues and infrastructure costs from IMPACT Deliverable 2. Total external costs are higher than shown here since the marginal costs are in some cases lower than the average costs. Note that the data on revenues and infrastructure costs are based on estimations and extrapolation of data for a limited number of countries (from IMPACT D2). Over time the revenues from marginal cost based charges for climate change strongly increase, while for air pollution revenues tend to decrease. Data for other years calculated by scaling variable revenues and external accident and noise costs with vehicle kilometre of the TREMOVE baseline; climate change costs use the different valuations from IMPACT D1, air pollution the TREMOVE emission factors for 2020.

# J Data on marginal kilometre-related costs and existing kilometre charges per vehicle-km

The table below shows the data for EU-19 of the graphs in Figure 2 to Figure 10. Note unlike the totals in Annex I and Table 5, that these data are per vkm and for *specific traffic situations and vehicle types*.

Table 36 Weighted averages in EU-19 for marginal kilometre-related costs and existing kilometre charges for various vehicle types and traffic situations (for 2010 in Euro-cent per vkm; currency €-2,000)

| | | | | | Costs | | | | | | Total marginal costs* | | Charges/toll | Cost coverage | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight (tones) | fuel | *Euro-ct/vkm* | | Accidents | Noise | Air pollution | Congestion | Variable infra costs | Fixed infra costs | off-peak | peak | | off-peak | peak |
| | | | | | | | | | | | | | | | |
| Car | | Diesel | metropolitan | Euro-3 | 4.3 | 0.8 | 2.4 | 29.3 | 0.2 | 4.6 | 7.7 | 37.0 | 0.0 | 0% | 0% |
| | | Petrol | motorway | Euro-5 | 0.3 | 0.1 | 0.0 | 9.7 | 0.2 | 2.7 | 0.6 | 10.3 | 0.9 | 136% | 9% |
| LDV | | Diesel | metropolitan | Euro-2 | 5.3 | 3.7 | 0.4 | 44.7 | 0.2 | 6.0 | 9.6 | 54.3 | 0.0 | 0% | 0% |
| | | Diesel | motorway | Euro-2 | 0.3 | 0.6 | 0.5 | 15.1 | 0.2 | 3.5 | 1.6 | 16.7 | 3.4 | 216% | 20% |
| HGV | 7.5-16 | Diesel | metropolitan | Euro-2 | 10.2 | 7.2 | 14.2 | 43.6 | 1.7 | 9.0 | 33.3 | 76.9 | 0.0 | 0% | 0% |
| | 7.5-16 | Diesel | motorway | Euro-2 | 0.3 | 1.0 | 7.5 | 19.8 | 1.2 | 5.3 | 10.1 | 29.8 | 11.8 | 117% | 39% |
| | 32+ | Diesel | metropolitan | Euro-2 | 10.2 | 7.2 | 9.1 | 98.2 | 16.9 | 11.9 | 43.3 | 141.5 | 0.0 | 0% | 0% |
| | 32+ | Diesel | motorway | Euro-3 | 0.3 | 1.0 | 3.8 | 44.5 | 11.6 | 7.7 | 16.8 | 61.3 | 12.5 | 74% | 20% |
| | 32+ | Diesel | motorway | Euro-5 | 0.3 | 1.0 | 1.4 | 44.5 | 11.6 | 7.7 | 14.4 | 58.9 | 12.5 | 87% | 21% |

* The listed total marginal costs do include the variable infrastructure costs, but not the fixed infrastructure costs.