



DIFFERENT

User Reaction and Efficient Differentiation of Charges and Tolls

D8.3 – D9.2 Report on Impacts of Charge Differentiation for HGV and Motorway Toll Differentiation to Combat Time Space Congestion

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*To Chiara Borgnolo,
who initiated this work with her usual enthusiasm and passion*



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EXECUTIVE SUMMARY

AIM OF THE DELIVERABLE

This document combines the two deliverables D8.3 “Report on the Impacts of Charge Differentiation for HGV” and D9.2 “Report on Motorway Toll Differentiation to Combat Time Space Congestion”, and synthesises the analysis related to the differentiation of interurban pricing for both freight and passengers, as carried out in Tasks 8.1 “Interurban pricing”, 8.4 “Interrelation freight and passengers” and 9.1 “Motorway charges”.

The main objectives of the Deliverable 8.3 - 9.2 are:

- to review at European level the implementation of the pricing legislative framework for heavy good vehicles and further developments to differentiate charges for infrastructure use;
- to show main evidences from recent experiences of distance-based charges for heavy good vehicles;
- to improve understanding of reactions of road hauliers to road charge differentiation;
- to present evidences from recent experiences of motorway toll differentiation;
- to present results of transport models test of impacts of charges differentiation for both freight and passenger traffic.

LEGISLATIVE FRAMEWORK AND STATUS OF DIFFERENTIATION

At European level, rules for road infrastructure charges are specified in Directive 2006/38/EC, which amends the Eurovignette Directive 1999/62/EC. The revision of the Eurovignette Directive has been prepared during a two years negotiation process. The Directive has the twofold aim of creating a uniform platform for motorway tolling in the EU and giving further incentives to improve capacity use and environmental performance in the road transport sector. The Directive allows (but not obliges) Member States to levy user charges or tolls on the entire road network and sets the rules for price for vehicles on the TEN-T network; it has the objective to reduce obstacles to the free movement of goods and guarantee fair competition between road haulage operators.

In the second half of the year 2007, the Directorate General for Transport launched a public consultation on the proposed approach to internalisation of external costs. Besides the public consultation, the Commission has commissioned the IMPACT study (IMPACT, 2008) aiming at reviewing and modelling the existing estimates of external costs in Europe and has carried out an impact assessment of the internalisation of external costs for all modes of transport, with a view to prepare an European strategy on this matter by June 2008. The Commission is entitled to produce a Proposal to the European Parliament and the Council for a further revision of the Eurovignette Directive, as common framework on which the charge levels for internalising could be based.

The current status of road charge differentiation in European countries is quite diversified. In recent years, a number of countries have implemented road charges for heavy vehicles, which have been differentiated according to environmental performance. These countries include Switzerland, Austria and Germany; lately, the Czech Republic has also worked on plans for freight road pricing system. In these States there is a distance-based road pricing scheme that imposes fees based on the number of miles or kilometres covered in a designated area in an attempt to discourage the use of vehicles. In France, Spain, Greece, Italy, Slovenia and Portugal parts of the motorways network have been operated by the private sector for several decades. These operators have right to levy tolls for use of their motorways. Toll levels are generally part of the contract between the national authorities and the motorways operator. In other States there is a different situation: Belgium, Denmark, Luxembourg, the Netherlands and Sweden have operated a vignette system; New Member States apply some kind of user charging on their motorway networks (Bulgaria and Romania operate time-based vignette systems for the use of all inter-urban roads; In Hungary, Lithuania and Slovakia vignette stickers are compulsory on certain motorway sections, while in Poland a toll is charged on a few sections) and



eventually some countries do not presently have any charging systems for road infrastructure, but some of these ones are currently examining the introduction of pricing schemes, such as UK.

There are margins for further differentiation in all countries and potentially, the Eurovignette Directive is an important environmental steering instrument, since it determines the scope within Member States can influence the environmental impacts of road freight transport by designing a road toll for trucks, particularly its scope of application and the level and structure of toll rates.

ANALYSIS OF CURRENT CHARGING SCHEMES FOR ROAD FREIGHT TRANSPORT

The Swiss HVF Scheme

The Swiss scheme for charging HGV has been analysed, with special reference to impacts of fee differentiation with regard to the emission category on haulage companies. The case study is developed through a desk analysis based on existing statistical figures and a survey among stakeholders: shipping companies, haulage companies, companies of branches with high transport intensity, rail transport operators, road transport associations, truck dealers. The main results are the following:

- The road freight transport sector is characterised by strong competition. In such an environment, incentives set by differentiated charges have a large impact on the behaviour of the “target group”. Cost reducing measures must be exploited in order to preserve the own competitiveness. In the Swiss case, such cost reducing measures could be observed in purchase and investment decisions as well as in decisions concerning the use of vehicles. The impact on the latter is probably the strongest effect of Heavy Vehicle Fee (HVF) differentiation.
- The HVF differentiation – as is the HVF itself – is a bigger challenge for small haulage companies than for larger ones. In an environment of strong competition the haulage companies will not be able to fully pass the cost increase caused by new charging regimes on to the shippers. Small companies will have more difficulties to compensate this development with productivity gains.
- The Swiss case study illustrates the relevance of the interplay between a charging regime and the regulation framework in the same policy field. The regulations concerning the emission standards for new vehicles partly dominated the incentives set by the HVF differentiation. An integrated policy strategy should consider both fields of state intervention in a co-ordinated way. Because a differentiated charge leaves more flexibility for efficient adjustment than regulation (e.g. fixed standards), one could argue that the charge differentiation in favour of less polluting vehicles should more clearly precede regulations than in the case of the Swiss HVF.
- The impact of charge differentiation does not only depend on the incentives set by the charge but also on other factors (e.g. cost differences, financing restrictions). This fact increases the inefficiency problem, if the spread of the differentiation is not related to the ecological performance of the vehicles but set in political negotiations. Countries leading the way in introducing differentiated user charges may affect neighbouring countries.

The German HVF Scheme

Analysis of data published before and after the introduction of the German Heavy Goods Vehicle (HGV) charging scheme provides an historical background and description of the German HGV toll scheme, and the effects of the tolling system on revenues, load factor of the vehicles, composition of the fleet, route diversion and modal shift have been analysed. The main results are the following:

- The German HVF scheme is the first step in the direction of user infrastructure financing in Germany. It can be concluded that not all toll aims have been achieved.
- Revenues are raised according to plan; environmental aims are only partly achieved with a long-term trend of a decreasing number of no-load trips and the increased use of environmentally friendly vehicles.



- Success concerning other aims, such as modal shift, is not recognisable at all. As a consequence of such reactions, some politicians and lobbyists, but also scientists, call for an extension of tolls to the secondary road network and second to extend toll to all vehicles over 3.5t.
- In addition, there are phenomena of toll avoidance as well as user reactions in direction of using vehicles under 12t.

Comparative Analysis of Swiss and German Case Studies

The comparative analysis is limited to certain fields, due to the differences in the charging structure. With respect to the weight-based differentiation, the Swiss case shows clearly that there are incentives to use heavier vehicles. This proposition is also confirmed by the respective market development. Similarly, the enhanced new registration of vehicles under 12 t in Germany is additional evidence that weight differentiation has a significant effect on the composition of the fleet. However the differentiated tariff structure of the Swiss HGV system seems to work better the simple German separation.

Turning to the differentiation according to the emission classes, the existing differences with respect to the division of the emission classes may have significant effects on the vehicles used. For Switzerland, we see a clear domination of the EURO5 technology for vehicles bought and registered in 2006, though the hauliers could still buy EURO3 vehicles. The price and the operation costs of a EURO5 or a EURO4 vehicle are rather higher than for a standard EURO3 vehicle. Therefore, we can assume that the high shares of EURO5 and EURO4 vehicles show the influence of the HVF. The hauliers anticipated the further development of the HVF, i.e. the differentiation between EURO3 (new HVF class 2) and EURO4/5 (HVF class 3) that Switzerland intends to introduce by 2008. As the German toll is only levied on motorways and is substantially lower in absolute terms, the incentive to switch to cleaner vehicles is obviously less strong than in the case of the Swiss HVF.

Finally the differentiation in Germany between the motorways and the rest of the network, revealed some toll avoidance phenomena. This problem does not exist in Switzerland, due to the fact that the fee is applied to the whole network, even if the Swiss detour traffic has occurred in neighbouring countries: before 2001 due to the lower Swiss GTW limit (28 tonnes) and after the removal of the weight limit (from 28 to 34 tonnes in 2001 and to 40 tonnes in 2005) due to the higher Swiss fee level in comparison with neighbouring countries fees (ARE, Detec, 2004).

Concluding from the comparison between the Swiss and the German scheme, it seems that fine differentiated tolling schemes according to the vehicle weight can provide the right incentives for vehicle use. In addition, the differentiation according to emission classes reveals, that it is important for regulators to anticipate market developments and react respectively, when defining the composition of the emission classes.

Evidence from the UK's M6 Toll

The tolls on the UK's M6 Toll road are differentiated according to type of vehicle (with higher charges for vehicles whose height at first axle exceeds 1.3 m). The toll for larger vehicles was originally set at £10 (5 times the toll for smaller vehicles). This ratio resulted in objections from operators of large freight vehicles and usage of the road by such vehicles was low. This fact was picked up by the toll operators who, after 9 months of operation reduced the toll for larger vehicles to £6 while increasing that for smaller vehicles from £2 to £3. This appears to be an example of toll differentiation being adjusted to reflect the demand response - presumably with the objective of maximizing income.

Road Haulage Survey on Tolls Differentiation

The survey organised according a two-steps procedure (firstly a main group of operators contacted and interviewed by phone, secondly a sample of 17 operators, 9 from Poland and 8 from Italy, contacted by e-mail), was focused especially on 'structural' and behavioural reactions to road freight tolls differentiation. The sample, little but well matched, included multimodal operators and third party logistic providers, which brought in a broader perspective on real alternatives to road freight transport in the shorter and in the longer term, as well as large and small companies and single hauliers (owner-



driver), the latter being the ones with tight cost constraints. Unfortunately, it was extremely difficult to get feedback from the contacted single hauliers and this category is therefore under-represented in the final results. On the whole, due to the difficulties in data collection, the survey results, even if interesting, do not lead to general conclusions. However, they can be summarised as follows:

- Tolls are not considered by the operators as the main problem or aspect of freight road transport, compared to road congestion and road quality (maintenance); this is probably due to the fact that road tolls account for less than 10% of the total production costs.
- The extension of toll differentiation on other corridors or on a whole road network could have relevant effects in terms of vehicle class and emissions (fleet renewal), which are also the actions that operators are willing to adopt (probably due to the fact that they are also required to renew fleets for other reasons, for instance operation costs).
- Differentiation based on time of day/night could have positive effects both on corridors and whole networks; nevertheless, it would have some problems in terms of acceptability from transport operators, as well as from the general population (even though local population was not involved in the survey). Major problems of acceptability are expected also in the case of differentiation by period of the year.
- The extension of toll differentiation to whole networks seems to be more effective than the introduction of the same policy on selected European corridors. Effects of further extensions of toll differentiation can be expected in the long term, with smaller or less relevant effects in the short term.

ANALYSIS OF CURRENT CHARGING SCHEMES FOR ROAD PASSENGER TRANSPORT

This desk work is related to two case studies of real applications of differentiated charging on motorways. The first one is the case of France, where applications of toll charge modulation to spread returning weekend and returning holiday motorways traffic have existed since 1992. United States HOT lanes are the second case, which refer to High Occupancy Vehicle (HOV) lanes that allow charged access to Single Occupancy Vehicles (SOVs) according to dynamic schemes.

Surcharging for congestion costs has been introduced in France on the A1 (Paris-Lille) motorway in weekends since 1992 (it is still going on) and experimented 12 years ago on the major links with the South (A10/A11, A5/A6) at the time of important movements for the summer holidays. These toll modulations were focused on light vehicle peak flows. Tolls on an urban section near Marseille are also differentiated according to day/night hours. Unfortunately, there is very little data available to assess the reaction of these modulation schemes.

More data have been collected for High Occupancy Toll (HOT) lanes within the United States, where it appears that these lanes have, in most cases, managed to improve the utilisation of road capacity, yield revenue and provide a superior level of service for those prepared to pay for it. The most successful schemes appear also to have reduced overall levels of delay and other externalities. HOT lanes offer an example of price differentiation (by time day and level of congestion) which can achieve effective yield management and an overall increase in social welfare.

The tolls on the UK's M6 Toll road were originally set in the light of evidence from models and market research. Data from the first six months of operation showed higher than anticipated usage by passenger traffic. The toll operators concluded that passenger traffic was willing to pay more to use the toll road (to avoid a notoriously congested stretch of the parallel M6 Motorway) and so raised the toll by 50%. This appears to be an example of toll differentiation being adjusted to reflect the demand response - presumably with the objective of maximizing income.

USING TRANSPORT MODELS TO TEST DIFFERENTIATED ROAD CHARGES

Evidence presented here is taken from new modelling work and from a synthesis of earlier model-based studies in the UK. The main NEW modelling application consists of the simulation of several differentiation scenarios using the Brenner TEN-T corridor model. This model was originally identified as the reference tool for the modelling exercises in the work packages WP8 and WP9 and a significant



part of the activities was devoted to its update and revision. In order to widen the modelling analysis simulating tolls differentiation in a diverse context, the Padana region motorway model was then added. In the Padana region supply and demand conditions are quite different from the Brenner corridor: instead of a major route mainly used by crossing traffic and with limited problems of capacity, a complex and often congested network where local traffic is prevailing. For the sake of comparability, similar approach and similar differentiation schemes have been followed as far as possible in the two modelling applications, even though they have diverse demand segmentations.

- *The Brenner TEN-T Corridor model* The Brenner corridor is one of the main gates for trans-Alpine traffic for both passenger and freight. Thus, a significant amount of crossing demand (with a substantial proportion of long distance HGV traffic) contributes to the traffic on the tolled motorway connecting Verona to Innsbruck and beyond. At the same time, especially in the Italian part, the road corridor is also used for (relatively) short-distance trips. Along the whole corridor, a national road runs parallel to the motorway and can be considered as an alternative route (of course especially for local trips). A major railway is also available on the corridor and a new rail tunnel is planned within the TENs projects.
- *The Padana Region Motorway model* The Padana Region study area comprises Lombardia, Emilia Romagna and Veneto regions and its motorway network includes : A4 Milano–Venezia, A1 Milano-Bologna, A22 Brennero-Modena, A21 Piacenza–Brescia and A13 Padova–Bologna. The region is densely populated and the motorway road network is also used for local trips within the study area. The model deals with freight and passenger traffic and also includes the network of national roads developed beside the motorway network.

Testing different toll schemes on the Brenner corridor and in the Padana region leads to some interesting results. In particular, the following points seem to be relevant:

- The impacts of the differentiation schemes are not the same in the Brenner model and in the Padana region model. This suggests that the context of application of the tolling scheme is very relevant.
- In the Brenner corridor, where congestion is limited and a large share of traffic consists of heavy trucks crossing the whole study area, the impact of differentiation schemes on the level of services and the environment is low. At the same time, the motorway operator is able to increase revenues even significantly. In the Padana region, where a more complex and congested network exists and demand includes many more local trips, level of services can be improved but the revenues of the network operator are less certain and require that also part of the road network (in addition to motorways) is tolled, which is politically challenging.
- Both models suggest that a trade-off between objectives does exist: improving levels of service can reduce motorway operators' revenues while higher revenues can well be produced without gains for the road users.
- Even when travel times can be reduced in non-negligible amounts, like in the Padana region, the rise of charges and, as a consequence, of total costs for travellers exceeds the benefits. In the Brenner context, scenarios oriented towards the minimisation of time spent can come up with benefits exceeding costs only if discounts are used, which might be undesirable from the motorway operator perspective.
- It seems impossible to significantly reduce emissions using differentiated tolls. If more polluting vehicles are overcharged they just shift to other roads and more elaborated schemes are able to produce only limited savings of pollution in the Brenner corridor, while in the Padana region even such a small result is not visible.
- Since in the Brenner corridor travel times cannot be improved, the only significant benefit from the social point of view can arise from a proper use of the revenues of the motorway operator, e.g. for developing alternative modes or promoting the renewal of the fleet.
- Toll schemes that provide for high charges on pollutant vehicles lead to clear positive results from the network operator perspective. However, if such a policy ensures remarkable gains in the short term, changes in the fleet structure could imply, in the long term, significant losses for the network operator. Instead, discounting tolls for "cleaner" vehicles seems a good strategy to minimise undesired effects on future earnings.



A number of model-based studies have been conducted in the UK; they include some modest early studies and some much larger studies under the umbrella of the Department for Transport's Multimodal Studies programme and National Road Charging Feasibility Study. The results of these studies suggest that appropriate differentiation of charges on motorways might provide an effective means by which to (i) reduce the diversion to local roads caused by introduction of charges on motorways and (ii) influence route choice with the objective of minimising delay or marginal social costs. Particularly effective differentiation schemes identified by the UK modelling work were:

- differentiation by time of day (to reflect different degrees of congestion);
- differentiation by type of vehicle (to reflect their different environmental externalities);
- differentiation by type of motorway (to reflect their different roles in the overall network – e.g. for strategic traffic or to relieve congestion on other roads); and
- differentiation by type of traffic (strategic or local).

Evidence from calibrated demand models also suggests that drivers would be willing to pay much higher tolls during congested periods if, by so doing, they could achieve near free-flow traffic conditions.

MAIN CONCLUSIONS AND RECOMMENDATIONS

From the experiences and analyses discussed in this deliverable, the main conclusions concerning inter-urban road charges can be summarised as follows:

- Differentiation of road tolls is effective. Its application induces perceptible changes in demand behaviour.
- There may be a particular role for tolls which are higher during periods of heavy congestion, – particularly if drivers who pay these higher tolls can be guaranteed a high level of service.
- Inter-urban road tolls differentiation is generally accepted and perceived as a fair measure.
- In the shorter term, the impact is generally low: some re-routing can be expected and the road haulage sector is encouraged to improve efficiency. Mode shift on non-road alternatives is quite unlikely especially for freight.
- In the longer term, emission-based charge differentiation is expected to lead to an accelerated fleet renewal. Some evidence of this is already available for freight. If tolls are progressively adapted to the new fleet structure, in order to keep the incentive alive, the cost for the freight sector could become significant and transferred on the haulage rates. If the differentiation scheme is not adapted, its effect is doomed to disappear and also revenues would shrink significantly.
- A consequence of the previous items is that inter-urban charge differentiation seems not an effective policy for environmental purposes in the short term, as any expected impact has only a poor positive correlation or even a negative correlation with lower transport emissions. Most likely, a similar conclusion holds for safety as well.
- Differentiation schemes can be designed with different objectives, but a trade-off between alternative targets most likely exists: e.g. the most preferable scheme for the motorway operator in case of project financing may well be not the best scheme for improving the level of service of the network.
- The specific context of application does matter. In non-congested corridors charge differentiation can raise money, but there is little room for social benefits, which can be achieved only if constraints are placed on the use of revenues. Instead, in congested areas the level of service of the road network can be improved, but this generally implies the charging of ordinary roads, which is politically challenging.



From the conclusions above the following recommendations arise:

- Careful consideration of the objectives of intra-urban charging differentiation, both in the short terms and in the long term, since diverse objectives may need diverse differentiation schemes.
- Consideration should be given to greater use of time-varying tolls following the model of the US HOT lanes.
- When designing a differentiation scheme, take into account network effects: appraising the impact of differentiated tolls according to a simple incentive-response mechanism measured on a single aggregated demand curve can be misleading.
- As a further specification of the previous item, if a differentiation scheme is applied with the “neutral” objective of internalising external costs, it should be applied extensively in order to avoid undesired effects. For instance, charging only more polluting trucks only on motorway can give rise to more traffic on ordinary roads and therefore larger environmental damages.
- Consider that a differentiation scheme may require a different model of road management. For instance, using road charging differentiations for improve the level of service of a network may require a network concessionaire rather than a motorway concessionaire.
- Consider that a differentiation scheme does not necessarily give rise to social benefits in terms of saved travel time or reduced emissions and therefore constraints on the use of the revenues could be needed.



1 INTRODUCTION

1.1 AIM OF THE DELIVERABLE

Within the DIFFERENT project framework, the activities related to the analysis of the differentiation of road charges have been planned to look separately at the reaction of road hauliers (in WP8) and car drivers (in WP9).

This deliverable synthesises the analysis related to the differentiation of **interurban** road pricing for both freight and passengers, as carried out in Tasks 8.1 “Interurban pricing”, 8.4 “Interrelation freight and passengers” and 9.1 “Motorway charges”. This document is a combined D8.3 “Report on the Impacts of Charge Differentiation for HGV “ and D9.2 “Report on Motorway Toll Differentiation to Combat Time Space Congestion”, which were foreseen as two separate deliverables in the two parallel workpackages 8 and 9.

The main objectives of the Deliverable 8.3 - 9.2 are:

- to review at European level the implementation of the pricing legislative framework for heavy good vehicles and further developments to differentiate charges for infrastructure use;
- to show main evidences from recent experiences of distance-based charges for heavy good vehicles;
- to improve understanding of reactions of road hauliers to road charge differentiation;
- to present evidences from recent experiences of motorway toll differentiation;
- to present results of transport models test of impacts of charges differentiation for both freight and passenger traffic.

1.2 THEORETICAL BACKGROUND

The theoretical framework of road pricing differentiation for both freight and passenger has been already illustrated in Deliverables D2.1 “Current status of differentiated charges for transport infrastructure use” and D3.1 “First survey on economic theory”. This paragraph resumes the main concepts referred to interurban road pricing schemes.

Economic theory provides a contribution along two main lines, moving from the normative approach (how transport charges should be in order to ensure welfare maximisation) towards the positive approach (how transport charges actually are in order to take account of several constraints).

The normative approach describes how price differentiation is affected by policy objectives, resource cost structures, as well as demand aspects, while the positive approach further elaborates on the existing constraints to the Social Marginal Costs Pricing (SMCP) application and the impact of policy makers and interest groups on the differentiated price structure.

The main findings of the normative approach show that pricing schemes and their degree of variability are determined by the aims of the actors involved, cost structures, as well as general demand parameters:

- The objectives: the aims of the agents involved can range from the very general (e.g. economic efficiency which comes down to welfare maximisation) to the very case specific (e.g. profit maximisation)¹.
- The resource cost structures: A structural incompatibility between cost recovery objectives and marginal cost pricing was identified for the transport sector, as the presence of scale economies leads to deficits when prices are set equal to marginal social costs. The suggested solutions are

¹ The following objectives have been distinguished in D2.1: economic efficiency, profit maximisation, cost coverage, environmental sustainability, equity and macroeconomic development.



Ramsey pricing, where prices are differentiated according to the type of user, and multi-part tariffs, with differentiation based on cost drivers.

- General demand properties: demand side parameters play an important role when significant differences exist in price elasticities over consumer subgroups. In addition to congestion phenomena, the existence of barriers to competition can also induce differentiated pricing schemes.

Taking these different parameters together results in a first-best scheme that is typically highly differentiated along many behavioural dimensions. The rules of SMCP assume that all the complements, substitutes and inputs to the transportation service are also priced at marginal cost. However, pricing a service at marginal cost might not be optimal if at least one potential complement, substitute or input is not priced at its marginal cost. In addition, several theoretical demonstrations have shown, that the following conditions should be met, to validate the SMCP:

- markets should be competitive (firms act as price-takers);
- there must not be any public goods nor external effects;
- cost functions should show no increasing return to scale;
- there should not be any information asymmetry.

These situations that are called “first best” by economists, in reality are never met completely. Numerous constraints make it necessary to amend the simple SMCP rule, leading to the sub-optimality of SMCP implementations. In fact, the degree of differentiation may have an impact on the efficiency of the pricing scheme as well as on its acceptability. As the scheme becomes more and more complex, a significant decision-making cost is experienced by the user. Taking into account this decision cost leads to an optimal degree of differentiation that is lower than what a first-best outcome suggests. In addition, there may be many barriers that prevent operator or government from implementing its optimal or desired toll. The main constraints that ask for a diversion from the rule of pure and strict SMCP are briefly listed here (Verhoef, 2002):

- Technological and practical constraints: first-best pricing requires charges that vary continuously over time, place, route chosen, type of vehicle, driving style etc, which might be too sophisticated and not understood by drivers or impossible to implement under available charging technologies;
- Acceptability constraints; there may be too much resistance and uncertainty (e.g. about objective and necessity of the measure) that may make it preferable to start with a few small-scale demonstration projects;
- Institutional constraints; one example is where local or regional governments cannot affect some transport charges that are set by a higher level government;
- Legal constraints; ideal prices might not be possible on the basis of legal arguments (e.g. when taxes should be predictable);
- Financial constraints; for instance the prior definition of minimum or maximum tax revenue sums to be collected;
- Market interaction constraints; transport taxes will have many consequences for other markets, among the most important is the labour market;
- Political constraints: charges may become a political issue much more than an economic question.

Additional insight can be gained from adding the positive view of economic analysis to these normative considerations. By introducing the influence of special interest groups into the analysis further (political) constraints are added to pricing policies. The main purpose of adding these policy based constraints is to be able to design tariffs which are as little amenable to political manipulation by interest groups as possible. It may be the case, for instance, under certain political circumstances that a uniform tariff (e.g. for a road) may lead to higher expected economic welfare than a highly differentiated tariff because the uniform tariff is less likely to be manipulated by politicians wanting to favour certain user groups (e.g. local residents vs. long distance travellers).



The Positive Approach

The positive approach focuses on the political constraints and describes the impact of policy makers and interest groups on the differentiated price structure. Special Interest Groups (SIGs) are interfering in the political field in order to gain as many advantages as possible for their members. Theoretical contributions in this field focus on the provision of information and campaign contributions. Past research indicates that for the transport sector, SIGs will certainly interfere in the political process in favour of their members. Their main concern is to achieve a certain degree of regulation, which guarantees the skimming of rents. This means that most of the SIG's activities are concentrated on imposing regulation and hence a certain price level. Laffont's contribution to the modelling literature indicates that when a pricing policy is already implemented the activities of the SIGs will centre not only on the tariff level, but also on the tariff structure, that is on the type of differentiation.

A policy-maker maximizes his personal utility but at the same time she/he takes into account also normative elements such as consumer surplus or more general welfare. SIGs will try to influence the political process and so to implement a policy according to their own preferences. SIGs favour of course regulation, but they will also try to affect the price level and/or the price structure.

The increasing number of well informed citizens, however, induces policy makers to be very careful. A transport policy in favour of one (or even more) interest group would be clearly recognizable by majority of the citizens. This would induce first also other SIGs with contrary policy preferences to become active in the transport sector and second well informed citizens are strategic voters (Kopp, 2006) and therefore they would penalize policy-makers at next elections. This makes politicians on the one side very careful. On the other side SIGs have a very difficult job in their effort to affect transport policies. They have to find more subtle ways to enhance the welfare of their members.

It is obvious that the previous mentioned theoretical aspects will have various consequences for the charges and the type of differentiation. A wide variety of dimensions can be identified for charge differentiation, ranging from optimal pricing which is highly differentiated (equal to marginal social costs) to a fixed charge. In reality different charging regimes are existing in transport that are somewhere in between those two extremes, as will be shown in case studies on existing schemes, that will be developed throughout this deliverable.

1.3 BEHAVIOURAL ASPECTS

Reactions of road hauliers and car drivers to the differentiation of interurban pricing schemes have been explored in Deliverable D4.1 "Interim results of behavioural analysis and framework" and are here briefly synthesised.

Responses to transport pricing for freight and passenger sectors are not straightforward and reactions to different pricing schemes can widely vary. The possible outcomes (in terms of behavioural responses) of pricing can be the following:

- trip suppression (travel frequency choice);
- departure time choice (and scheduling of daily activities);
- different route choice;
- changes in modal split;
- changes in vehicle occupancy;
- spatial choices related to relocation;
- change in driving style (e.g. speed choice);
- vehicle ownership;
- technology choice;
- changes in destination choice;
- class choice (for public transport).



The response of infrastructure users will to a considerable extent depend on the exact design of the pricing scheme (e.g. a yearly tax on car ownership can be expected to affect kilometrage of a given vehicle relatively weakly, compared to a kilometre charge). Equally important, however, is the price sensitivity (often expressed as elasticities by economists) of transport users for the various relevant types of user reactions that together define transport behaviour.

Ubbels (2006) reviewed empirical literature on the effectiveness of pricing measures and finds the following important factors affecting price sensitivity of travel behaviour

- *type of price change*: the different types of pricing measures can have different impacts on travel behaviour. Parking charges and road tolls may affect travel routes and destinations. A time-variable fee probably shifts some trips to other times; fuel price increases tend to affect the type of vehicles purchased more than vehicle mileage.
- *type of trip and traveller*: commuting and business travel is less sensitive to changes in fuel prices than travel for other purposes; in addition, travellers with higher incomes tend to be less price sensitive than lower-income travellers;
- *quality and price of alternative routes, modes, and destinations*: price sensitivity tends to increase if alternative routes, modes and destinations are of good quality and affordable; road users tend to be more price sensitive if there is a parallel untolled roadway;
- *time period*: there is a significant difference between short-term and long-term price elasticities, as these tend to increase over time, as consumers have more opportunities to take prices into effect when making long-term decisions; it may take many years for the full effect of a price change to be felt.

Elasticities can provide indicative and useful answers to the questions about the effectiveness of policy measures. However, policy makers must realise that *the* elasticity of some measure does not exist. Elasticities of travel demand for both cases of freight and passengers will vary with circumstances and very much depend on the contexts. Relevant contexts include the geographical scale of the study, the short-term or long-term, the existing price levels and alternatives and the composition of the population, as well as the types of change in travel times and costs (e.g. small or big change, increase or decrease, and gradual or drastic change). This makes it difficult to compare and interpret different elasticities. Moreover, elasticity cannot sufficiently describe which cognitive or motivational processes are behind quantitative changes of consumer behaviour. Therefore it is important to include psychological aspects, as they are necessary to understand and predict user reactions towards differentiated pricing and thus to manage demand.

The analysis of theoretical knowledge has identified many potential psychological determinants of user reaction, which can depend on:

- *Cognitive determinants of price evaluation*: the perception and the knowledge of prices play an important role for user reaction. Whether people can understand a pricing system and its communication depends on their prior knowledge and experience with principles of differentiated charging in various domains of life. Furthermore there is always the question on psychological costs of behavioural adaptation. If the differentiation becomes too extensive for individuals to understand, people tend to base their behaviour on a simplified mental model of the price structure, thus use heuristics. Processing a large amount of information is also restricted by people's limited attention and mental capacity to process information.
- *Motivational Factors*: even if a differentiated charging system is designed in a way that people would be able to understand it, they may not be willing to do so. Therefore, apart from the cognitive aspects, a central motivational factor that might influence user reaction toward differentiated pricing is acceptability. Several factors have been identified, which contribute to the acceptability of transport pricing measures (e.g. personal goals, problem perception, perceived effectiveness, perceived fairness, etc.).
- *Personal and situational factors*: inter-individual differences in the ability and willingness of people to deal with extensive information are due in part to cognitive abilities and motivation, but there are also some personal and situational factors that have to be taken into account when analysing



consumer reaction to differentiated prices. Therefore users' age, gender, education and income have to be considered when analysing consumer reaction on differentiated prices.

Most of research and evidence concerning psychological aspects is related to car drivers and road pricing sector. There is however very little material in the psychological literature on the behavioural responses of logistics and freight operators. Throughout this deliverable, behavioural aspects will be considered as part of the analysis on potential effects of more differentiated road charging schemes. In particular, they will be taken into account in chapter 3, where reactions of hauliers to further Heavy Good Vehicles charge differentiation will be shown.

1.4 CONTENT OF THE DOCUMENT

This deliverable illustrates the work done for a better understanding of users reaction to motorways toll differentiation through case studies based on data from existing schemes (Germany, Switzerland, US, France), data from the road haulage surveys and modelling exercises of the Brenner TEN-T corridor and the Padana Region.

Chapter 2 will synthetically provide an overview of existing charging criteria for road transport across Europe (EU 27 + Switzerland), distinguishing between freight and passenger. For Heavy Good Vehicles, the Eurovignette Directive legislative framework and its potentialities are described.

Chapter 3, dedicated to freight transport, includes evidences from ex-post analysis of recent experiences of distance based charges on HGV in Switzerland and Germany (including the comparison between the two cases) as well as results of the surveys of Italian and Polish road hauliers to explore their reaction to further differentiation of charges (modal and route shift effects, impact on location decisions, effects on fleet: fleet renewal and emissions, etc.).

Chapter 4, dedicated to passenger transport, presents evidences from the French experience of motorway charges modulation according to time and the US High Occupancy Toll (HOT) lanes.

Chapter 5, on modelling freight and passengers differentiated tolls on motorways and inter-urban roads, describes the results of the huge number of scenarios tested in two modelling applications: the Brenner trans-Alpine corridor and the Padana Region.



2 THE LEGISLATIVE FRAMEWORK AND THE CURRENT STATUS OF DIFFERENTIATION

2.1 INTRODUCTION

The present chapter examines charge differentiation criteria currently in use for transport infrastructure.

The aim is threefold:

- to summarise the basic rules and the opportunities of the “Eurovignette” directive;
- to provide an overview of existing charging differentiation criteria across Europe, whose application is currently under way;
- to give insights about possible future developments in infrastructure charging practices.

The review covers roads transport, with a distinction, if possible, between freight and passenger, although only for freight transport there is a European Community framework, known as Eurovignette Directive. The geographical scope of the analysis covers EU Member States and Switzerland.

2.2 THE EUROVIGNETTE DIRECTIVE

At European level, rules for road infrastructure charges are specified in Directive 2006/38/EC, which amends the Eurovignette Directive 1999/62/EC. The revision of the Eurovignette Directive has been prepared during a two years negotiation process.

The previous Directive was updated with the twofold aim of creating a uniform platform for motorway tolling in the EU and giving further incentives to improve capacity use and environmental performance in the road transport sector. The Directive allows (but not obliges) Member States to levy user charges or tolls on the entire road network and sets the rules for price for vehicles on the TEN-T network; it has the objective to reduce obstacles to the free movement of goods and guarantee fair competition between road haulage operators.

It is useful to illustrate the main features of the directive making reference to the following relevant themes:

- network extension: the Directive applies to the whole of the trans-European network and not just to motorways, as was previously the case. Although not obliging to do so, the Directive also allows Member States to levy tolls and user charges on all other roads as well. For charges on other roads and other vehicles (cars and vans) only the general rules of the Treaty of the European Union apply (the principles of non-discrimination and proportionality);
- vehicle involved: the Directive applies to vehicles over 3.5 tonnes; Member States are thus free to implement charging schemes for all such vehicles, or alternatively may choose to continue existing schemes or introduce new ones for vehicles over 12 tonnes, but only until 2012;
- “polluter pays” principle: a fairer system of charging for use of the road infrastructure is provided for on the basis of “user pays” principle. Member States will be able to charge different tolls depending of 1) day of the week and time of day, and even to vary fees on the basis of 2) EURO emission classes or PM/NO_x emissions as of 2010. The maximum variation between the highest and lowest fees is 100% for each of these two factors, and the variations can be added;
- “regulatory charges”: the Directive allows Member States to levy additional so-called “regulatory charges” that are specifically designed to combat time- and place-related congestion or environmental impacts, for example in urban areas. These charges can be levied on top of the “weighted average fee”, but the Directive does not define “time- and place-related congestion” or “environmental impacts”;
- “mark-ups”: “mark-ups” are a new instrument introduced in the amended Directive, allowing Member States to add 15% or 25% to the average toll on roads in mountainous areas, according to some conditions:



- the road section must be subject to acute congestion or the vehicle using these road sections must cause significant environmental damage;
- the revenues must be invested in priority projects of the TEN-T networks;
- the maximum level for mark-ups is 15% (25% in case of cross-border projects);
- discounts may be given to frequent users, but not exceeding 13% of the standard tolls.

The Directive lists the conditions to be met by Member States wishing to introduce and/or maintain tolls or introduce user charges. These conditions are as follows:

- tolls and user charges may not discriminate, directly or indirectly, on the grounds of nationality of the haulier, the country or place of establishment of the haulier or of registration of the vehicle, or the origin or destination of the transport operator, not resulting in distortions of competition between operators. Fees should be transparent and proportionate to the objective pursued, and their collection should not involve excessive formalities or create barriers at internal borders;
- revenues from tolls or user charges must be used for the maintenance of the infrastructure concerned and for the transport sector as a whole, in the interest of the balanced and sustainable development of transport networks. The Directive recommends that the revenues should be used to benefit the transport sector and optimise the entire transport system (not just for roads). As recommendations are not legally binding, Member States may also use the revenues for non-transport purposes. Tolls will still be based on the principle of recovery of infrastructure costs although environmental considerations will also play a key role in determining the rate charged. The revenues of user charges or tolls may not exceed the infrastructure costs, but the Directive specifies that the weighted average toll shall in principle not exceed construction costs and operating costs, maintaining and developing the infrastructure network concerned. The weighted average toll may also include a return on capital or profit margin based on market conditions. In the absence of a Community framework for tolled motorway concessions, the notion of weighted average tolls is quite a broad umbrella for the variety of approaches used in different Member States to determine tolls;
- Member States have to ensure that systems are properly implemented; to achieve this, they may take all necessary measures and establish penalties which are effective, proportionate and dissuasive.

With regard to the internalisation of the external costs, the Directive states that: “No later than 10 June 2008, the Commission shall present, after examining all options including environment, noise, congestion and health-related costs, a generally applicable, transparent and comprehensible model for the assessment of all external costs to serve as the basis for future calculations of infrastructure charges”. Moreover, it adds that: “This model shall be accompanied by an impact analysis of the internalisation of external costs for all modes of transport and a strategy for a stepwise implementation of the model for all modes of transport”.

In the second half of the year 2007, the Directorate General for Transport launched a public consultation on the proposed approach to internalisation of external costs. Besides the public consultation, the Commission has commissioned the IMPACT study (IMPACT, 2008) aiming at reviewing and modelling the existing estimates of external costs in Europe and has carried out an impact assessment of the internalisation of external costs for all modes of transport, with a view to prepare an European strategy on this matter by June 2008. The Commission is entitled to produce a Proposal to the European Parliament and the Council for a further revision of the Eurovignette Directive, as common framework on which the charge levels for internalising could be based.

2.3 THE STATUS OF IMPLEMENTATION IN EU MEMBER STATES AND IN SWITZERLAND

In recent years, a number of countries have implemented road charges for heavy vehicles, which have been differentiated according to environmental performance. These countries include Switzerland, Austria and Germany; lately, the Czech Republic is also working on plans for freight road pricing system.



In these States there is a distance-based road pricing scheme that imposes fees based on the number of miles or kilometres covered in a designated area in an attempt to discourage the use of vehicles². These pricing systems have had different positive effects, for example, in regard to fleet composition, with reduction of empty trips, and a larger use of more specialised and less polluting vehicles.

In some cases, for example, in Austria and in Germany, parts of secondary roads network have seen a substantial increase in the number of heavy vehicles following the introduction of the pricing system. In order to tackle diversion into parallel roads, heavy vehicle fees have been introduced in some secondary roads in Austria and in Germany.

Switzerland is the only country that has implemented a heavy goods vehicle fee on all roads; this pricing scheme is generally considered as a success due to:

- the application of “polluter pays” principle;
- the emissions-dependent charging schemes;
- the extension in the whole road network;
- the use of revenues for all transport modes.

The Swiss system has the highest km-charge in Europe and covers all roads in the country. Nevertheless, according to the World Economic Forum³, Switzerland is ranked best in the world in terms of overall infrastructure quality and railway infrastructure development, which contribute to the overall competitiveness rating.

In France, Spain, Greece, Italy Portugal and Slovenia⁴ parts of the motorways network have been operated by the private sector for several decades. These operators have right to levy tolls for use of their motorways. Toll levels are generally part of the contract between the national authorities and the motorways operator. The toll level covers operating costs, including a surplus as a profit. The toll level scheme covers all types of vehicle, according the type of vehicle (motorcycle, cars and light and heavy goods vehicles), without any differentiation according to emission class.

In other states there is a different situation:

- Belgium, Denmark, Luxembourg, the Netherlands and Sweden have operated a vignette system since 1 January 1995. The vignette fees apply to the motorway network, and certain national roads for vehicles over 12 tonnes. The fee is time-based⁵ and works on a pre-paid basis. Differentiation is on the basis of the environmental performance of the vehicle (EURO class) and number of axles and is in the form of a fixed annual fee;
- New Member State apply some kind of user charging on their motorway networks: Bulgaria and Romania operate time-based vignette systems for the use of all inter-urban roads. In Hungary, Lithuania and Slovakia vignette stickers are compulsory on certain motorway sections, while in Poland a toll is charged on a few sections.

2 Distance-Based pricing: is defined as a pricing scheme based on the kilometres driven on a limited network of interrelated roads (TIS.pt, 2001). This scheme can be distinguished in two types:

- Limited network: the system applies to part of the road network in the country (countries with motorway concessionaires, Austria, Germany and Czech Republic, that are progressively extending the toll scheme to a number of selected secondary roads);
- Nation-wide network: the system applies to the whole network in the country, including secondary and local roads (Switzerland).

3 ASFINAG 2005 : The Austrian Toll System, September 2005

4 Slovenia system of charges for motorway use was introduced in 1973, while Electronic Toll Collection started in 1995.

5 Time-Based pricing: is defined as being a charge (vignette) which is levied for permission to drive within a certain area and within a certain time period and which is differentiated according to vehicle classes (TIS.pt, 2001).



REPORT ON MOTORWAY TOLL DIFFERENTIATION

Several countries do not presently have any charging systems for road infrastructure, but some of these ones are currently examining the introduction of pricing schemes: for example, Ireland has three tolled motorway links according to vehicle class; and the UK has a charging schemes according to vehicle class on the M6 and certain infrastructures sections (for example, tunnels and bridges).

The following tables report the situation in Member States and Switzerland, according to the pricing approaches currently chosen by EU member states.

Table 2-1 Countries with Distance-Based Systems

Country	Scheme	Objectives	Tolled Vehicles	Tolled Network	Differentiation	Average Fee Level for 40 Tonnes €/km	Use of Revenues
Austria ⁶	Distance-based system since January 2004	Financing of road infrastructure	> 3.5 tonnes	All motorways and a few express ways	<ul style="list-style-type: none"> • Axles • Additional differentiations for type of road (mountain areas) and time (Brenner motorway day/night) 	0.227 - 0.269	Road construction and maintenance; 58% for underground construction
Czech Republic	Distance-based system since January 2007	<ul style="list-style-type: none"> • Optimise the transport system • Invest in other transport modes • Protect environment 	> 3.5 tonnes	All state-managed motorways and express ways	<ul style="list-style-type: none"> • Axles • Emission class 	0.14	Regions for transport projects
Germany	Distance-based system since January 2005	<ul style="list-style-type: none"> • Transport infrastructure financing • Apply "user pays" principle 	> 12 tonnes	Motorways and 3 national highways	<ul style="list-style-type: none"> • Axles • Emission class 	0.135	Transport infrastructure: 50% to motorways, 38% to railways, 12% to waterways
Switzerland	Distance-based system since January 2001	<ul style="list-style-type: none"> • Limit growth of lorry traffic • External cost coverage • Increase rail share 	> 3.5 tonnes	All roads within the country	<ul style="list-style-type: none"> • Maximum laden weight • Emission class 	0.57 – 0.74	2/3 to an intermodal fund, 1/3 to the regions for infrastructure projects

6 In addition, Austria introduced a time-related vignette schemes for light vehicles under 3.5 tonnes:

- on highways and motorways, motorcycle and vehicles below 3.5 tonnes have to pay a vignette that amounts to 29€ for motorcycles and 73€ annually for cars;
- on a number of particularly expensive roads (due to high investment and maintenance costs) with many bridges and tunnels, motorcycles and cars have to pay special toll. For example, on the Brenner pass, this toll is twice as high during night-time (47€) than during the day (23.5€).



Table 2-2 Countries with Motorways Concessionaires

Country	Scheme	Tolled vehicles	Tolled Network	Differentiation	Use of Revenues
France	Toll	All vehicles	Part of motorway network (approx. 8000 km; no tolls on urban motorways and some inter-urban motorways)	Vehicle class	Motorway operators; high-speed railways
Greece	Toll	All vehicles	<1000 km motorways	Vehicle class	Motorway operators
Italy	Toll	All vehicles	Part of motorway network (5600 km)	Vehicle class	Motorway operators
Portugal	Toll	All vehicles	Part of motorway network (1300 km)	Vehicle class	Motorway operators
Slovenia	Toll	All vehicles	Motorways and express roads	Weight Vehicle height Axles	Motorway construction, maintenance and loan repayment
Spain	Toll	All vehicles	Part of motorway network (2800 km)	Vehicle class	Motorway operators

Table 2-3 Countries with Time-Based Systems

Country	Scheme	Tolled Vehicles	Tolled Network	Differentiation	Use of Revenues
Belgium	User charge since January 1995	> 12 tonnes	Motorways	Axles Emission class	Regions for transport projects
Bulgaria	User charge since April 2004	All vehicles	All roads, except urban and ring roads	3 categories: bus, truck, light vehicle	Road infrastructure fund
Denmark	User charge since January 1995	> 12 tonnes	Motorways	Axles Emission class	None
Hungary	User charge since January 2000	All vehicles	70% of motorway network (670 km)	Weight	Motorways
Lithuania	User charge	Good vehicles, buses, agricultural vehicles	Highways and national roads	Weight/length	Road construction and maintenance
Luxembourg	User charge since January 1995	> 12 tonnes	Motorways	Axles Emission class	None
Netherlands	User charge since January 1995	> 12 tonnes	Motorways	Axles Emission class	None
Poland	User charge since 2002	> 3,5 tonnes (+ motorway toll for all motorised vehicles)	Motorways and national roads	Weight Axles Emission class	Motorways and national roads
Romania	User charge	All vehicles	All roads, except urban	Axles Weight Emission class	Road infrastructure fund
Slovakia	User charge	All vehicles	Motorways and first class roads	Weight	Motorways
Sweden	User charge since January 1995	> 12 tonnes	Motorways	Axles Emission class	None



Table 2-4 Countries without Charging Systems

Country	Scheme	Tolled Vehicles	Tolled Network	Differentiation
Cyprus	None	-	-	-
Estonia	None	-	-	-
Finland	None	-	-	-
Ireland	None (except for 3 motorway links)	(But all vehicles on 3 tolled motorway)	(But 3 motorways link)	(But vehicle class on tolled links)
Latvia	None	-	-	-
Malta	None	-	-	-
United Kingdom	None (But 42 km tolled on M6)	(But all vehicles on tolled motorways)	(But 42 km motorways)	(But vehicle class on tolled motorways)

2.4 FUTURE DEVELOPMENTS IN ROAD PRICING SYSTEMS

The Eurovignette Directive is important not only for transport and economy, but it has also high environmental relevance.

It defines the framework within which Member States can help make goods transport more environmentally compatible by using road user charges to:

- increase economic transport efficiency,
- bring cost charging in line with the “polluter-pays” and “user-pays” principles,
- finance a more environmentally compatible transport infrastructure,
- improve the use of more environmental friendly transport modes.

Member States have the freedom to choose between distance-based tolls and time-based charges. Of these options, only a distance-based toll is both fair to users and at the same time creates incentive to use heavy vehicle more efficiently and thus reduce negative impacts. Cost charging in keeping with the “polluter pays” and the “user pays” principles is much better achieved through distance-based scheme. When the implementation of a distance-based system is technically too complex for some Member States, vignettes should only be an interim solution.

Potentially, the Directive is an important environmental steering instrument, since it determines the scope within Member States can influence the environmental impacts of road freight transport by designing a road toll for trucks, particularly its scope of application and the level and structure of toll rates.

The ongoing discussions over the reduction of CO₂ emissions and over compliance with the limit values for pollutants highlight the environmental importance of the Eurovignette Directive, but it would have to provide the possibility to extend the toll scheme to recover not only infrastructure costs but also external environmental costs. For example, the Directive could limit chargeable external costs as a percentage of the costs of infrastructure use which would increase over time.

As a new instrument, the Directive introduces the possibilities of levying additional mark-ups in sensitive mountain areas: it would have a very important application in some link in the Alpine or Pyrenees regions or in other mountain areas in Europe.

The following table shows the main changes that are expected in road pricing systems in Member States, according as these ones are planned or their future opportunities.



Table 2-5 Planned Measures and Future Possibilities in Member States which have Implemented Pricing Systems

Country	Planned Measures	Future Opportunities
Austria	<ul style="list-style-type: none"> • The federal government passed a resolution on “greening” the road toll system for heavy vehicles in the Council of Ministers on 17 September 2007 • Discussion on inclusion of parallel roads, but there are no immediate plans 	<ul style="list-style-type: none"> • Extension to the entire road network • Differentiation by emission class • Regulatory charges in congested areas • Mark-ups for alpine regions • Revenues used for non-transport projects
Belgium	<ul style="list-style-type: none"> • Plans for introduction of a vignette for vehicles under 12 tonnes • Debate on the introduction of “Maut” system implementation on the Flanders region and recently also in the Walloon one⁸ 	<ul style="list-style-type: none"> • Regulatory charges in congested areas • Shift to distance-based fees for vehicles over 3.5 tonnes on all roads
Bulgaria	<ul style="list-style-type: none"> • No plans 	<ul style="list-style-type: none"> • Distance-based system on all roads • Use of revenues for all transport modes • Regulatory charges in congested areas
Czech Republic	<ul style="list-style-type: none"> • Plans are planned about use of revenues from toll on minor roads by the regions to improve the quality of road network • By 2009-2010 tolls for vehicles over 3.5 tonnes on other roads • Extension to light vehicles within 2020 	<ul style="list-style-type: none"> • Regulatory charges in polluted areas • Use of revenues for other investments or in alternative transport modes, in public transport projects or for remediation of pollution
Denmark	<ul style="list-style-type: none"> • No plans 	<ul style="list-style-type: none"> • Regulatory charges in congested areas • Shift to distance-based system for vehicles over 3.5 tonnes on all roads
France	<ul style="list-style-type: none"> • Proposal by several associations to introduce road charging in Alsace due to volume of HGV traffic diverted due to Germany tolls • Discussion about implementation of the Eurovignette Directive 	<ul style="list-style-type: none"> • Pricing system on all roads with differentiation by emission class • Mark-ups in mountain areas • Regulatory charges in congested or polluted areas • Revenues used for transport projects
Germany	<ul style="list-style-type: none"> • Possible inclusion of more parallel roads • Possible introduction of pricing differentiated according to day-time or place in order to face congestion on road links⁹ 	<ul style="list-style-type: none"> • Extension to the entire network • Tolls for vehicles under 12 tonnes • Regulatory charges in polluted or congested areas • Revenues used for not-transport projects

7 The new rules are to enter into force no later than in 2010. With effect on 1 January 2010, toll rates will be differentiated according to EURO emission categories. The vehicles are grouped into EURO categories based on their emission levels. The EU made the introduction of charging categories in 2010 a binding requirement: in Austria the go-ahead has been given for restructuring the road charging system even before that. Different road tolls based on emission classes can be enacted by decree already in the next two years. Furthermore, it will become possible to establish charges varying according to the time of the day (EurActiv, 2007).

8 In December 2007 the Flanders region decided to cooperate with the Netherlands in order to implement a km charging system like the German Maut. The application of this system on motorways and probably on other roads, including also passenger transport, is under discussion. The Brussels region joined the Flanders region position. The Walloon region, that until the beginning of 2008 showed the preference for the implementation of the vignette sticker, joined in March 2008 the “Maut” group. So Belgium both with Netherlands, and probably also Luxemburg, seems to start the negotiation for a common system, like the German one, to be implemented in 2012.

9 In the Master-plan for freight transport and logistic the German Federal Ministry of Transport stresses how the constantly increasing freight traffic bring to an increasing number of road links, which are always more often



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Greece	<ul style="list-style-type: none"> • No plans 	<ul style="list-style-type: none"> • Pricing system on all roads with differentiation by emission class • Mark-ups on sensitive areas • Regulatory charges in polluted or congested areas
Hungary	<ul style="list-style-type: none"> • Possible introduction of distance-related system • Future extension to light vehicles by 2020. 	<ul style="list-style-type: none"> • Differentiation by emission class • Regulatory charges in polluted or congested areas
Italy	<ul style="list-style-type: none"> • No plans • Introduction of distance-based charges under debate 	<ul style="list-style-type: none"> • Pricing system on all roads with differentiation by emission class • Regulatory charges in congested or polluted areas • Mark-ups on alpine regions • Revenues used for transport projects
Lithuania	<ul style="list-style-type: none"> • No plans 	<ul style="list-style-type: none"> • Tolls for all vehicles on all roads • Differentiation by emission class
Luxembourg	<ul style="list-style-type: none"> • No plans 	<ul style="list-style-type: none"> • Shift to distance-based charges for vehicles over 3.5 tonnes on all roads • Regulatory charges in congested areas
Netherlands	<ul style="list-style-type: none"> • Plans under discussion for possible introduction in 2012 of distance-based system (for all vehicle on all roads) 	<ul style="list-style-type: none"> • Regulatory charges in congested areas • Use of revenues for other transport
Poland	<ul style="list-style-type: none"> • Possible introduction of user charges on all national roads in 2009 or 2015 	<ul style="list-style-type: none"> • Tolls for all vehicles on all roads • Differentiation by emission class
Portugal	<ul style="list-style-type: none"> • No plans 	<ul style="list-style-type: none"> • Pricing system on all roads with differentiation by emission class • Regulatory charges in polluted or congested areas • Revenues used for transport projects
Romania	<ul style="list-style-type: none"> • No plans 	<ul style="list-style-type: none"> • Shift to distance-based system on all roads • Regulatory charges in congested areas
Slovakia	<ul style="list-style-type: none"> • By 2009 distance-based system for vehicles over 3.5 tonnes (all vehicles from 2011) on highways and first class roads 	<ul style="list-style-type: none"> • Mark-ups for mountain areas • Regulatory charges in polluted areas
Slovenia	<ul style="list-style-type: none"> • Plans to introduce distance-based system to all vehicles on all roads are under discussion, but no plans have yet been finalised 	<ul style="list-style-type: none"> • Mark-ups for mountain areas • Regulatory charges in polluted areas
Spain	<ul style="list-style-type: none"> • No plans 	<ul style="list-style-type: none"> • Mark-ups for mountain areas • Regulatory charges in congested or polluted areas • Pricing system on all roads with differentiation by emission class • Revenues used for transport projects
Sweden	<ul style="list-style-type: none"> • Plans about distance-based charge are under discussion, not yet finalised 	<ul style="list-style-type: none"> • Shift to distance-based charges for vehicles over 3.5 tonnes on all roads • Regulatory charges in congested areas

Table 2-6 shows future possibilities in States without charging schemes, in particular in Finland, in Ireland and in the United Kingdom, due to these States are currently examining the possibility of introducing road pricing schemes.

stacked with traffic. The introduction of a road pricing with different tolls according to day-time or place should have an effect of traffic control and it would decrease the congestion on road links. Moreover the road pricing system as designed by the Ministry should be determined according driving time and emissions classes of the vehicle.



Table 2-6 Planned Measures and Future Opportunities in Member States without Charging Systems

Country	Planned measures	Future opportunities
Finland	<ul style="list-style-type: none">• No concrete plans to introduce road user charging, but a preliminary study has been undertaken in 2006 on road charging for heavy and light vehicles	<ul style="list-style-type: none">• Possible introduction of distance-based fee to all vehicle over 3.5 tonnes on all roads• Differentiation by emission class
Ireland	<ul style="list-style-type: none">• The Irish National Roads Authority is considering construction of new toll roads under public-private partnership	<ul style="list-style-type: none">• Introduction of tolls for all vehicles on all roads• Differentiation by emission class
United Kingdom	<ul style="list-style-type: none">• There are ongoing discussions of a national distance-based system for all vehicles. Provisional implementation date is 2015	<ul style="list-style-type: none">• Regulatory tolls for congested and polluted areas in secondary roads• Differentiation by emission class



3 ROAD FREIGHT TRANSPORT

3.1 INTRODUCTION

This chapter illustrates two case studies on the real implementation of differentiated road charges structures: Switzerland and Germany.

The Swiss case study examines the reactions to one of the limited number of distance-dependent and differentiated charging regimes in force in the transport sector. It deals with the responses of the haulage companies to the Heavy Vehicle Fee (HVF), introduced in Switzerland in the year 2001.

The first evidences on user reactions to the German Heavy Vehicle Fee (in place since the year 2005) are analysed on the basis of a survey carried out by TUD as well as on a study made by the Federal Agency for Freight Transport (BAG).

The chapter includes also the results of a survey to a restricted number of road freight operators carried out in Italy and Poland.

The detailed description of both cases studies and the survey is contained in deliverable D8.2.

3.2 THE SWISS HEAVY VEHICLE FEE

3.2.1 Description of the Swiss Heavy Vehicle Fee

The calculation of the Heavy Vehicle Fee (HVF) is based on the following three criteria:

- The number of kilometres driven on all public roads in Switzerland.
- The gross total weight (GTW) according to the registration documents of the vehicle.
- The emission category of the vehicle

It follows that the rate in Swiss Francs (CHF) per kilometre driven in Switzerland (vkm) is differentiated according to two characteristics:

- The vehicle weight: there is a proportional differentiation of the rate, i.e. the rate of a 20 t HGV is half of the one for a 40 t HGV.
- The emission technology with regard to air pollutants exhausted: the fees for the different types of trucks are within a spread of +/- 15% from a weighted average fee level¹⁰.

The adopted approach is the results of a political agreement between the European Commission and the Swiss Government. In addition, there is no differentiation according, for example, to the infrastructure that is used (motorway or other road) or to the time of travelling (peak or off-peak).

Table 3-1 shows that the HVF rate increased over time in co-ordination with the increase from 28 to 34 tonnes in 2001 and to 40 tonnes in 2005 of the permissible gross total weight (GTW) of heavy vehicles using the Swiss road network. The rate level is not the only feature of the HVF that is adjusted over time. The same applies to the way the more or less environmentally harmful HGV are attributed to the three vehicle categories (classes 1 – 3) as shown in Figure 3-1.

¹⁰ Weighted means here that the shares of vehicle kilometres per emission category are taken into account.



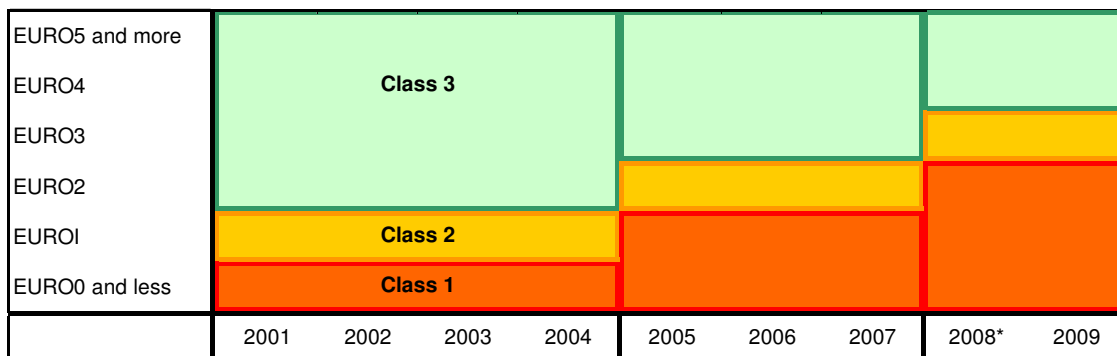
Table 3-1 Rates of the HVF Over Time, in Rp. / t_{GTW}km

Vehicle Categories	Old regime (FHVF) From 1984 to 2000	New regime (HVF)		
		1. stage 2001 – 2004	2 nd stage	
			2005 - 2007	2008 -
Class 1	Flat rate (fixed annual charge)	2.00	2.88	3.16*
Class 2		1.68	2.52	2.89*
Class 3		1.42	2.15	2.63*
Max. total weight of HGV	28 t	34 t	40t	40t

* = The final rates will have to be settled between Switzerland and the EU. In Mai 2007, the negotiations were ongoing. The Bilateral Agreement on Land Transport only fixes the average rate of 2.75 Rp. as well as the spread of +/-15% for the differentiation between the categories of vehicles.

Rp. = Cents of a Swiss Franc (1 CHF = approx. 0.61 € in May 2007)

t_{GTW}= Gross total weight of the vehicle according to the registration documents



* = The final allocation of the different EURO standards to the three classes that was eventually agreed between Switzerland and the EU is slightly different as Switzerland had to accept that EURO3 vehicles remain one more year (i.e. the year 2008) in the cheapest class (i.e. in class 3)

Figure 3-1 Allocation of the Different EURO Standards to the HVF Classes over Time

3.2.2 Basic Incentives of the Differentiation of the HFV and Research Interest

Because of its distance-related design, the HVF sets a general incentive to realise logistic improvements in order to reduce the mileage performed in road goods transports. The focus here is not on this general incentive, but rather on the ones set by the way the HVF is differentiated, i.e. according to the vehicle weight and emission standard. The two kinds of differentiation affect the decisions of road transport hauliers in three respects:

- a. Purchase decisions, i.e. decisions concerning the purchase of new vehicles: what type of vehicle is bought?
- b. Investment decisions, i.e. decisions concerning the fleet renewal: what is the cost minimising point in time to renew the vehicle fleet?
- c. Usage decisions, i.e. decisions concerning the use of vehicles: what is the cost minimising way to use the different types of vehicles?

Differentiation According to the Weight of the Vehicle

Road haulage companies have a business interest to purchase vehicles that fit the best the types of transports the vehicles are used for. If, for example, a HGV is needed for transports of light and voluminous goods, a cost minimising haulage company will buy a vehicle with a high transport volume and only a low total weight, given the cost differences in favour of lighter vehicles compared to heavier



ones. As the HVF to be paid per vehicle-kilometre raises proportionally with the gross total weight of the HGV, the HVF sets an *additional* incentive to adjust the vehicle to the transport characteristics. The HVF enforces the pressure to pursue a cost minimising behaviour, as the potential cost savings of an improved strategy are greater with than without the HVF. Against this background, the research question in the following box has been derived.

Research questions with regard to the weight differentiation of the HVF: Can we observe an impact of the HVF weight differentiation on the behaviour of haulage companies in the sense that there are intensified efforts to adjust the gross total weight of the vehicles to the types of transport the vehicles are used for? These intensified efforts refer to:

- a. purchase decisions;
- b. investment decisions;
- c. vehicle usage decisions.

Differentiation According to the Emission Standard of the Vehicle

The HVF sets an incentive for the haulage companies to take into account the emission standards when they buy new vehicles. An example can illustrate the cost differences caused by the HVF differentiation. Let us assume that a 34t truck should be bought in 2005 and then be used until 2009, with an annual mileage within Switzerland of 100'000 vkm per year. The haulage company can chose between a EURO2 and EURO4 truck. The following table shows the differences in the annual and in the total HVF to be paid by the haulage company. As can be expected from the high level of the HVF, the HVF savings per year (last column in the table) are substantial.

Table 3-2 Differences in the Annual HVF Charge for HGV with Different EURO Standards, in CHF

Year	Mileage vkm/a	HVF rates / vkm (34t HGV)		Annual HVF charge in CHF		
		EURO2	EURO4	EURO2	EURO4	Difference
2005	100'000	85.68	73.1	85'680	73'100	12'580
2006	100'000	85.68	73.1	85'680	73'100	12'580
2007	100'000	85.68	73.1	85'680	73'100	12'580
2008	100'000	107.44	89.42	107'440	89'420	18'020
2009	100'000	107.44	89.42	107'440	89'420	18'020
Total	500'000			471'920	398'140	73'780

In the example, we assume that there is a decision situation "EURO2 or EURO4 truck". This is not necessarily the case, due to two reasons¹¹:

- Regulations: There may be regulations that prescribe the purchase of certain technologies.
- Availability of technology on the market: It may well be that the different technologies (EURO2 and EURO4 in the example) are not both available on the market in a specific point in time.

The research questions with regard to this second type of differentiation of the HVF are summarised in the following box.

Research questions with regard to the emission standard differentiation of the HVF: Can we observe an impact of the HVF EURO standard differentiation on the behaviour of haulage companies in the sense that the charge savings achievable with less polluting vehicles are systematically and rationally taken into account? These charge saving behaviours refer to:

- a. purchase decisions;
- b. investment decisions;
- c. vehicle usage decisions.

¹¹ These reasons are discussed in detail in deliverable D8.3.



3.2.3 Research Methodology

The research was articulated in two steps: firstly, a descriptive statistical analysis and, secondly, a direct survey among transport haulage sector representatives.

Descriptive Statistical Analysis

Data from different sources were evaluated to come to a first assessment of the impacts of the HVF differentiation. There was no econometric or modelling work to identify the impacts of the HVF differentiation on the behaviour of transport haulage companies. Relevant data and data sources of the statistical analysis were:

- Sales figures for new vehicles and data of new registrations (reflecting investment and purchase decisions),
- Data on the vehicle stock (reflecting investment and purchase decisions),
- Data on vehicle's mileage (reflecting vehicle usage decisions).

Interview Programme

In early 2007, an interview programme with representatives of the transport sector was carried out based on a comprehensive questionnaire and on the statistical evidence mentioned above. The different modes of the transport sector were covered as follows by the interview programme:

- Shipping companies: 2 representatives
- Haulage companies: 4 representatives (large and small companies, bulk goods and mixed cargo)
- Companies of branches with a high transport intensity (high share of transport costs on total production costs like for example construction, retail): 4 representatives
- Rail transport: 1 representative
- Road transport associations: 2 representatives

The interview programme was complemented with direct contacts with representatives of four truck dealers (Volvo, Scania, MAN and Mercedes).

3.2.4 Main Results of the Analysis

Impacts of the Weight Differentiation of the HVF

The analysis gives strong evidence that the weight differentiation of the HVF did influence the behaviour of the haulage companies with respect to investment and purchase decisions as well as to decisions on the use of vehicles:

- Adjustment of the characteristics of the vehicle fleet to specific transport needs: The HVF supported the trend to heavier vehicles, although the main reason for this trend was not the HVF itself, but rather the increase of the permissible total weight in parallel with the introduction of the HVF. As could be expected, this trend was more marked in the case of vehicles used for long-distance transport, where the specific transport volumes are – on average – larger than in short-distance transport.
- There have been additional efforts to use vehicles that more closely correspond to the specific transport needs (i.e. more specified vehicles, no usage of heavy vehicles for light volume transports). This reaction to the incentives set by the HVF was easier for large haulage companies, because they have more and better options to optimise their logistic chain (number of vehicles, know how in route planning, re-financing possibilities, etc.).
- There was a switch to vehicles with a gross total weight of less than 3.5t because these vehicles do not pay the HVF. Haulage companies completed their vehicle fleet with light goods vehicles in order to save HVF payments. However, the interviewees also stress that there was an over-



reaction because some companies were not completely aware of the potentially increasing operative costs connected with a switch from heavy vehicles to a larger number of light vehicles (e.g. higher salary costs because of an increased number of drivers).

Impacts of the Emission Standard Differentiation

The main impacts of the differentiation of the HVF according to the emission standards of the vehicles can be summarised as follows:

- Rather limited evidence of a strong effect of the HVF on accelerated fleet replacement was found. Often, dirtier vehicles are kept as reserve vehicles or used as vehicles for specific transport needs (e.g. crane vehicles) and therefore still appear in stock figures.
- The much larger effect can be seen in the use of vehicles: clearly, the share of less polluting vehicles on the annual mileage of all vehicles is higher than the share of these vehicles on the stock figures. The incentive of the HVF to improve logistics efficiency is here: haulage companies made efforts to use their cleanest trucks the most.
- The HVF differentiation influenced the purchase decisions: in those cases where the haulage companies did have a choice between HGV of different categories, the incentive of the HVF to buy cleaner HGV than demanded by regulations worked. A higher share of vehicles with the highest EURO-standard was found in Swiss vehicle registration figures compared to German figures, in addition to a higher share in the mileage of Swiss domestic vehicles compared to foreign vehicles.
- As the incentive is connected with the mileage performed, an earlier replacement of vehicles used in long-distance transport is expected. This effect has been already observed: Swiss domestic transport with a rather low annual mileage shows a higher use of older vehicles than long-distance transport.

3.2.5 Conclusions

From the analysis carried out in D8.3 and from the brief considerations summarised in the preceding sections, the following conclusions can be drawn:

- The road freight transport sector is characterised by strong competition. In such an environment, incentives set by differentiated charges have a large impact on the behaviour of the “target group”. Cost reducing measures must be exploited in order to preserve the own competitiveness. In the Swiss case, such cost reducing measures could be observed in purchase and investment decisions as well as in decisions concerning the use of vehicles. The impact on the latter, is probably the strongest effect of HVF differentiation.
- The HVF differentiation – as is the HVF itself – is a bigger challenge for small haulage companies than for large ones: while the latter have more reaction options to optimise their logistic chain (number of vehicles, know how in route planning, re-financing possibilities), the former face financing problems. Furthermore, in an environment of strong competition the haulage companies will not be able to fully pass the cost increase caused by new charging regimes to the shippers and small haulage companies will have more difficulties to compensate this development with productivity gains.
- The differentiation of charges challenges also the regulator, that could anticipate behaviour adjustments with right incentives, referring to the timing: an early announcement of the development of the charge differentiation over time would increase the effectiveness and efficiency of the differentiation because it improves the planning ability of the haulage companies.
- The high competition pressure leaves very little room for irrational behaviour. Only very little evidences were found in case study. Probably, the cost saving potential of switching to light goods vehicles (<3.5t) has been overestimated by many companies. One can conclude that psychological aspects discussed in deliverable 4.1 of the DIFFERENT project¹² do not play an important role for the reaction to road freight user charges. Beside the competition that penalises inefficient reaction patterns, the high professionalism in the transport sector is another reason.

¹² Hoffmann J. et al. (2006).



There is a very limited probability that price signals of differentiated charges are not understood. For road haulage companies, the Swiss HVF with its limited differentiation is certainly not a scheme with a too high complexity.

- In the theoretical work of DIFFERENT, the hypothesis is formulated that exemptions to pricing schedules have an adverse effect on the effectiveness of the price measure¹³. In the case of the Swiss HVF, the hypothesis is relevant with regard to the exemption of light goods vehicles (<3.5t) from the charging regime. There is a certain incentive to switch to such vehicles even if this strategy is not efficient from a purely internal cost point of view. It can be predicted that this switch to light goods vehicles would have been more marked if the borderline had been set at 12t like in the case of the German Maut.
- The Swiss case study illustrates the relevance of the interplay between a charging regime and the regulation framework in the same policy field. The regulations concerning the emission standards for new vehicles partly dominated the incentives set by the HVF differentiation. An integrated policy strategy should consider both fields of state intervention in a co-ordinated way.
- Because a differentiated charge leaves more flexibility for efficient adjustment than a regulation (e.g. fixed standards), one could argue that the charge differentiation in favour of less polluting vehicles should more clearly precede regulations than in the case of the Swiss HVF. If the allocation to the different HVF classes had been adjusted as soon as new technologies (cleaner trucks) appeared on the market, first movers would have been rewarded. The incentive to switch to cleaner vehicles would have been increased. One can doubt whether policy processes are flexible enough to react in such a fast way to market developments. For the Swiss HVF, this is certainly not the case as each adjustment of the allocation of the different emission standards to the three HVF classes must be negotiated with the European Commission in the frame of the Bilateral Agreement on Land Transport.
- In the case of the HVF, the differentiated charge rates were finally defined in a political process (+/- 15%). The differences between the environmental performance of the EURO standards do not correspond with this spread. One can conclude that the HVF emission differentiation is a step in the right direction. However, a differentiation that is more closely oriented at the environmental performance of the different vehicles would be more convincing from the point of view of effectiveness and efficiency (incl. environmental costs).
- Of course, the impact of charge differentiations does not only depend on the incentives set by the charge but also on other factors (e.g. cost differences, financing restrictions). This fact increases the inefficiency problem if the spread of the differentiation is not oriented at the ecological performance of the vehicles but set in political negotiations.
- First mover countries introducing differentiated user charges may affect neighbourhood countries. In international transport, the HVF differentiation sets an incentive to use the cleaner vehicles for trips through and into Switzerland and the older vehicles for trips into and through countries without a differentiated charging regime.

3.3 THE GERMAN HEAVY VEHICLE FEE

3.3.1 The Main Characteristics of the Scheme

The German HGV tolling system is the technically highest developed system in Europe. The system enables a free flow charging without any delay for the user. In addition, it offers the opportunity of provision of value added services like navigation systems etc.¹⁴. Furthermore, the system is extendable to other types of vehicle, to secondary road networks and to other European and non-European countries. It refers to a dual system, which contains both automatic log on option with an On Board Unit (OBU) and the manual log on option (via internet or special terminals). The automatic log on option is a combined application of the satellite based GPS and the GSM technology.

¹³ See Rietveld P. et al. (2006), p. 33.

¹⁴ This matter corresponds with the data protection problem. To appease data protectors the legislator specified in the toll act (§ 9 ABMG) that all data have to be deleted after the payment occurred.



The charging level of the German HGV Toll is based on a cost study made by IWW/Prognos (see Table 3-3). The calculation refers to a fully distributed cost methodology which's main elements were developed by DIW at the end of the 60's. However, due to the willingness of the German administration to support domestic hauliers the final toll level was lowered down initially to an average level of 12.40 Ct./km (cent/kilometre) and currently to an average charging level of 13.5 €/Km (see Table 3-4). In addition, the German HGV toll is differentiated according to emission classes and the number of axles. The German government also established a successive modification of the emission classes (see Table 3-5), based on the respective proposal made in the IWW/ Prognos study.

Table 3-3 Infrastructure Costs for the German Federal Motorways

Year	Total infrastructure Costs	Cost Share for HGV	Infrastructure Cost per Vehicle-Kilometre
2003	7.51 bill. €	3.40 bill. €	0.15 €/km
2005	8.30 bill. €	3.62 bill. €	0.15 €/km
2010	9.30 bill. €	4.13 bill. €	0.16 €/km

Source: IWW/Prognos, 2002.

Table 3-4 The German Toll Charging Level

Emission Class	Maximum 3 Axles	Minimum 4 Axles
A	9 Ct./km	10 Ct./km
B	11 Ct./km	12 Ct./km
C	13 Ct./km	14 Ct./km

Source: MauthV

Table 3-5 Time Based Modification of the Emission Classes

Emission Class	Until 30. September 2006	01 Oct. 2006 – 2009	From 01. Oct. 2009
A	EURO -4, -5, EEV (Enhanced Environmentally Friendly Vehicle)	EURO -5, EEV	EEV
B	EURO -2, -3	EURO -3, -4	EURO -5
C	EURO -0, -1	EURO -0, -1, -2	EURO -0, -1, -2, -3

Source: MauthV

3.3.2 Effects of the German Tolling System

The already mentioned German Federal Office for Freight Transport (BAG) has the responsibility of market observation. To that aim, BAG made yearly surveys on the effect of the German toll system. BAG interviewed 340 representatives of the transport industry. The recognizable effects can be classified as follows:

- General effects
- Effects on the load factor of the vehicles
- Effects on the composition of the fleet
- Deviations from the toll network
- Modal shifts

It must be noted that these effects are general ones, resulting from the toll existence per se. The price differentiation with respect to the number of axles and the emission classes is relatively small to have any significant impact (the most clearly recognisable effect resulting from price differentiation deals with new investments in enhanced environmental vehicle technology).



General Effects - Revenues

First of all, BAG states that the new system (apart from some expected initial difficulties) has been accepted by the industry. The most convincing evidence is the constantly increasing number of OBU's. Six months after the toll introduction there were around 450,000 OBU's installed. Until April 2006 installed OBU's exceeded the number of 500,000. According to Transport Ministry press release, at the end of the year 2007 there are 517,000 OBU's installed.

Toll revenues met the government's expectations. According to the latest data published by the German Ministry¹⁵, the trend of toll revenues is as follows:

- 2nd midyear 2006: 1.5 billion €
- 1st midyear 2007: 1.6 billion €
- 2nd Midyear 2007: 1.7 billion €

In the first 8 months of the year 2007 (January to August), the charged traffic has reached the total figure of 18.26 billion veh-km, which is 8% more than the corresponding value for the year 2006 (16.95 Billion veh-km). 66% of the 2007 veh-km is domestic traffic, while the rest is considered as foreign traffic (the share of domestic traffic was a bit smaller - 62% - one year before). At the end of the year 2005, the net revenues from the heavy vehicle fee reached approximately 2.400 billion EUR and were earmarked as follows: 50% allocated to motorways, 38% to railways and 12% to waterways.

In its second survey one and a half years after the toll introduction, BAG recognised no significant differences between the tolls paid by the domestic and the foreigner hauliers. According to BAG calculations domestic hauliers paid in average 11.8 Ct./ kilometre whereas foreigner hauliers paid 11.9 Ct./ kilometre. However, this calculation regards tolls paid until the 30th of June 2006. As already mentioned, since the October 2006 the toll differentiation scheme underwent a restructuring, with Lorries of the EURO 2 category falling in the first (more expensive) class. Therefore, it is likely that this relation between domestic and foreign hauliers could change. For the future, the intention of the Federal Government to subsidize the purchase of environmentally friendly vehicles will definitely change the situation for the benefit of domestic hauliers.

Table 3-6 Trips Development After the Introduction of the German HGV Toll

Midyear	Number of Trips in Thousands		
	Domestic	Foreigners	Total
1st 2005	54,870	14,943	69,813
2nd 2005	59,361	14,828	74,189
1st 2006	60,780	16,068	76,848
Total	175,010	45,840	220,850

Source: BAG, 2006

Regarding the form of payment users can choose from a variety of methods: using a fuel card, with a credit account, participating in the so-called LogPay plan, for the users taking part in the automatic log on system and using a fuel card, with credit card, with EC card, cash for the unregistered users.

The fuel card and the LogPay methods have the advantage that the payment occurs once a month, which means the date of payment is usually delayed at an average of two weeks compared to the date of the trip. This advantage of the two modes of payment seems to be appreciated by the hauliers. Therefore, the LogPay and the fuel card are the most frequent used form of payment. Almost 90 percent of the total revenues have been paid with one of these two forms of payment.

Regarding the question on how the surveyed firms evaluated their financial situation after the toll introduction, the answers were predominantly negative, although not as bad as expected thanks to the

¹⁵ <http://www.bmvbs.de/Verkehr/Strasse-,1436/LKW-Maut.htm> (visited February 2008)



fact that, in almost all cases, hauliers pass the additional costs of the toll to their customers. Therefore, after the toll introduction on the one hand hauliers optimise their trips and on the other hand ask for higher prices, especially if they have to organise transports to those regions from where they expect to travel back empty (such as structurally underdeveloped regions).

Regarding the toll effects on the general price level, several studies show that these are negligible. Aberle (2006) states that end products inflated less than one percent due to the toll. Especially inflation of consumer goods is lying under 0.2 percent.

However, an example named by BAG within the survey shows a relevant impact of the toll on regional development: a firm from north Germany is at the moment examining the possibility to be relocated to central Germany, because the toll induced new cost structures, which have to be taken under consideration

Effects on the Vehicles Load Factor

One of the aims of the German HGV toll was a better utilisation of the existing fleet through the avoidance (or reduction) of empty trips. With respect to this effect, BAG also considered long run trends on the vehicle's load factor, observing that the ratio load kilometre to total kilometre increased within the ten years before 2004 at a yearly average increase of one percent reaching 79.2 percent in the year 2004 (BAG, 2005). According to the hauliers, the most important reason for that is the increasing cost, particularly the increasing gasoline prices. In other words cost pressures forced the hauliers to improve trips planning. This trend continued also in 2005 and the ratio load kilometre to total kilometre reached in 2005 the value of 80.3 percent. Until May 2006 the ratio increased to 80.8 percent (see BAG, 2006). The surveyed firms gave the HGV toll as well as the very high fuel costs, as the dominant reasons for that. This trend is confirmed also by other studies that show in 2007, the number of loaded runs reached 82.1% (East West TC, 2007).

Regarding the weight utilisation of the lorries there is no recognisable effect of the HGV toll. The long-run trend with diminishing weight utilisation continued also in the year 2005. The ratio of the weight of carried goods to the total supplied weight per trip continued to decrease to 58.2 percent, also after the introduction of the toll. Here it must be stated that, on the one hand, hauliers want to fill the lorries as much as possible and that, on the other hand, the structure of the transported goods shows the other direction. However, if this trend carries on, then it will be also a reason in the long run to use smaller lorries (under 12 t axle weight).

Effects on the Composition of the Fleet

The effects on the composition of the fleet include the effects of price differentiation as well as those of the motorway toll introduction.

Concerning the first type of effects, it has already been mentioned that the German tolling system features a price differentiation with respect to emission standards. The kilometres travelled according to the price differentiation since the introduction of the tolling system give a clear picture on what is happening in the market.

Table 3-7 shows clearly that over 95 percent of the total kilometres travelled has been made with lorries of the emission class Euro 2 or better. The long run trend to use environmentally friendly lorries has been intensified since the toll introduction. For the first midyear of 2006, the use of lorries of the class Euro 3 or better for domestic trips reached a share of 74.40 percent of the total use. Especially the use of vehicles of the EURO 3 emission class increased significantly and the use of the Euro 2 lorries decreased. One of the reasons for that seems to be the scheduled reordering of the differentiation classes effective from October 1st 2006 on. However, it is very likely that there are additional reasons affecting this development. In particular, the natural process of replacing older vehicles with newer ones of superior technology certainly plays a decisive role in the decrease of EURO 2 vehicles.

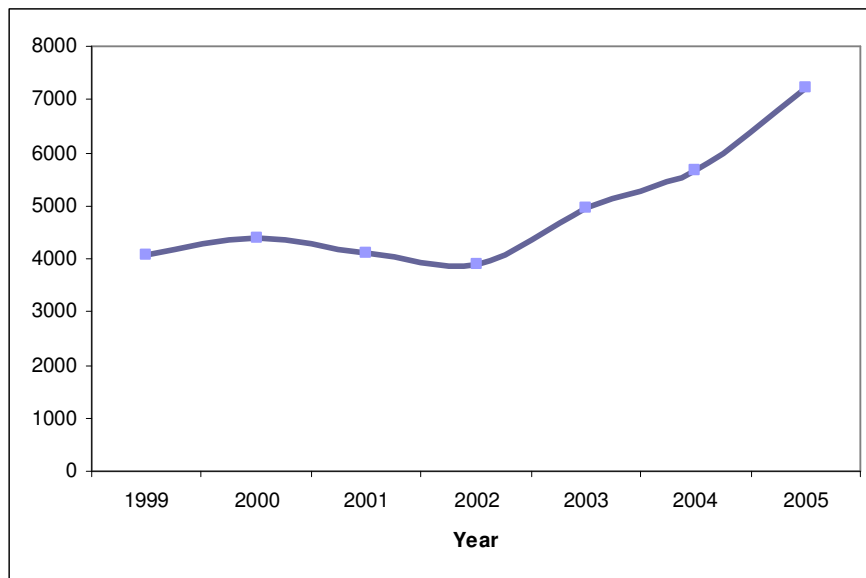


Table 3-7 Kilometres Travelled Share According to the Emission Classes

Emission Class		Kilometres Travelled		
		January – June 2005	July - December 2005	January - June 2006
		%	%	%
A	EEV	0.0	0.0	0.0
	Euro 5	0.2	1.3	3.9
	Euro 4	0.9	1.5	2.5
B	Euro 3	62.4	65.9	68.0
	Euro 2	32.8	28.1	23.2
C	Euro 1, Euro 0 etc.	3.7	3.1	2.4
Total		100.0	100.0	100.0

Source: BAG, 2006

Also the increase of vehicle use of the EURO 5 emission class is considerable and this trend is expected to continue and intensifies. The most important reasons for that are the new emission classes from October 2006, the intention of the Federal Government to subsidise environmental friendly vehicles as well as the government’s intention to spread the charges according to the emission classes more strongly¹⁶. Indeed, with respect to decisions on investments on new lorries, the hauliers showed less willingness to invest in new lorries of the Euro 4 class and instead were more in favour of Euro 5 vehicles, or in Euro 3 vehicles.



Source: BAG, 2006

Figure 3-2 New Registrations of Lorries between 10 and 12t for the Period 1999-2005

Regarding the second type of effects – i.e. those due to the tolls introduction, independently from their differentiation - it can be clearly seen that the number of new registered lorries between 10 and 12 tons has increased rapidly (Figure 3-2) since the decision to introduce the tolling system. This trend stabilised on a high level in the first six months of 2006. Compared to the first six months of 2005, the

¹⁶ There are thoughts expressed by the Ministry of Environment to propose a stronger spread of the charges in order to advance the use of environmentally friendly vehicles.



new registrations of the related vehicle category declined marginally at about 1.3 percent. The main reason given by the surveyed firms was that they couldn't pass the additional costs caused by the toll to their clients. This effect was mainly observable in close up range. As a result of this awareness, there are many politicians, experts as well as special interest groups who claim an extension of the charging system for all lorries over 3.5t.

Toll Avoidance

The relevance of road freight traffic deviations from the motorway network in order to avoid the charge are the subject of controversy within Germany. While until April 2005 the Federal Government stated there was no need to take any additional measures, a lot of municipalities complained about increased traffic in the secondary network. Finally, the Federal Government admitted the problem, which however, according to the government, is limited to certain regions/routes.

In the second quarter of 2005, the average traffic growth on secondary roads was 7.6% compared to 2004 and the main part of this increase was caused by the *LKW-Maut* (6.6%) (East West TC, 2007). Also in 2006, the Ministry of Environment reports an average increase of traffic in the secondary network at 7.6 % (about 57 lorries per day) whose 6.6% (49 lorries per day) due to the toll.¹⁷

The deviations effects of the German HGV toll were recognised in a study presented by IVV to the Federal Parliament (see Deutscher Bundestag Drucksache 16/298). According to these results, the toll avoidance problem is not extended to the whole motorway network but rather to certain routes. However, the authors pointed out that these results have a preliminary character. The reason is, that the data used are related to the first 3 months after the toll introduction and hence not enough representative. Thus, after consultations with the Federal States, the Federal Government decided primarily to extend the toll to 8 routes of the secondary network. After much discussion with the Commission, the German Federal Government announced the toll extension to three routes only of the road secondary network¹⁸ since 1st January 2007. In addition, the municipalities obtained the freedom to impose administrative measures such as detours or speed limits and, during summer 2006, a considerable number of municipalities imposed such measures. However, there are serious doubts as to whether such measures will show results (Wieland, 2005), as especially hauliers from the eastern neighbour counties are often willing to undertake longer deviations in order to avoid paying toll. Due to the unavailability of reliable data with respect to toll avoidance, Henninger performed several simulations applying two diverse models in two scenarios for the motorway network of Bavaria (Henninger, 2006): the VISUM software package multilearning procedure (Lohse, Schnabel 1997 and PTV 2004) and the TRIBUT model¹⁹. In both models, the value of time plays a decisive role, although they are procedurally different: the multilearning procedure uses a best route algorithm and simulates toll avoidance by taking into account the capacity constraints of the potential alternative routes. Besides, the Tribut model uses a multi-route algorithm and a stochastic value of time. Contingent upon the model and the scenario, Henninger found out that toll avoidance lies between 1.3 percent with respect to the total volume of traffic (long haul routes using the TRIBUT model) and 32.99 percent (local traffic using the multilearning procedure).

The two scenarios refer to different values of time for the long haul sector (71.00 € for scenario 1 and 34.59 € for scenario 2)²⁰. Table 3-8 depicts the main findings with the two different simulation methods. The positive algebraic sign suggests additional use of motorways. Private cars and vehicles under 12 t will therefore increase the use of motorways (mostly due to less congestion). As expected, results show that the higher the value of time, the less the toll avoidance phenomena. However, regardless of the level of value of time, both models result in toll avoidance.

17 The federal government assigned two studies concerning this topic, which due to forthcoming decisions are not available for the public. However there was a parliament hearing regarding that theme, in which the results of the studies have been presented. The provided data from the ministry of environment are based on that hearing.

18 The first route concerns B 75 (around Hamburg), between motorways A 7 and A 253, the second route has to do with B 4, a parallel route of motorway A 7, north of Hamburg and the third route (B 9) extends from the German – French border until motorway A 65 (Kandel).

19 The Tribut model is a special toll effect simulation model which was developed by INRETS.

20 Henninger used the following values of time: 24.27 € for private cars and vehicles under 12t, 29.65 € for the short haul, 30.08 € for regional routes and 71.00 (scenario 1) or 34.59 € (scenario 2) for long haul routes.



As a conclusion, the Henninger models findings, the IVV study and the fact that the government extended the toll in the three routes, combined with the municipalities' administrative measures, suggest that this problem exists de facto. Therefore, it is certain that this problem will be a matter of discussion also in the future.

Table 3-8 Traffic Shift Effects Due to the Toll

Traffic Segment	Toll Avoidance in Percentage			
	TRIBUT		VISUM Multi-Learning Procedure	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Private Cars	+ 1.29	+ 4.46	+ 5.72	+ 7.12
Vehicles under 12 t	+ 12.78	+ 16.55	+ 5.43	+ 4.33
Vehicles over 12 t				
Long haul	+ 67.19	- 1.34	- 13.64	- 21.09
Regional transport	- 24.99	- 21.38	- 29.39	- 27.80
Short haul	- 28.52	- 6.6	- 32.99	- 32.03

Source: Henninger, 2004

Modal Shifts

One of the aims of the German HGV toll was a modal shift in favour of the railways. During the first months of the introduction, the ministry of transport claimed that there had been considerable shifts from road to rail. However this was countered by the BAG study, whose results show that no considerable modal shifts have occurred. There have been increases within the intermodal transport, which can be seen as a result of the toll and are also expected to continue in the future. Rothengatter and Doll (2001) made a estimation on that point: an average charge of 20 ct/km as well as a surcharge of 5 Ct/km for vehicles over 18t would bring a modal shift of 3 percent. In a further scenario, they calculated that modal shifts of 15 percent correspond to a price level of 1.05 € per km combined with a 69 Ct per km charge for smaller vehicles²¹. This result has been later confirmed by Special Interest Groups (Allianz pro Schiene, SNCF, DB AG etc.) and was contrasted by the International Road Transport Union (IRU), which assigned TransCare to study shift effects of road charges for France, Germany and Switzerland, whose calculations suggest a modal shifts of 1.2 percent for an additional charge of 1.0 € per km. It must be noted that these studies are based on different assumptions in relation to cost elasticities and that direct elasticity estimation has been made since the toll introduction.

3.3.3 User Reactions to Higher Toll Levels

As already analysed in the subsections above, there are several charging levels up for discussion. In this subsection the German HGV-Toll reactions for higher charges are assessed on the basis of an ad-hoc survey performed by TUD (Fritzsche, 2007), whose results are also compared with those of the BAG study.

The survey sample of 853 logistic service operators was contacted by e-mail. The low rate of participation - only 61 logistic companies responded to the survey – implies that no statistically significant estimates can be derived. However, the survey gives an impression whether demand is elastic or not. Based on the current average charging level (12.4 Ct/ Km), four charging scenarios were considered:

²¹ The elasticity values used in this study, derived the German Institute for Economical Research (DIW, 1994), are in a range of -0.02 to -0.03.



- 15 Ct per km, as result of a fully distributed cost method for the German Motorways
- 20 Ct per km, levied by a mixed calculation for Motorways and secondary federal roads
- 70 Ct per km, chosen in order to have an intermediate point between 20 Ct per km and 1 € per km
- 1 € per Km, in order to result in substantial modal shifts in favour of railways.

Table 3-9 Load Factors for the Different Toll Scenarios

Charging Level	12.4 Ct/ Km	15 Ct/ Km	20 Ct / Km	70 Ct/ Km	1 €/ Km
Loaded Km to total Km ratio(%)	80.80	85.40	85.08	86.20	85.83
Carried weight to total supplied weight ratio (%)	58.20	61.20	63.06	63.82	64.93

Source: Fritsche, 2007

In order to guarantee the comparability, the presentation of the potential user reactions is the same of the BAG study. Taking the utilisation of the existing fleet into account, Table 3-9 clearly shows that there is less space for optimising unloaded trips: the ratio "load trips to total trips" can increase until the level of around 85 to 86 percent²². It must be said that the potential increase of load would take place also due to the competitive forces in the industry. As shown in the BAG report, such a development was already taking place before the introduction of the toll.

Turning to the utilisation of the lorries, the same table shows the potential reaction at increasing toll levels. Both results presented above suggest that there is less space for hauliers to cut costs due to a better utilisation of the existing fleet.

As toll avoidance is a sensible issue, hauliers were asked whether they consider the use of the secondary road network as a real option (Table 3-10) and results show that, as expected, the higher the toll, the higher the share of diverted traffic. The same table illustrates the answers in relation to the possibility to use lorries under 12 tons in order to avoid the toll payment and the result is consistent with the recent development of new registrations of trucks between 10 and 12 t described above. Further, at almost all charging levels, a nearly constant share of the sample (around 30%) saw a possible solution in the use of environmental friendly vehicles. However the quality of the responses was not sufficient enough in order to calculate concrete rates in percentage of trips.

The third information reported in Table 3-10 is related to the modal shifts in favour of railways. To that end, hauliers were asked if they would be willing to choose another transport mode, and to what extent in terms of transported tons. Data confirms the BAG findings and gives, as a first impression, that the structural advantages of HGV's still hold at also very high charging levels. As a result, it can be expected, that the demand on German motorways is rather inelastic²³.

22 The inconsistencies depicted in the table have two main reasons: I) at a charging level of 0.20 € per Km there are several operators which can not bear the additional (due to the toll) financial burden and ii) the charging scenario of 1.00 € per Km seems to be inconceivable for some of the firms surveyed;

23 Due to the small sample it was not possible to separate between short, medium and long haul.



Table 3-10 Reactions in Terms of Route Diversion, Trucks Size and Modal Share

Charging Level		12.4 Ct/ Km	15 Ct/ Km	20 Ct / Km	70 Ct/ Km	1 €/ Km
Route diversion of trips compared to the current situation (%)			2.02	2.50	8.80	9.96
Use of trucks under 12 Tons as percentage of total trips compared to the current situation			1.04	1.40	4.67	4.47
Change of modal shares in percentage (with respect to the transported tons)	HGV	98.00	97.55	97.03	95.91	95.05
	Railways	1.36	1.76	2.27	3.31	4.14
	Seaways	0.61	0.66	0.66	0.69	0.71
	Air	0.03	0.03	0.04	0.09	0.10

Source: Fritsche, 2007

Taking all mentioned effects into account, the calculation of arc elasticities with respect to the tons transported (Table 3-11) confirmed the low values expected, with small differences among the proposed charging levels and with some inconsistency, as demand seems to react inelastic the higher the arc considered. For this inconsistency there are several possible reasons:

- The responses to the survey (61 out of 853 questionnaires) are not enough in order to calculate statistically significant results.
- Strategic answers of the surveyed firms can play a substantial role to the results, especially when the sample is not big enough.
- The charging levels of 70 Ct/ Km and 1.00 €/ Km are in a way inconceivable for hauliers. Logistic firms do not believe that the charge could increase up to this (high) level.
- Due to the poor quality the answers some possible effects (e.g. the use of environmental friendly vehicles) could not be quantified.

Table 3-11 Arc Elasticities with Respect to the Tons Transported

Charging Level	12.4 – 15 Ct/ Km	12.4 - 20 Ct/ Km	12.4 - 70 Ct / Km	12.4 - 100 Ct/ Km
Arc elasticity	- 0.024	- 0.021	- 0.015	- 0.020

Source: Fritsche, 2007

Notwithstanding these inconsistencies, Table 3-11 shows a very inelastic demand, which seems to be closer to the Rothengatter/ Doll estimation than to other estimations. As a result we can conclude that HGV demand is a rather inelastic one.

3.3.4 Conclusions

The German HGV toll scheme is the first step in Germany in the direction of user infrastructure financing. It can be concluded that not all toll aims have been achieved. Revenues are raised according to plan. Environmental aims are only partly achieved, with a long-term trend of a decreasing number of empty trips and the increased use of environmentally friendly vehicles.

Other objectives such as modal shifts are not recognisable at all. In addition, there are phenomena of toll avoidance as well as user reactions in direction of using vehicles under 12t, effects that are higher the higher the charging level. As a consequence of such reactions, some politicians and lobbyists, but also scientists, call firstly for an extension of tolls to the secondary road network and secondly to extend toll to all vehicles over 3.5t.



Sporadically, there are also opinions to introduce a road charge for private cars in form of a vignette in order to drop a part of fuel taxes (whilst the Minister of Transport states that there is no existence of such a point) by presenting first calculations regarding the revenues. This is an opinion that was hardly conceivable to hear publicly only a couple of years ago. This fact supports the assumption that the German HGV toll is just the first step to rearrange the country's infrastructure financing scheme.

Taking into account the presented results as well as estimations in the literature, we can conclude that freight demand at the German motorway network reacts inelastic to price increases.

3.4 COMPARED ANALYSIS OF SWISS AND GERMAN CASE STUDIES

The comparative analysis of the Swiss and the German HGV charging schemes starts with similarities and differences of the two tariff structures:

- **Vehicle weight.** The Swiss structure provides a higher degree of differentiation according to the vehicle weight. In contrast the German charging structure is much simpler separating vehicles over 12 t (which have to pay a charge) and vehicles under 12 t (no charge).
- **Number of axles.** There is no differentiation according to the number of axles within the Swiss scheme. The German scheme differentiates vehicles in two categories according to the number of axles.
- **Emission standards.** Both systems are similarly differentiated according to emission standards. All vehicles are separated in three categories according to their EURO classification. This separation changed over time for both systems. However, this occurred in Germany faster than in Switzerland. The Swiss differentiation seems to follow the market development than to frame it. The spread between the classes is rather similar, approximately 15 percent of average class.
- **Type of network.** The Swiss scheme is applied for the whole Swiss network, whereas the German scheme is applied only for the Motorway network²⁴
- **Charging level.** The Swiss charge is about 5 times higher than the German charge for a 4 axles 40 t HGV. In general the charge in Switzerland is higher than in Germany the higher the vehicle weight.

Turning to the impact of both schemes, it has to be stated that a comparative analysis is limited to certain fields. The reason for this is the limited comparability of two case studies, as well as the differences in the charging structure mentioned above.

Competitive forces within the European industry drive all actors to respond to tolling systems in a rational economical way. This is also valid for differentiation elements. Hauliers react rationally in order to cut costs and offer their services at "market" prices. The long time decrease of empty trips, as well as the better utilisation of the existing fleet in Germany, are some of the evidences for this development. However, developments in the market are proved to be different, if we take into account different submarkets.

With respect to the higher degree of charges differentiation according to the vehicle weight, in contrast to the German charging structure²⁵, the Swiss case clearly shows that there are incentives to use heavier vehicles. This proposition is also confirmed by the market development.

Turning to the differentiation according to the emission classes, Figure 3-3 shows very well that the existing differences with respect to the division of the emission classes may have significant effects on the vehicles fleet.

For Switzerland, we see a clear domination of the EURO5 technology for vehicles bought and registered in 2006 though the hauliers could still buy EURO3 vehicles: 51.4 percent of the new

24 There are only three federal roads of the secondary network that are included in the tolling system.

25 The German tariff structure is simply separated between vehicles over 12 t (which have to pay a charge) and vehicles under 12 t (no charge).



vehicles belong to the emission category EURO5, and another 29 percent to EURO4. One fifth of the new vehicles only complies with the mandatory minimum standard EURO3.

The price and the operative costs of a EURO5 or a EURO4 vehicle are rather higher than for a standard EURO3 vehicle. Therefore, we can assume that the high shares of EURO5 and EURO4 vehicles are the results of the influence of the HVF. The hauliers anticipated the further development of the HVF, i.e. the differentiation between EURO3 (new HVF class 2) and EURO4/5 (HVF class 3) that Switzerland intends to introduce by 2008.

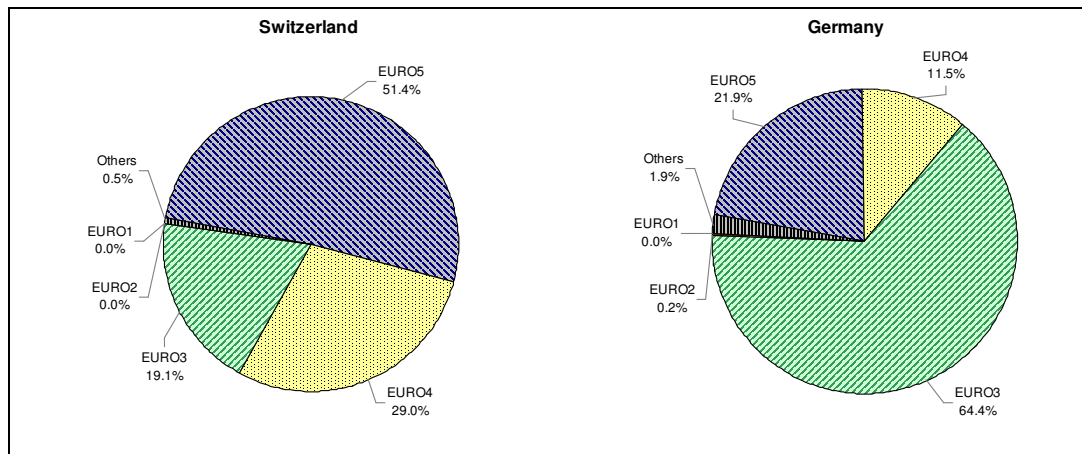


Figure 3-3 Registration of New Goods Vehicles of Different EURO Standards in Switzerland and in Germany, year 2006

The comparison with the corresponding figures from Germany supports this interpretation. In Germany, we find a much higher share of EURO3 and a clearly lower share of EURO5 vehicles on total sales and registration of new HGV. It can be assumed that a comparison with figures from other European countries would lead to an even larger difference “in favour” of Switzerland. In 2006, German motorways were tolled with a charge that also differentiated between vehicles of different emission standards. EURO4 – only until September 2006 – and EURO5 vehicles paid lower rates than EURO3 vehicles. As the German toll is only levied on motorways and is substantially lower in absolute terms, the incentive to switch to cleaner vehicles is obviously less strong than in the case of the Swiss HVF.

As already said, the reason for a low share of EURO4 in Germany could be the result of the same level of toll for EURO4 and EURO3 vehicles (after September 2006), added to the absence of savings in buying EURO4 vehicle instead of a EURO5. These tendencies are expected to strengthen if we take into account the intention of the German Government to subsidise the investment in vehicles of the EURO5 class. Exactly this is shown in the last developments of the accelerated use of EURO5 vehicles (with respect to vehicle kilometres).

Finally the differentiation in Germany between the motorways and the rest of the network, revealed some toll avoidance phenomena. This problem does not exist in Switzerland, due to the fact that the fee is subjected to the whole network.

Concluding from the comparison between the Swiss and the German scheme, it seems that fine differentiated tolling schemes according to the vehicle weight can provide the right incentives for vehicle use. In addition, the differentiation according to emission classes reveals, that it is important for regulators to anticipate market developments and react respectively, when defining the composition of the emission classes.



3.5 ROAD HAULAGE SURVEY ON TOLLS DIFFERENTIATION

3.5.1 Definition of the Objectives

The survey was focused especially on 'structural' and behavioural reactions to road freight tolls differentiation with the objective to collect qualitative responses on themes like:

- mode shift;
- renewing of the vehicle fleet (e.g. lighter vehicles, cleaner vehicles);
- different timing of deliveries (e.g. travelling overnight);
- restructuring of the hauliers sector (e.g. agreements between single hauliers for optimising loads and minimise empty trips);
- cognitive and motivational aspects of individual decision maker (e.g. perceived complexity and intelligibility of the pricing structure, acceptability and perceived fairness of differentiated transport charges).

The extension of the toll differentiation scheme - single corridor or whole network - was considered in the survey design process as well as the issue of how realistic/feasible is to use alternative routes, for instance to investigate if the application of differentiation of freight tolls on a given corridor (e.g. Brenner) can result in a significant shift of road freight transport on alternative corridors (e.g. Gotthard).

3.5.2 Survey Design and Administration

In order to obtain a comprehensive picture of the attitudes of transport suppliers towards road tolls differentiation, the sample included multimodal operators and third party logistic providers, which brought in a broader perspective on real alternatives to road freight transport in the shorter and in the longer term, as well as large and small companies and single hauliers (owner-driver), the latter being the ones with tight cost constraints. Unfortunately, it was extremely difficult to get feedback from the contacted single hauliers and this category is therefore under-represented in the final results.

The sample selection was made according to the objectives of obtaining qualitative responses from an operator's perspective and to investigate behavioural reactions to more than one element of differentiation (i.e. emission class, time of the day, etc.) and to two scenarios of scheme extension (single corridors vs entire motorway network). The following two-step interviewing methodology was therefore applied:

- A sample of operators contacted and interviewed by phone in Italy (TRT) and Poland (ILiM);
- A larger group of operators throughout Europe contacted by e-mail with an invitation to fill in a simplified electronic version of the questionnaire (on-line survey)²⁶.

The survey was conducted by direct telephone interviews with key area or general manager of some selected firms. Together with the official invitation to take part in the survey, a self-administered version of the questionnaire was submitted by e-mail both to assist phone meetings and give the option of self-compilation. On a total of 30 (20 to Italian operator and 10 to Polish Operators) relatively long and complex questionnaires sent, 17 questionnaires were returned, 9 from Polish operators and 8 from Italian operators.

A shorter questionnaire was designed for the implementation of the web survey. A wide-spectrum strategy was adopted for promoting the survey among operators from all over Europe during the period from October 2007 to January 2008:

- A broad list of operators was prepared in cooperation with the project's partners;

²⁶ <http://www.trtrasportieterritorio.it/quest-different/welcome.htm>



- An ad-hoc invitation was sent to road haulage representatives and industry associations, asking for promoting the survey and circulating the web link to their own members;
- A banner was posted on the TruckEurope.net website (which is part of TruckEurope, the European-wide industry magazine) and the survey invitation was also circulated through the magazine newsletter (webzine of 22.12.2007).

Despite these efforts, results were not satisfactory and only 3 questionnaire were filled on-line (1 from Sweden, 1 from Poland and 1 from Italy). Therefore, no additional qualitative evaluations have been used to complement those derived from the direct interviews.

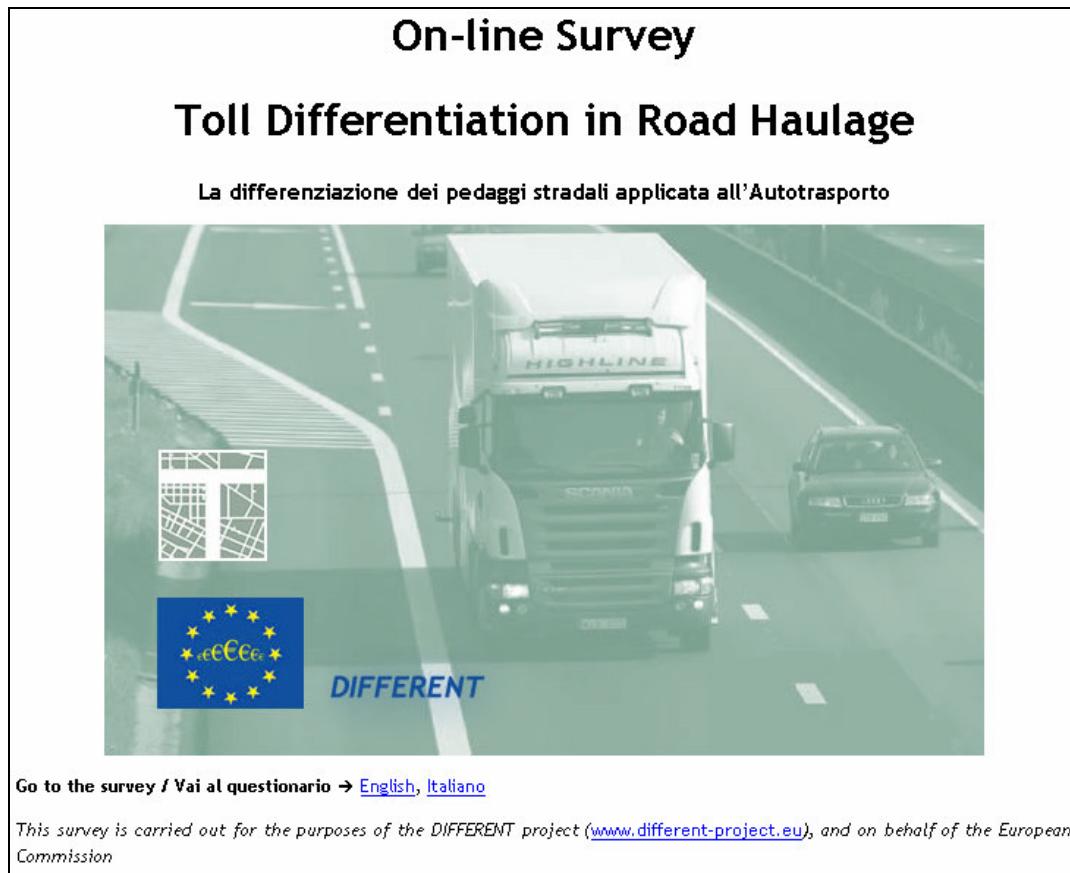


Figure 3-4 Overview of the Survey's Home Page

3.5.3 Operators' Reaction to Current Pricing Policies

Given that the answers of the interviewees show few differences (that are underlined where appropriate), results are analysed considering together Italian and Polish operators.

The analysis of road transport problem perception among operators leads to identify road congestion on non-motorway roads as the main issue, without significant differences among Italian and Polish operators; congestion on motorway is perceived as a less relevant problem. Poor quality of roads and/or poorly maintained roads are problems perceived mainly by Polish operators; on the contrary, road tolls and charges represent a major problem for Italian operators.



According to the answers, tolls' share of total vehicle operating costs is less than 10% for more than 80% of the operators, while for the remaining 20% the share is less than 15%²⁷. Operators' reactions to changes in toll structure and values vary significantly: in fact, on one side, about 20% of the operators do not consider tolls as a relevant variable, being tolls a small/insignificant part of their total production costs and, on the other side, about 35% of the operators react with new fares and surcharges. Moreover, about 50% of the operators continuously monitor road tolls and only 30% of the operators have an ex-post or periodical monitoring systems.

Operators' ability to internalise higher tolls vary significantly (Figure 3-5): in fact, on one side, about 40% of the operators introduces a toll surcharge on existing contracts and new rates for new contracts, whilst about 55% of the operators introduce new rates or in the long term or when contracts are renewed; only one operator does not internalise changes in tolls also in the long run. All the operators are able to evaluate or calculate toll expenditure in an absolutely precise way or with an approximation of less than then 10%.

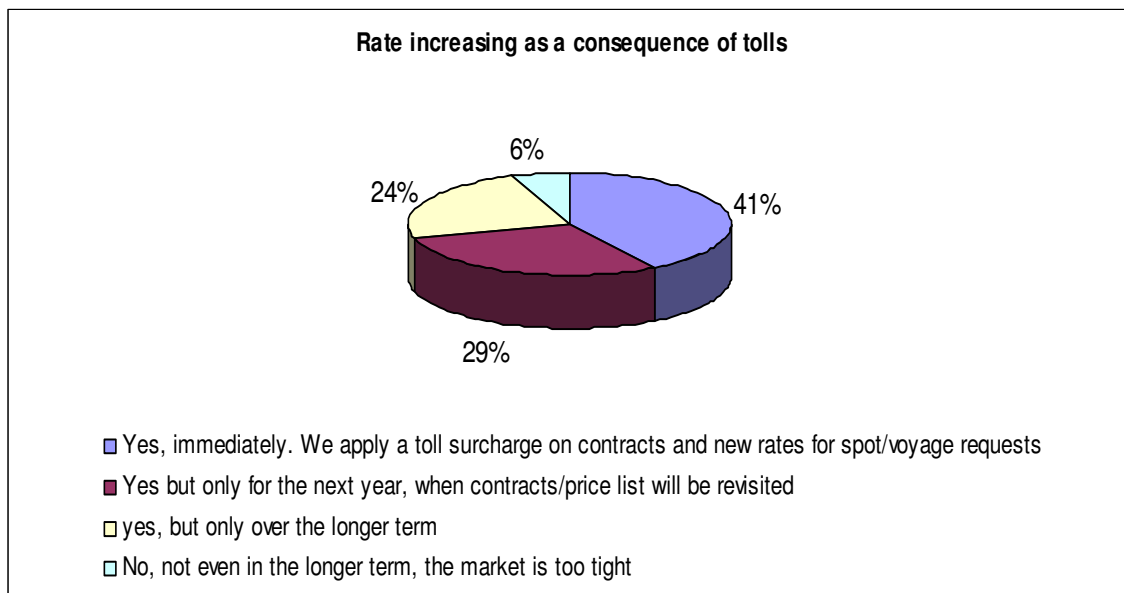


Figure 3-5 Operators' Ability in Increasing Fares to Internalise Higher Tolls

With reference to the TEN-T Brenner corridor (a specific case of the questionnaire), even though all operators were affected by the introduction of tolls on the Austrian section (A13), only 2 declared changes in their behaviour and their travel choice: both crossing between 5:00 and 22:00 to avoid night toll and through fleet renewal but only one also re-routing via parallel roads or using non accompanied/inter-modal rail services. In general the system is considered fair and acceptable, and few doubts on its effectiveness in financing maintenance of road infrastructures.

The second specific case was the German Maut systems and all the operators stated they did not change their behaviour and their travel choice after the introduction of the MAUT system. This system was also perceived as fair and acceptable, whereas some doubts on its effectiveness in financing road infrastructures maintenance were expressed.

3.5.4 Operators' Reaction to Future Road Toll Differentiation

Response to future toll differentiation on other corridors or networks is analysed starting from two different approaches, both *ex post* fruitful and effective. On one side, the first approach investigates the impact on hauliers' actions of different elements of toll differentiation (differentiation based on

²⁷ A higher weight of tolls on total operating costs seems not to be correlated with fleet dimension, even though the small sample is not a significant statistical base to point out a conclusion.



vehicle class, emissions, etc.); on the other side, the second approach describes and evaluates the magnitude of operators' responses in terms of possible actions in case of introduction of further road toll differentiation. It is important to preliminary note how operators' answers could have been influenced by their present experiences and knowledge of tolling systems, even though there are no explicit confirmations of this fact.

According to the first approach, response to future toll differentiation on other corridors or networks is analysed considering seven possible "areas of impacts":

- A Vehicle class (axles/weight)
- B Emissions (Euro standards)
- C Time of day/night (peak/off-peak hours)
- D Type of traffic (crossing/internal traffic)
- E Type of road (motorways/express/local roads)
- F Geographical (mountainous or sensitive areas)
- G Period of the year/day/week

The analysis considers two different scenarios: the former is the implementation of road toll differentiation on European corridors and the latter is the introduction of road toll differentiation on whole road networks²⁸.

The future extension of road toll differentiation has, in general, strong effects or some effects (Figure 3-6), even though in some cases operators believe it not to have any effect (this can be referred to Polish operators only). The introduction of toll differentiation on European corridors has strong effects on one side on vehicle emissions and, as it could be obvious, on routing, but on the other side also on the time of day in which trips are made. On the other side, the introduction of toll differentiation on the whole road network has strong effects only in terms of emissions and vehicle type (axis).

The introduction of future toll differentiation is largely acceptable (Figure 3-7) if imposed on an emissions or vehicle class basis, whilst it would be rather unacceptable if imposed on a period of the year/week/day basis. Results are similar considering Italian and Polish transport operators and considering the scenarios of imposition on European corridors only or on whole networks.

The introduction of future toll differentiation is considered absolutely fair or quite fair both on European corridors and whole road networks for the majority of the possible areas of impact (Figure 3-8). Once again, it is possible to see how the introduction of toll differentiation on emission or vehicle class basis is perceived as the fairest solution by freight transport operators. Italian and Polish operators provided similar answers.

28 One of the Italian operators provided answers only for the first scenario.

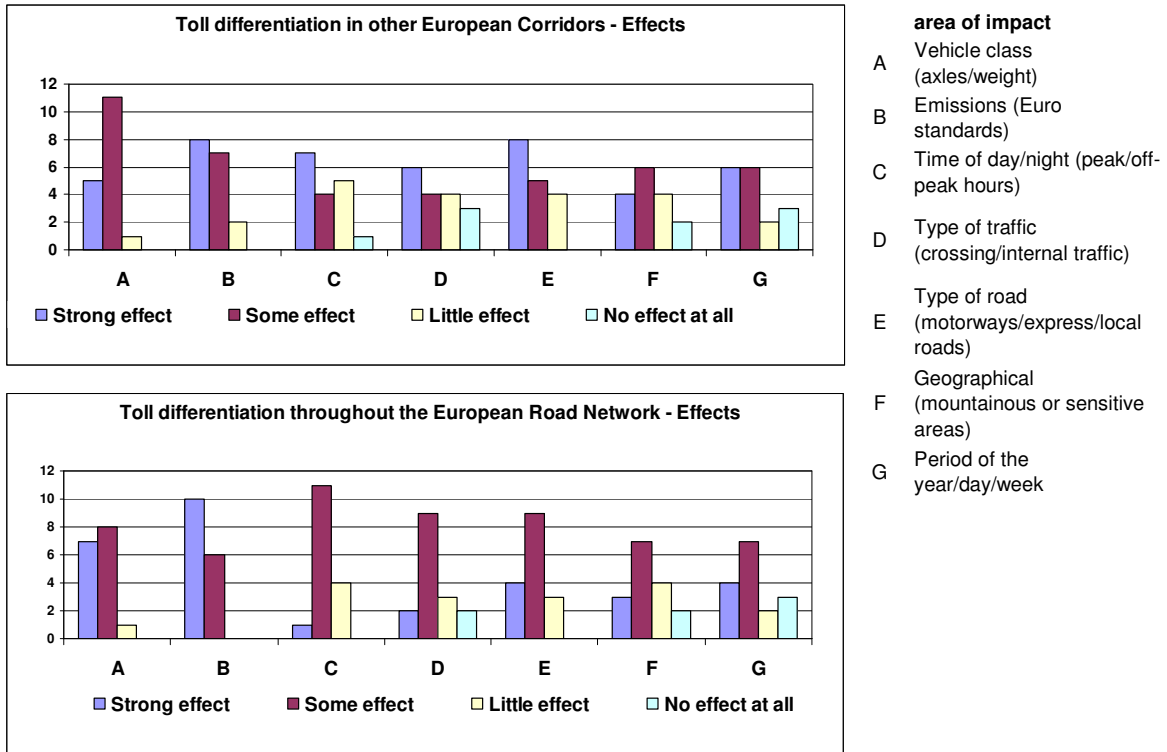


Figure 3-6 Effects of Extension of Toll Differentiation

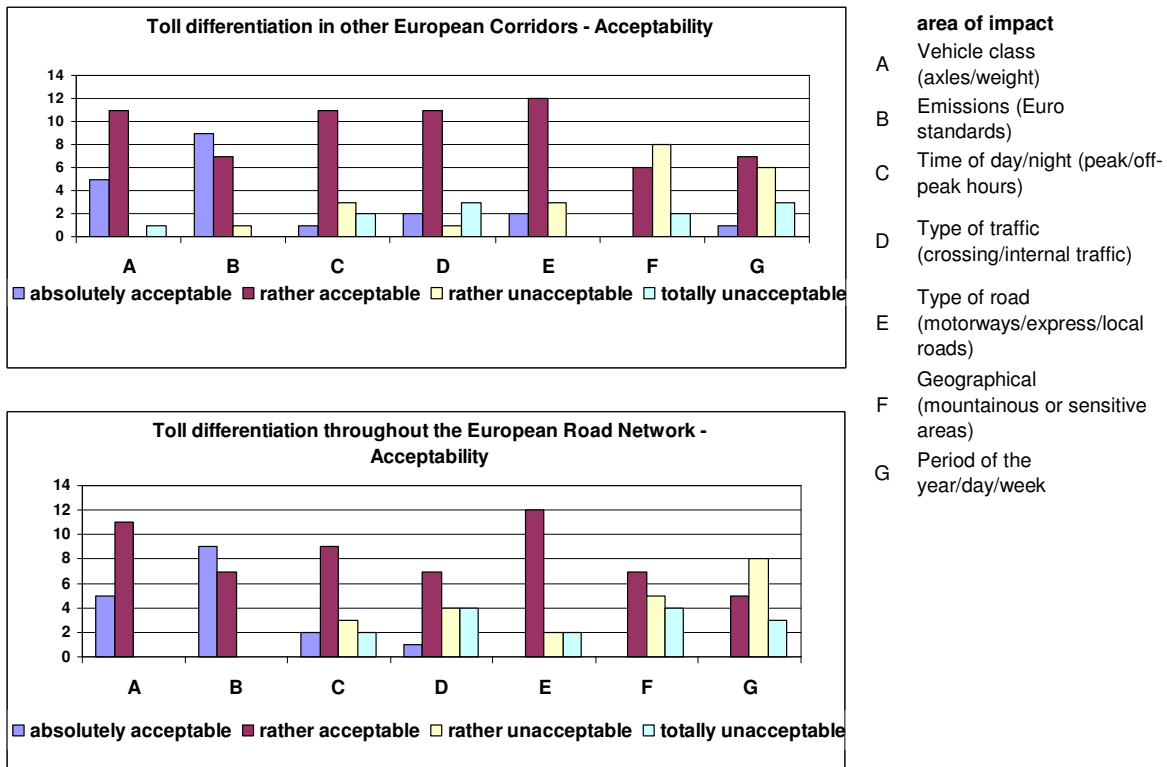


Figure 3-7 Acceptability of Extension of Toll Differentiation

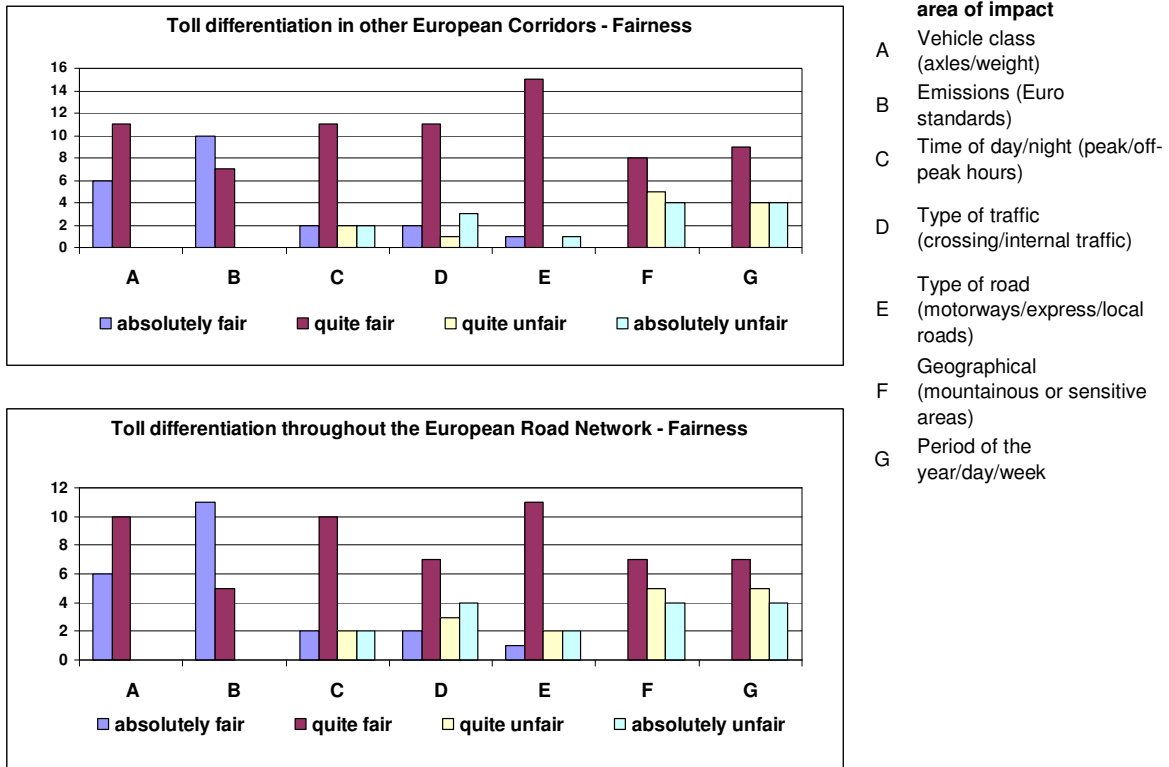


Figure 3-8 Fairness of Extension of Toll Differentiation

Under the second approach, a further indication on the effects of road toll differentiation can be derived analysing the likelihood of operators' behaviour with reference to some possible actions. As it is possible to observe, the introduction of road toll differentiation on other portions of the European network has no relevant effects in the short term, in particular in terms of re-routing to other motorways or to parallel roads; alliances or agreements with other transport operators is the preferred action, even though its magnitude is between likely and unlikely. Concerning, in particular, Italian operators, some possible effects in terms of fleet renewal can be identified, in particular if toll differentiation should be implemented on whole road network.

In the long term strong fleet renewal effects can be identified, whilst relatively small effects can be shown in terms of re-routing or changes in delivery times. Implementation of toll differentiation on whole road networks can lead to significant effects in terms of optimisation of loads.

If it is trivial that effects are stronger in the long term, more interesting is the fact that effects are bigger for Italian transport operators than for Polish transport operators. Moreover, if in the short terms the effects of the two toll differentiation scenarios are largely similar, on the contrary the scenario of toll differentiation on whole road networks has stronger effects.

3.5.5 Conclusion

Due to the difficulties in data collection, the survey results, even if interesting, do not lead to general conclusions. However, they can be summarised and suggest conclusions and policy indication as follows:

- Tolls are not considered by the operators a main problem in their activity compared to road congestion and road quality (maintenance); this is probably due to the fact that road tolls weight for less than 10% of the total production costs and more than 50% of the operators can respond to changes in toll structures and values varying tariffs or operational choices in the short term



(immediately) or without variations (21%). Moreover, to confirm this result, 70% of the operators is able to modify its tariffs in the short or medium (yearly revision) term. This result could be partially explained observing that the panel of interviewed operators (included the 3 respondents of the on-line survey) was composed by relatively large operators;

- The extension of toll differentiation on other corridors or on the whole road network could have relevant effects in terms of vehicle class and emissions changes (fleet renewal), which are also the actions that operators are willing to adopt (probably due to the fact that they are also required to renew fleets for other reasons, for instance operation costs). Toll differentiation based on type of road is considered largely acceptable and fair whilst, on the contrary, toll differentiation based on type of traffic is considered less acceptable and fair in case of toll schemes extended to whole networks. The relatively high acceptance of emission-based differentiation (B) could reflect the fact that the environmental aspect is not the only reason why vehicles with higher EURO standards are bought and used by transport operators. Haulage companies buy these vehicles because they are more energy efficient, and because in some cases they have to buy them due to regulations. The other environmentally motivated differentiation (F) is maybe rejected because it is considered as unfair that mountainous countries collect money from foreign users.
- Differentiation based on time of day/night could have positive effects both on corridors and whole networks; nevertheless, it would have some problems in terms of acceptability from transport operators as well as from population (even though local population was not involved in the survey). Major problems of acceptability are foreseen also in the case of differentiation by period of the year.
- The extension of toll differentiation to whole networks seems to be more effective than the introduction of the same policy on selected European corridors. Effects of further extensions of toll differentiation can be expected in the long term, with smaller or less relevant effects in the short term.



4 ROAD PASSENGER TRANSPORT

4.1 INTRODUCTION

This Chapter is based on desk work related to two case studies of real applications of differentiated charging on motorways. The first one is the case of France, where applications of toll charge modulation to spread returning weekend and returning holiday motorways traffic exist since 1992. United States HOT lines are the second case, which refers to High Occupancy Vehicle (HOV) lanes that allow charged access to Single Occupancy Vehicles (SOVs) according to dynamic schemes.

Although both systems are in place since many years, the quality and the amount of information about their impacts is not the same: while it was possible to gather a good deal of data for the U.S. schemes of the last two decades, very few data have been collected in the case of the French motorways.

4.2 THE FRENCH TOLL MODULATION SCHEMES

4.2.1 Description of the French Motorway System

The French motorway system is based upon the principle of concessions for building and operating. The relationship between the State which issues the concession and each of the companies is ruled by the concession agreement (covering 35 years in principle) and specifications enclosed to it. The State plans the operation in the national road master plan, selects the routes, determines the technical rules covering design and construction, harmonises the levels of service and the general operating conditions and controls the toll charges.

The concessionaire companies finance, build, maintain and operate the toll motorway network. A five year "Plan Contracts" drawn up between the State and each motorway concessionaire company fixes their obligations in terms of toll tariff evolution investments, financial ratio.

In France, there are currently thirteen tolled motorway operators; some are semi-public (such as AREA, ASF, ESCOTA, SANEF, SAPN, and SAPRR) and some is private (such as COFIROUTE), in addition to three public concessionaire companies operating international tunnels and motorways (ATMB, SFTRF and SMTPC)²⁹, with a total toll network length of 8395,2 Km³⁰. The operators are responsible for single bridges, tunnels or an entire motorway network in a particular region. The national «umbrella» organisation of motorway operators is ASFA (Association des Sociétés Françaises d'Autoroutes et d'ouvrages à péage). Parts of the motorway network are purely public roads, with no tolls. These motorways are located mainly in agglomerations, e.g. around Paris and in Alsace.

The main characteristics of the existing charging schemes are listed here below:

- Pricing principle: In France is applied a target-oriented motorway charging (second best charging scheme with multipart tariff with elements of marginal cost pricing³¹).
- Pricing instruments: All the motorway operators apply different tolls. These schemes cover all types of vehicles, i.e. motorcycles, cars and light and heavy goods vehicles. Additional charges are also levied for some bridges and tunnels, including the Fréjus and Mont Blanc tunnels (to Italy), and the Puymorens and Envalira (Andorra) tunnels in the Pyrenees.
- Tariff structure: The toll level covers operator costs, including a surplus as a profit. Although the tolls are distance-based, their level is not usually indicated per kilometre but in the form of a matrix

29 <http://www.asecap.com/english/mem-france-en.html> and ASFA

30 avec les ouvertures réalisées en 2007, 88,5 Km sur l'autoroute A85, entre Saint-Romain et Druye and 10,5 Km sur l'A51 entre Coynelle et le Col du Fau. Source: ASECAP and ASFA

31 Revenue Deliverable 3, 2005



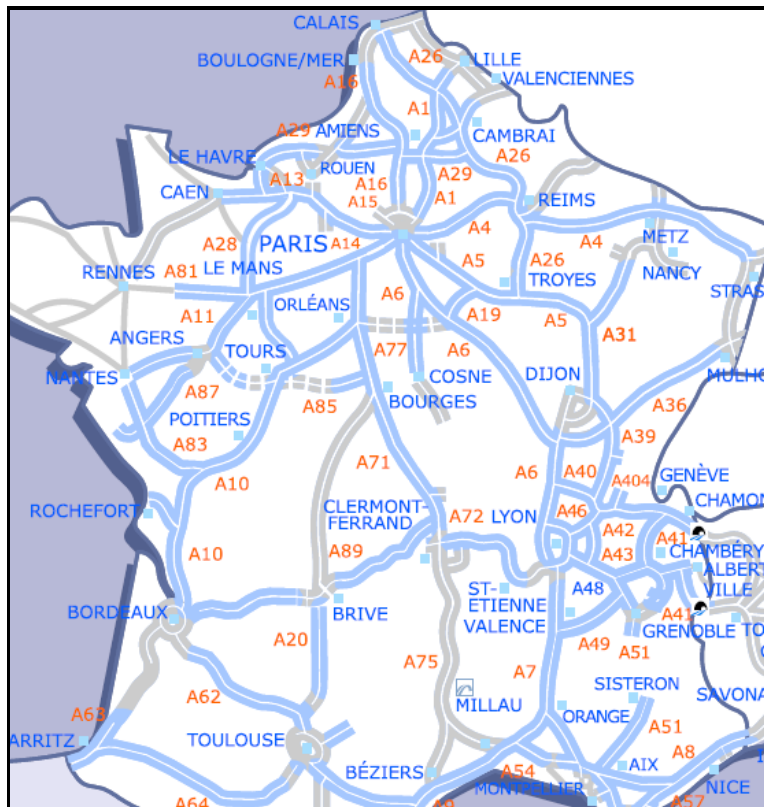
from motorway entry to exit. Few of the schemes differentiates tolls according to emission classes or emissions. The tariffs differentiation is per 5 vehicle classes (axles).

- Level of tariffs: There is no common national toll level, all the motorway operators applying different fees. Frequent users are eligible for considerable discounts. The amended Eurovignette Directive 2006/38 includes a maximum rebate level for frequent users of around 13%. The European Commission warned France in June 2006 that the discounts offered to frequent users of up to 30% were not in line with the Directive as road user charges must be linked to the infrastructure costs. Discounts for frequent motorway users may not exceed the administrative cost savings.

4.2.2 Modulation of Motorway Tariffs

On several tolled motorways, toll levels are or have been differentiated so to spread returning holiday traffic more evenly over the day; tariffs in peak hours are increased. Motorway operators are in general in favour of tariff modulation, in order to better manage the infrastructure capacity and to reduce the increasing level of emissions.

Surcharging for congestion costs has been introduced in France on the A1 (Paris-Lille) motorway in weekends since 1992 (it is still going on) and experimented 12 years ago on the major links with the South (A10/A11, A5/A6) at the time of important movements for the summer holidays. These toll modulations were focused on light vehicle peak flows. Tolls on an urban section near Marseille are also differentiated according to day/night hours.



Source: ASFA

Figure 4-1 French Motorway Network

Some assessments of the interurban motorway schemes have been conducted. They showed that notable traffic transfers occurred from peak periods to off-peak periods, or from congested to less congested link. In the case of A5/A6 the orders of magnitude obtained indicate that +/- 6%



differentiation induces a diversion of 5% to 12% of the traffic from peak to off-peak. Assessments also concludes that the diversion of traffic on non-motorways (untolled) link was negligible. Acceptance proved to be generally good.

Experiences from the US indicate that such differentiation may reduce congestion considerably, also when targeting commuter traffic. In Florida, there are examples of differentiation of 50% in bridge toll levels that diverts 20% of the traffic from peak to off-peak periods³².

On the basis of the current implementations, the ASFA Association³³ has put forward a set of policy proposals to regulatory authorities, where the main tariff modulation methods identified are:

- temporal modulation “peak day/off-peak day” for all vehicles, that requires a national coordination and an important information system for French and foreign drivers;
- temporal modulation of “return weekend” for all vehicles, on the basis of the pilot project already in place on the A1 since 1992;
- temporal modulation of “urban or peri-urban areas”, whose aim is to prevent the overlapping of traffic and transit commute. Its implementation requires a case-by-case basis depending on the nature of the section and traffic profiles;
- temporal modulation specific for “HGV” - Heavy Good Vehicles - , aimed at encouraging the use of the highway by HV during off-peak periods. Its implementation should be studied on a case-by-case basis, depending on network and taking into account the social acceptability. The magnitude of this modulation may itself be modulated according to the Euro classes of vehicles;
- “ecological pricing for HGV” on the basis of their Euro class, based on the one that exists since 2002 for the Mont Blanc and Frejus tunnels; within the framework of the Eurovignette EU directive, its implementation can be possible under the HGV telematic toll.

Table 4-1 Frejus and Mont Blanc Tunnels Tariffs in Euro

Class		Single Trip	Round Trip 7 days	Subscription 10 Crossing Trips 24 Months	Subscription 50 Crossing Trips 24 Months
Motorcycle		21.40	26.80	67.10	234.80
1	Light Vehicle	32.30	40.30	100.70	352.30
2	Van	42.70	53.70	134.20	469.70
Class		France Side		Italy Side	
		Single Trip	Round Trip 15 days	Single Trip	Round Trip 15 days
3	Euro 0* & 1	123.90	198.70	124.30	199.40
	Euro 2 & 3	117.10	187.80	117.50	188.50
4	Euro 0* & 1	248.90	403.00	249.70	404.40
	Euro 2 & 3	235.20	380.90	236.00	382.20

Note: There is also a lump sum subscription of 859.30 Euro for 6 months.

Source: www.atmb.net

32 US FHA, Congestion pricing, US Department of Transportation, Federal Highway Administration, December 2006

33 Asfa – « LES SOCIÉTÉS D'AUTOROUTES ET LES ENJEUX DE LA MOBILITÉ », Dossier de presse – 23 janvier 2007



4.2.3 Details of Current Applications

A1-Sanef : Tariff Modulation for Returning Time to Paris on Sunday Evening

- Tariff modulation: On some sections of the A1 motorway, since 1992, tariffs in off-peak periods (from 14.30 to 16.30 and from 20.30 to 23.30) are reduced by 25% (green tariff), whereas tariffs in the peak period are increased by 25% (red tariff). 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.
- Tariff reduction calculation: the reduction is applied to the Lille/Paris gear direction, at the exit tolls 10, 9, 8 and at the toll barrier of Chamant (Senlis); it concerns the trip made on the A1; it is considered the payment hour; for the very short trips, the tariff reduction is more than 25%; the reduction concerns only vehicles belonging to classes 1 and 2 (cars, monospace, 4x4 hauling or not caravan or tow).
- Impact of the time modulation: Data on impacts deriving from the A1 tariffs modulation are available for the first year after the introduction (1992)³⁴. The impact of the scheme was mainly on the timing of trips. Comparisons of traffic counts showed that southbound traffic at the mainline toll barrier near Paris declined approximately 4% during the red period and rose approximately 7% during the green period, relative to a six-year trend for comparable Sundays. The most pronounced shift was from the last hour of the red period to the later green period. A survey in November 1992 confirmed that many people – about one-fifth of those travelling during the green period – sought to lower their toll by shifting the timing of their trips, sometimes by stopping for meals at service areas along the highway. However, more recent existing estimates suggested by the US experiences³⁵, show higher possible impacts of tariff modulation actions by time: traffic shifts of about 5 to 10%, congestion reduction of around 10-20%.

A14-SAPN: Tariff Reduction for Off-Peak Time around Paris during the Week-End

- Tariff modulation: On the A14 exists the possibility of doing a week-end subscription that allows tariff reduction of 50% for round trips made on the motorway.
- Tariff reduction calculation: The subscription contract *Liber-t A14 Week-End* is characterised by the following conditions: it is limited to light vehicles belonging to toll class 1; the outward trip has to be made within 12h on Friday and 20h on Saturday; the return trip has to be made within 12h on Sunday and 20h on Monday. Round trips unfinished or made out of the fixed periods do not allow any tariff reduction.
- Level of tariffs: The base tariff (6h-10h / 16h-20h) amounts of 7.10 Euros. The reduced tariff (10h-16h / 20h-6h) amounts of 5 Euros. The tariffs applied during Saturday, Sunday and the other working days, correspond to the base tariffs.

A86-Cofiroute: Modulate Tariff Reduction for Off-Peak Days and Time

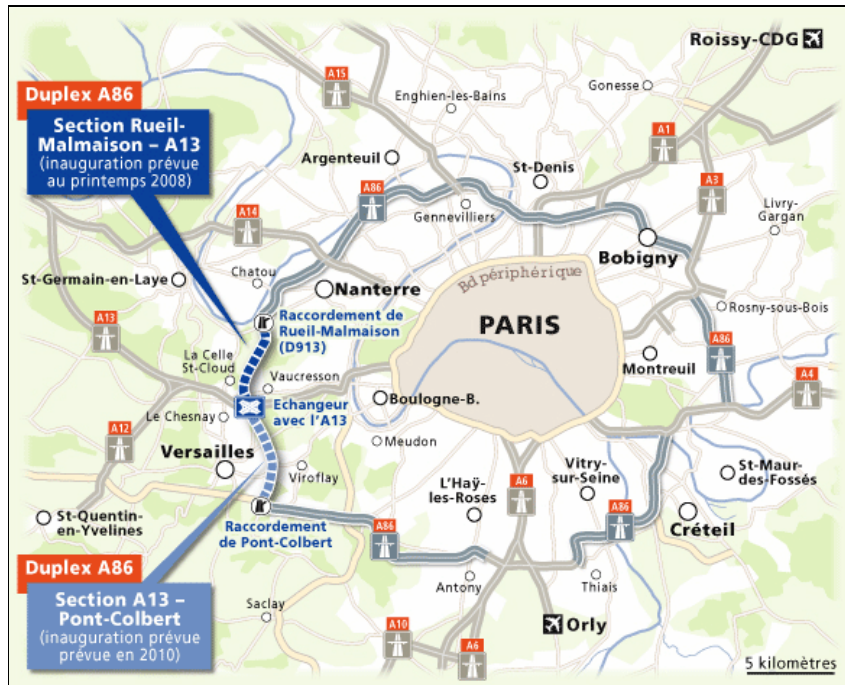
- Tariff modulation: The cost of the toll *Duplex A 86*, the tunnel that links the A86 with the western part of Paris, which will be launched in spring 2008, will be adjusted according to the schedules of passages: lower at off-peak, higher at peak.
- Tariff reduction calculation: Subscriptions formulas will be offered to individuals or companies, for example offering discounts up to 35% for home-work trips. Cofiroute is also studying formulas to people with limited mobility, electric vehicles, students or car-sharing users.
- Level of tariffs: The *Activ-t A86* subscription (home-work trips) will provide for a reduction starting from the thirteenth monthly crossing, lowering the average price of the trip to around 2.50 Euro. All

34 Centre d'Etude Techniques de l'Equipeement Nord-Picardie, Modulation des Péages sur A.1, prepared for Service d'Etude Technique des Routes et Autoroutes (SETRA) Government of France, 1993.

35 US FHA, Congestion pricing, US Department of Transportation, Federal Highway Administration, December 2006

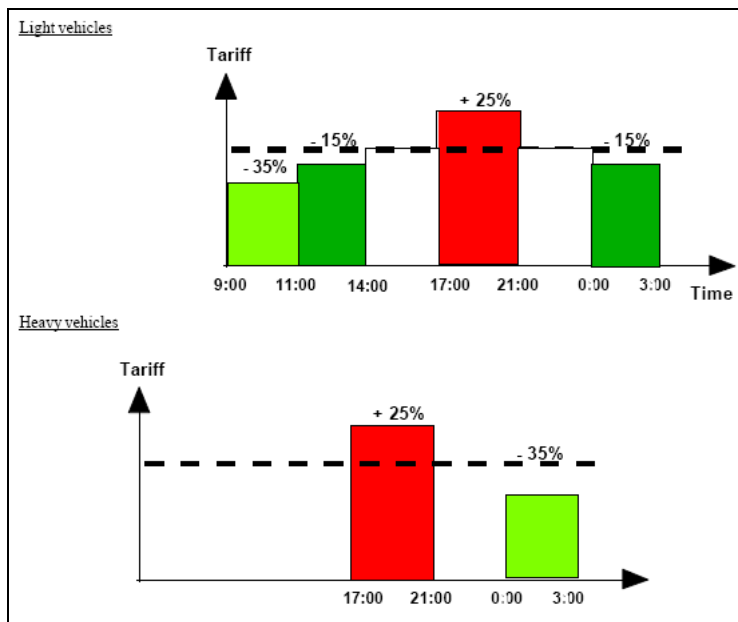


these tariff formulas emphasize the telematic toll, which allows a transaction twice as fast as other forms of payment and contributes to the flow of traffic.



Source: www.cofiroute.fr

Figure 4-2 Duplex A86



Source: Delache, Alibert, 2003

Figure 4-3 Tariff Modulation According to Time on A10/A11 in 1996



4.2.4 Previous Experiments

Tariff Modulation on A10-A11³⁶

From March to November 1996, a toll modulation experiment was implemented for light and heavy vehicles returning to Paris. The result was a decrease of peak-low traffic by 12%, and of time squared through congestion by 60%, traffic transfer on parallel network has been negligible (0.5% per weekend). The peak hour traffic decrease was between 6% to 9%.

Tariff Modulation on A5-A6³⁷

The A6 motorway links the area of Paris to Lyon, on the way to the southeast of the Alps. There is a periodic congestion on this motorway during winter holiday departures and returns. Since December 1994, the A5 motorway provides an alternative route to A6. But the A5 way is 71 kilometres longer than the A6 motorway between Paris and Beaune and is more expensive and not well known. The main objectives of the pilot project was to shift traffic from A6 to A5 (15-20% expected), reduce congestion on A6, make the A5 motorway well known to users. During winter holidays and easter weekend, differential toll tariffs were implemented for light vehicles in favour of A5 motorway (years 1995-1997). It consists of an increasing price on A6 and a decreasing price on A5. The pricing scheme operation had an impact on route choice. About 7000 vehicles were transferred on A5 per week-end and per direction. 15-20% of the traffic concerned with route choice was on A5.

4.2.5 Future Opportunities

As already said, parts of the un-tolled motorway network are located in Alsace. The introduction of road charging in Germany in 2005 has had a serious knock-on effect in the border region of Alsace due to diversion of heavy goods traffic on to the French road network. Several associations have therefore presented a proposal to introduce road charging in Alsace to the regional administration, national Ministries and the European Commission.

The proposal for road charging for HGV in Alsace has been under consideration for some time at national level. There is ongoing discussion of how the revenues should be distributed between the local, regional and national levels. The current plan would cover motorways only. A trial scheme could enter into force around 2010 , but there is as yet no official confirmation.

The French Ministry of Transport is also developing a proposal for a national road charging scheme to be applicable to HGV on those motorways which are not already run under concession by private operators. Whilst it appears that no change is planned for the concessionary network, the amended Eurovignette Directive offers opportunities to levy tolls or fees on all motorways and on all other roads. Tolls could also be differentiated according to emission class. Details of any scheme are not yet concrete, and no introduction date has been discussed but a new impulse has been given with the National Debates on Environment (« Grenelle de l'environnement ») and the principle of HGV pricing seems to have reached a certain degree of consensus.³⁸

In the Alps and Pyrenees, France could have the opportunity to levy mark-ups. In urban areas and other areas with environmental problems, regulatory charges could also be levied.

36 Source: Xavier Delache, Christiane Alibert, Working Paper, 16-18 November 2003 Cyprus.

37 Source: Xavier Delache, Christiane Alibert, Working Paper, 16-18 November 2003 Cyprus.

38 A price worth paying, T&E 2007



4.3 DIFFERENTIATED TOLLS ON MOTORWAYS: U.S. HOT LANES

4.3.1 Introduction

This section outlines the development of High Occupancy Toll (HOT) lanes within the United States (U.S.) over the last 17 years. Although the concept of HOT lanes can vary between applications, the general principal refers to High Occupancy Vehicle (HOV) lanes that allow access to Single Occupancy Vehicles (SOVs) in return for a toll. This note will outline the HOT lane concept in more detail, describe their development over the last two decades and discuss what the impacts have been in terms with reference to changes in driver behaviour, changes in costs and revenue and political/public opinion.

4.3.2 The HOT Lane Concept

The HOT lane concept combines traditional HOV lanes with 'value pricing' (a useful term widely employed in the US to denote pricing of scarce commodities). Normal HOV lanes provide exclusive access to vehicles carrying at least two occupants and may be taken from existing highway capacity or added later. The general decline in use of such lanes during the 1990s (experienced, according to the U.S. Census Bureau (2000), by 36 of the 40 largest metropolitan areas in the US) led to calls for their removal. The HOT lane "solution" to the under-use of HOV lanes was to allow some of the spare capacity to be "purchased" by traffic which would not normally have access to the HOV lane (FHWA, 2002).

HOT lanes offer general traffic managed access to dedicated lanes on payment of a fee. Usage of the HOT lane is effectively rationed to maintain free flow conditions even during peak periods. This is achieved either by setting the fee at a level just sufficient to deter over-use or by limiting the number of usage permits in circulation. In most HOT lane schemes, the charge varies by time of day according to a published schedule but departures from the schedule may be generated by unexpected traffic conditions. Variable message signs are widely used to inform motorists of the current charge levels well before they approach the HOT lane. Drivers who do not wish to pay the current charge can opt to use the "normal" (free) lanes. Charges may also vary by vehicle type (e.g. motorcycles, low emission vehicles might not be charged) but this is not a necessary feature of HOT lanes.

Most HOT lanes employ electronic payment systems (or, during trial periods, monthly passes) to collect the tolls. This avoids delays associated with toll booths but restricts the use of HOT lanes to those who have pre-registered to use them. Access to HOT lanes is also restricted by the use of barriers (either physical or lane markings) and entry/exit points (sometimes intermittent, other times single).

4.3.3 HOT Lane Schemes

There are currently seven HOT lane schemes in the U.S. with a further scheme due to commence construction in 2008 with, potentially, a further 24 schemes under consideration. Table 4-2 details the seven existing schemes. A key distinction can be drawn between the Utah I-15 scheme (where access is restricted to the limited number of people who have pre-purchased a monthly pass), the Texas I-10 and US-290 schemes (which operate a fixed charge for use of the facility during peak periods) and the rest (labelled in the table as having "dynamic pricing") which charge according to a notional schedule which may vary depending on current traffic conditions.

During normal operation, the dynamic pricing schemes switch between well-publicised, pre-defined, tolls levels which reflect the level of demand normally expected at the specified time on the specified day (for example, the SR-91 price schedule is different on each day of the week and the scheduled price may change up to 16 different times in the course of a single day). In exceptional circumstances these pre-defined levels can be over-ridden and a much higher charge imposed.

Under a fully dynamic pricing regime, prices would be set, in the light of information about current and expected demand, at levels which are just sufficient to maintain prescribed traffic speeds (the I-394



scheme, which is close to being fully dynamic, sets prices designed to ensure that speeds do not fall below of 50 to 55 mph).

Some schemes provide free access to all HOVs even during peak periods, others offer a discount for vehicles carrying more than 2 (sometimes 3) people. Differential pricing is sometimes (e.g. on I-15 Utah's I-15 Express lanes) used to encourage use of clean vehicles. Buses, motorcycles, taxis and emergency vehicles are generally exempt from the charges while large freight vehicles tend to be prohibited.

Table 4-2 HOT Lane Schemes in the U.S.

Scheme Location	Scheme Description	Pricing Structure	Year Operations Commenced	Website
I-15 FasTrak – San Diego, California	8 mile, 2 lanes.	HOV2+: free SOV: dynamic pricing – average variation \$0.5 to \$4, with max. of \$8	1996	http://fastrak.sandag.org/faq.html#anchor98216
State Route 91 (SR91) Express Lanes – Orange Country, California	10 mile 4 lanes in median of existing highway.	HOV3+: discount/free off peak SOV: dynamic pricing - \$1.20 to \$10	1995	www.91expresslanes.com
Katy Freeway (I-10) – Harris County, Texas	13 mile 1 lane reversible in the median of an existing highway.	SOV: prohibited. HOV2: peak pricing of \$2 each way in peak./free off peak HOV3+: free	1998	www.quickride.org
Northwest Freeway (U.S. 290) – Harris County, Texas	15.5 mile, 1 lane reversible.	SOV: prohibited. HOV2: peak pricing of \$2 each way in peak./free off peak HOV3+: free	2000	www.quickride.org
I-394 MnPASS – Minneapolis, Minnesota	8 miles, 2 lanes	HOV2+: free SOV: dynamic pricing – average variation \$1 to \$4, with max. of \$8.	2005	www.mnpass.org/394/index.html
I-15 Express Lanes – Utah	38 miles, 2 lanes	HOV2+: free Clean-fuel vehicles: free SOV: fixed price of \$50 per vehicle per month – limited to 2,200 vehicles.	2006	www.expresslanes.utah.gov
I-25 Express Lanes, Denver, Colorado.	7 miles, 2 lanes	HOV2+: free SOV: dynamic pricing – average variation \$0.5 to \$3.25, however in principle no limit to what could be charged if congestion warranted it.	2006	www.dot.state.co.us/cte/expresslanes/tollmain.cfm

HOV2: vehicles with 2 persons on board;
 HOV2+: vehicles with 2 or more persons on board;
 HOV3+: vehicles with 3 or more persons on board.

4.3.4 Expected Performance of HOT Lanes

The combination of lane management and value pricing provides a powerful tool for highway authorities to influence travel conditions and promote a number of benefits for motorists. The US Federal Highway Administration has identified a number of potential benefits of HOT lanes (FHWA, 2002). These include: improved journey time reliability, particularly during the peak period; reduction in journey times throughout the day but particularly at peak periods; revenue generation and reduction in environmental emissions – due to reductions in stop-start traffic and to mode shift.



FHWA also identify a number of political advantages of HOT lanes: they offer SOV motorists an additional choice (to pay for a quicker more reliable travel option); they can help utilise spare capacity in HOV lanes (helping to justify retention of an HOV facility); and they can demonstrate the attractions of congestion pricing and may thereby facilitate wider introduction of the concept.

It is recognised that a key elements in the success of any HOT lane scheme is obtaining political and public support before the scheme commences and then maintaining that support afterwards. In addition to financial viability, safety and potential inequity are key concerns. Safety concerns tend to focus on the amount of lane changing required on the approach lanes. The equity concern, often referred to as the 'Lexus Lane' problem (Gilroy and Pelletier, 2007), is associated with the widespread assumption that HOT lanes will only benefit the wealthy, those who can afford to drive around in a Lexus car.

4.3.5 Evidence on the Performance of HOT Lanes

Evidence on the performance of HOT lanes can be found in a number of reports (see references). We do not here seek to go into detail with regard to every scheme but do seek to summarise the most significant and widespread results under a series of subheadings.

- Improved traffic conditions. The main rationale for variable pricing structures in HOT lanes is to maintain free flow conditions and/or maintain speeds at a prescribed level. Most HOT lanes have had great success in achieving this and have provided considerable travel time savings for HOT lane users. For example, the QuickRide HOT lanes motorists on the Katy Freeway in Texas have seen an average time saving per vehicle of 17.3 minutes (am flows) and 15.0 minutes (pm flows) compared to traffic using the general purpose lanes (Burriss and Sullivan, 2006). A similar story can be told for the I-394 MnPASS which, since 2005, has managed to increase traffic volumes in both HOT lanes (up 17%) and GPLs (up 3%) whilst maintaining free flow traffic (at 65.6 mph) in the former and increasing speeds by 6% (to 62.2 mph) in the latter (TollRoads News, 2007). Similar results have been achieved on the SR-91 and I-15 San Diego (Cambridge Systematics Inc, 2002; Sullivan, 2000) and are attributed to better utilisation of existing HOV lanes, the encouragement of car pooling and bus usage and peak spreading of demand. This can result in large benefits for HOT lane users - recent calculations by Sullivan and Burriss (2006) - suggest that the annual value of travel time savings on the SR-91 was around about \$35 million in 2005.
- Revenue generated. Most HOT lanes have generated enough revenue to cover their operating costs, fund a portion of capital expenses and pay for alternative modes of public transport (Cambridge Systematics Inc, 2002; GAO, 2003). However there are exceptions. For example the annual revenue from the I-394 MnPASS was around 50% of that forecast and resulted in a \$1 million annual deficit (TollRoad News, 2007) a result which is attributed to there not having been enough congestion to justify the scheme.
- Vehicle Operating Costs. The expected reduction in stop-start traffic should result in more efficient fuel usage for HOT lane users but, since more fuel is consumed at higher speeds, the net effect may be minimal or even negative. The annual saving per driver on the Katy Freeway was however assumed to be about 30 gallons of fuel or \$33 (Burriss and Sullivan, 2006) and would appear typical across HOT lane schemes.
- Environmental impacts. The environmental benefits of HOT lanes appear to be quite modest and may even be negative. Burriss and Sullivan (2006) report very small environmental savings on the Katy Freeway, Cambridge Systematics Inc. (2006) conclude that the deployment of MnPASS had not increased CO emissions and had not significantly increased corridor noise levels, and Sullivan and Burriss (2006) report small but significant additional environmental costs (\$266,000) on the SR-91.
- Public Opinion and political support. It is acknowledged (e.g. Smirti et al, 1996 and Munnich & Buckeye, 2007) that the most successful HOT lane schemes have been very conscientious in canvassing and obtaining the support of the politicians and using out-reach programs to consult key actors in the decision making process and convince them of the benefits associated with HOT lanes. Almost all schemes have had to overcome a degree of local opposition but most appear to



have achieved lasting support from the local population. Local businesses have generally been supportive after a period of scepticism.

- Equity. Evidence from two of the longest running schemes suggests that, whilst use of HOT lanes increases slightly with income, there is a more or less even spread of high and low income users. Figures for the SR-91 indicate that 19% of motorists accessing the SR-91 Express Lanes have incomes less than \$40,000 and that a further 23% have a household income of \$40,001 to \$60,000 (Sullivan, 2000). Other evidence suggests that a substantial proportion of users use the facilities intermittently, when a specific journey calls for a fast and reliable guarantee, rather than on a regular basis. Further evidence comes from telephone interviews with the lowest income motorists (<\$40,000 household income) using the San Diego I-15 corridors - 80% of whom agreed that 'People who drive alone should be able to use the I-15 Express Lane for a fee' (Norman, 2002).
- Comprehensibility Although the cost of using a HOT lane can vary considerably and, in some schemes, cannot be predicted for certain before commencing the journey, the resulting unpredictability has not surfaced as a significant concern for individual motorists. It seems that, provided that motorists are informed, via variable message signs, of the charge they might incur before they commit to using the HOT lane, and provided that they still have the option of using the free, all be it congested, lanes, the potential variation in charges is not a major concern. Interestingly, the unpredictability of daily charges has apparently been more of a concern for commercial firms who, initially at any rate, were finding it difficult to predict what level of expenses their drivers may present to them at the end of each month. The variation in charges for different types of vehicle seems to be accepted and understood.

4.4 CONCLUSIONS

The main conclusions from the evidences analysed for road passenger transport can be here summarised:

- 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. Unfortunately, there are no data available to assess the reaction of these modulation schemes.
- More data have been collected for High Occupancy Toll (HOT) lanes within the United States, where it appears that these lanes have, in most cases, managed to improve the utilisation of road capacity, yield revenue and provide a superior level of service for those prepared to pay for it. The most successful schemes appear also to have reduced overall levels of delay and other externalities. HOT lanes offer an example of price differentiation (by time day and level of congestion) which can achieve effective yield management and an overall increase in social welfare.
- The tolls on the UK's M6 Toll road were originally set in the light of evidence from models and market research. Data from the first six months of operation showed higher than anticipated usage by passenger traffic. The toll operators concluded that passenger traffic was willing to pay more to use the toll road (to avoid a notoriously congested stretch of the parallel M6 Motorway) and so raised the toll by 50%. This appears to be an example of toll differentiation being adjusted to reflect the demand response - presumably with the objective of maximizing income.



5 MODELLING FREIGHT AND PASSENGERS DIFFERENTIATED TOLLS ON MOTORWAYS AND INTER-URBAN ROADS

5.1 INTRODUCTION

This chapter reports the outcome of some modelling exercises carried out in order to simulate impacts of differentiated road tolls on motorways and inter-urban roads for both passengers and freight modes. The text is also complemented by some results from modelling studies on motorway tolling in the UK.

The main modelling application consists of the simulation of several differentiation scenarios using the Brenner TEN-T corridor model. This model was originally identified as the reference tool for the modelling exercises in the work packages WP8 and WP9 and a significant part of the activities was devoted to its update and revision. In order to widen the modelling analysis simulating tolls differentiation is a diverse context, the Padana region motorway model was then added. In the Padana region supply and demand conditions are quite different from the Brenner corridor: instead of a major route mainly used by crossing traffic and with limited problems of capacity, a complex and often congested network where local traffic is prevailing.

The Padana region model, already existing, was used with relatively limited changes to its structure. Therefore, the two applications described in this chapter should be regarded as independent exercises: the Brenner model being the core of the modelling activities and Padana model providing relevant additional elements for the analysis. It should also be considered that both tools were not set up specifically for the analysis of the tolls differentiation, but built on existing models. Thus, the types of differentiation that could be simulated depended on the models' features (especially demand segmentation). Notwithstanding, a similar approach and similar differentiation schemes have been followed as far as possible in order to make the results at least broadly comparable.

A common feature of the models that is important to clarify is that they do not handle long term effects which may happen when differentiated tariffs are applied: for instance, the vehicle fleet could evolve and the more charged vehicle types could be replaced by others or - on the logistics side - empty trips might be reduced, etc. Another type of decision that the two transport models do not tackle is the application of differentiation schemes based on aspects like the day of the week or the period of the year. A differentiation of tolls in e.g. summer week-ends with respect to other periods of the year could actually lead some demand to change route, but also to shift the trip to another period or to change destination. However, decisions concerning the change of travel time or destination are necessarily based also on extra-transport elements. Therefore, the impact of this kind of differentiation cannot be analysed with transport model, which generally simulate a limited time span (e.g. two peak hours).

The largest part of this chapter is dedicated to the description of the Brenner corridor model and of its results (paragraph 5.2). The following paragraph 5.3 discusses the other two modelling applications. Finally, and paragraph 5.4 presents the conclusions drawn from the results of the simulations and paragraph 5.5 brings in some reflections from the UK modelling applications.

5.2 BRENNER TEN-T CORRIDOR MODEL

The Brenner corridor model allows an ex-ante simulation of impacts of further toll differentiation on the motorway section of a TEN-T corridor.

The Brenner corridor is one of the main gates for trans-Alpine traffic for both passenger and freight. Thus, a significant amount of crossing demand (with a substantial proportion of long distance HGV traffic) contributes to the traffic on the tolled motorway connecting Verona to Innsbruck and beyond. At the same time, especially in the Italian part, the corridor crosses areas where population and activities are intensively located, so that the road corridor is also used for (relatively) short-distance trips within the study area. A national road runs parallel to the motorway and can be considered as an alternative route (of course especially for local trips). A major railway is also available on the corridor and a new rail tunnel is planned within the TENs projects.



The Brenner corridor has been considered an ideal candidate also because that Italian legislation (1998) has introduced the possibility of experimenting the key option in both the Swiss scheme for HGV and the Commission White Paper on European transport policies up to 2010, that is re-investment of net revenue from the tolled motorway section of the Alpine TEN-T corridor to increase capacity standards of its rail section.

The Austrian A13 Brenner motorway is a particular example of differentiated tolling system for lorries in Europe: vehicle category classes (based on vehicle's axles), day/night crossing rates, exceptional toll "Sondermauten" (levied also on other parallel links through the Alps). The emission class element (EURO standard) has been also introduced and considered in terms of a transit ban to comply with the Brenner characteristic of "sensitive mountainous area": from 10.01.2007 to 30.04.2007 crossing was prohibited for Euro 0 and Euro 1 lorries whose maximum admissible weight exceeds 7,5 tonnes. A more general ban for Euro 0 heavy goods vehicles were already in force until 31.12.2006, resulting from the European (EC) Regulation N. 2327/2003 which was introduced to replace the old Austrian Ecobonus system.

The seasonal restriction was introduced on the basis of a wider framework agreement signed in October 2006 among the Italian provinces South-Tyrol and Trentino and the Austrian Land Tyrol. The cross-border action plan includes also the proposal for a new and Alpine-focused "toll Directive" to be introduced at European level, the provision of subsidies to hauliers that use rolling motorway services and a progressive extension of the transit ban also to Euro 2 lorries. This programme is in line with the transport protocol of the Alpine Convention.

In brief, there is evidence that the attitude to introduce a differentiation according innovative criteria is already existing in the corridor.

5.2.1 Characteristics of the Model

The Brenner model builds on an existing integrated transport and land use model of the Italian section of the corridor (Alto Adige/South Tyrol). The model is implemented using the Meplan software package. The model simulates both modal split and route choice of both passenger and freight demand. Given the level of detail of the analysis, rail is considered as the unique alternative mode to road transport. Air transport is not considered assuming that the choice between air and car does not depend much on Brenner corridor tolls. Two alternative road paths are considered for long-distance traffic: one is the corridor through St. Gotthard tunnel, the other is the Tarvisio pass. These two alternatives are not modelled at the same level of detail than the Brenner corridor, but in a very simplified form.

The zoning system (Figure 5-1) includes 42 zones (33 being part of the study region and the rest as external zones) defined with the objective of simulating local traffic as well as crossing traffic on the corridor. Two parallel segmentations of demand are used in the model, one concerning vehicles and one concerning individuals or transported goods.

Vehicle Types

Several types of freight road vehicles and passenger cars are modelled according to three main dimensions: size, fuel type and standard EURO. There are four EURO categories:

- EURO-I or less,
- EURO-II,
- EURO-III,
- EURO-IV



In terms of size/fuel, the following categories of passenger cars are considered:

- Gasoline
- Diesel

Since the segmentation by fuel type is not a major one with respect to the main aim of the model (i.e. analysing tolls differentiation), other fuel types (e.g. LPG) which account for a minor share of the European car fleet are not modelled in order to reduce the complexity of the model structure.

Finally, three categories of road freight vehicles are considered:

- <3.5 tons;
- 3.5-16 tons;
- >16 tons.

These groups, both for passenger cars and for freight vehicle, are consistent with the COPERT classification.

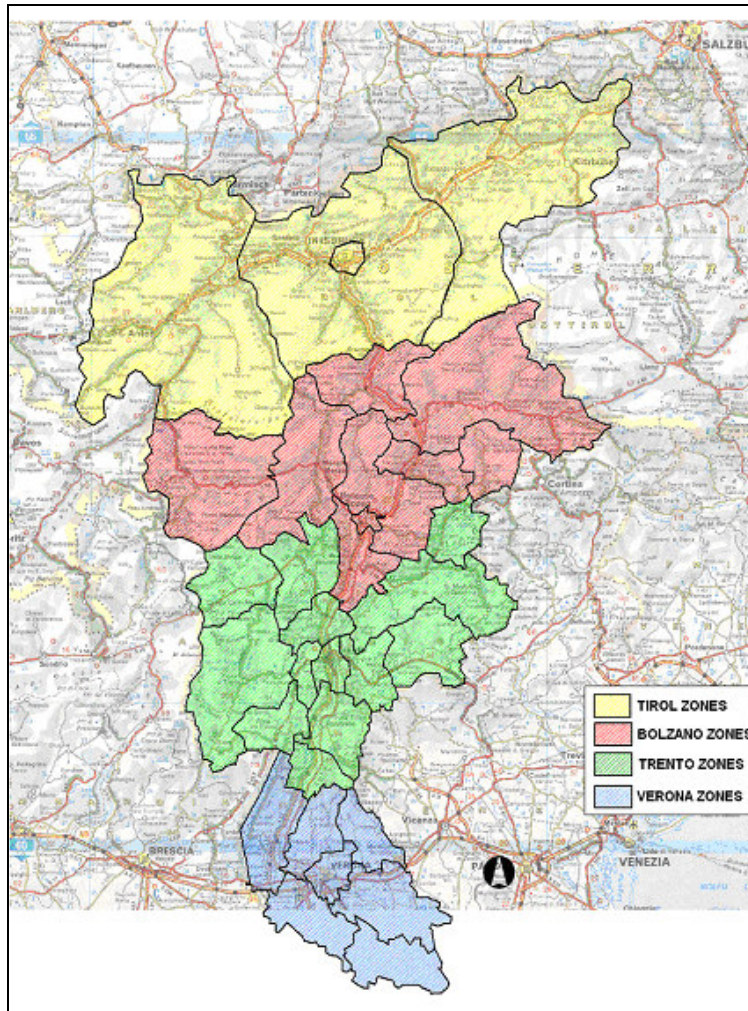


Figure 5-1 The Brenner Corridor TEN-T Model Zoning System



Passenger Demand Categories

Passenger demand is mainly segmented according to trip purpose and the following segments are defined:

- Business,
- Commuting,
- Tourism,
- Personal trips.

Another segmentation criterion is the average length of trips:

- Crossing traffic;
- Short-distance traffic;
- Long-distance traffic.

Table 5-1 shows how the different segments of demand are combined. Some combinations are not included because they are regarded as unlikely or irrelevant (e.g. crossing trips for personal purpose) and thus 8 demand segments are used. The distinction according to trip purpose is justified for applying different behavioural parameters (e.g. value of travel time). The segmentation of demand according to trip length is relevant both for tolling schemes and for distinguishing different elasticities. Each of the 8 segments is further crossed with the 4 emission classes. In the end, $8 \times 4 = 32$ demand segments are used for passengers.

Table 5-1 Demand Groups Combinations – Passengers

Purpose	Average Trip Length		
	Crossing	Short Distance	Long Distance
Business		X	X
Commuting		X	X
Tourism	X	X	X
Personal trips		X	

Freight Demand Categories

Freight demand is segmented according to two criteria: commodity groups (High value goods unitised; High value goods not unitised e.g. machinery, vehicles; Low value goods) and average trip length (Crossing traffic; Short and Long distance traffic). As for passengers, not all possible combinations are actually used in the model. As shown in Table 5-1, crossing traffic for low value goods is not considered.

Table 5-2 Demand Groups Combinations - Freight

Commodity	Average Trip Length	
	Crossing	Short-Long Distance
High Unitised (HU)	X	X
High Not Unitised (HNU)	X	X
Low (LOW)		X

The demand segments are used only to define different behavioural parameters (e.g. value of travel time) and not tolls differentiation schemes. However, the demand groups are further split into 12 categories of vehicles obtained by combining the 4 emission classes and the three weight



categories³⁹. Such elements are used to define differentiation toll schemes. Finally, 44 demand segments are used for freight demand.

Transport Modes

As stated above, the Brenner corridor model is multimodal one. Even if the focus is on road transport tolls, alternative modes are included in the model in order to simulate modal shift as reaction to the tolling measures. For passengers, the following modes are available in the Brenner corridor model:

- Car (only driver),
- Car (driver + passengers),
- Coach,
- Passenger train.

The two car modes are considered because one possible response to pricing policies is car pooling. The two car modes are available for working and personal trips, while for tourists only driver+passengers car is modelled.

For freight, train is the only alternative to road modes. The alternative is modelled only for those demand segments correspondent to a large truck (>16 tonnes). The assumption is that deliveries using lighter vehicles are too small in volume and too frequent in time to have rail as a realistic alternative.

Origin/Destination Matrix

The Origin/Destination matrix was estimated using existing databases, models and origin-destination matrices. In particular, the following sources referring to previous projects were utilised:

- The South Tyrol integrated land-use and transport model,
- The Alp crossing model,
- The ETIS database and the TRANS-TOOLS model,
- The SCENES model.

The South Tyrol integrated land-use and transport model was originally built in 1993 as a supporting tool for the Transport Master Plan. The model was updated in 2001 for the assessment of the Regional Transport Plan and its base year was updated to 1998. Even though the South Tyrol model simulates only a section of the study area, its detailed zoning system allowed the reconstruction of trips in the Bolzano province area, including local trips that were introduced in the model to pre-load some links.

The Alps Crossing database is one result of a monitoring project managed by the countries of the Alps region (France, Switzerland, Austria and, lately, Italy). Each five years, a traffic survey is carried out on main Alps passes in order to collect information on the amount of road and rail freight traffic and its features (freight type, containerisation, etc.)⁴⁰. The origin-destination matrix within the Alps Crossing database is even more detailed than the zoning system used for the Brenner model. The data of the Alps Crossing database was used to estimate the quantity of goods across the Brenner border and derive an origin-destination matrix.

Within the European Transport policy Information System (ETIS) project, ETIS-BASE developed a database of passenger and transport data which is expected to become the reference database for

39 Actually, crossing traffic is considered only made of heavy trucks (>16 tonnes)

40 A report of the latest survey can be found at:

<http://www.uvek.admin.ch/dokumentation/00655/00895/01152/index.html?lang=it>



European strategic modelling⁴¹ and has been used also in the development of the TRANS-TOOLS model.

The ETIS database represented a source for estimating the freight matrix, to and from the South-Tyrol region. The SCENES model is a European network transport model developed for the European Commission since the late 90's and used as support for several studies of the impacts of transport policy on the European demand. In 2005, the SCENES model was used within the project focused on the mid-term assessment of the EC White Paper on transport⁴². The origin-destination matrix produced by the SCENES model represented a starting point for the estimation of passenger trips in the study area.

All sources provided useful data, but none of them provided information in the same format (demand segmentation) required for the model. Additionally some sources were partially overlapped. For this reason, a significant amount of work was devoted to come up with a final homogenous matrix. The procedure to assemble the different sources and build an overall matrix for the study area was developed along the following steps⁴³:

- a. Aggregating/splitting matrices from the different sources in order to match the zoning system defined for the South Tyrol model. To split aggregated flows in the study area, a gravitational criterion (based on the relative weight of the zones under some criteria, proxies of generation or attractiveness) has been adopted. Flows (passengers and freights) are considered "crossing flows" if both the origin and the destination are outside the study area; for passengers, the category "short distance" has been assigned to flow whose length is below 80 kms.
- b. Revising demand segmentation of the matrices from the different sources in order to match the demand segmentation defined for the South Tyrol model.
- c. Updating the matrices from the different sources to the base year 2005. Such an updating has been obtained by simply applying growth rates (one for passenger and one for freight) to the original matrices. The growth rates were estimated on the basis of traffic counts data in time series and were set to 1% p.a. and 2% p.a. for passenger and freight respectively.
- d. Adjusting the resulting matrix according to observed traffic.

Calibration of the Model

The Brenner Corridor model was calibrated in order to reproducing sound elasticities (i.e. comparable to literature values) of demand with respect to cost. Of course, attention was also paid to the realism of traffic flows and mode split on the corridor. However, observed demand data was only partially available and with a level of detail and segmentation not consistent to the model. Therefore, a detailed validation of the model could not be performed.

The main objective of the calibration was to reproduce realistic elasticities. Reference values were extracted from literature (see Deliverable 8.2 for details on the elasticities review). The tables below report the comparisons between the reference cost elasticities and the elasticities estimated from the Brenner Corridor model. The latter have been estimated by increasing of 10% the transport costs either on the motorway or on the national road and measuring the correspondent reduction of the number of vehicle-kms (either on the motorway or on the national road). The intervals reported in the tables consist of the two elasticity values obtained from the two tests for each demand segments. For the passenger demand, the elasticity with respect to the motorway cost has been considered for the crossing traffic, while for local demand only the elasticity with respect to the road cost has been used. In both cases the choice depends on the relevance of the road and the motorway for the traffic components: crossing traffic does not use the national road, which is the predominant choice for local demand instead. The same holds for freight crossing traffic, while for freight local both elasticities have been computed. Passenger reference elasticities were available only for short distance trips, while for

41 More information on ETIS and ETIS BASE can be found at: <http://www.iccr-international.org/etis/>

42 See Ying J., Deane G., Zhu Y., Jakimovska V., Martino A., Fiorello D. (2005), Results from the SCENES model, Annex VI of ASSESS Final Report, DG TREN, European Commission.

43 For more details on the estimation of the demand matrices for the Brenner corridor model, the reader is referred to the Different Deliverable D8.2



long distance trips it is expected that elasticities should be higher. This is not the case in the Brenner model: the size of the elasticity is the same.

Table 5-3 Comparison between Reference and Modelled Cost Elasticities for Road Passenger Demand

Trip Purpose	Reference Elasticities	Modelled Elasticities
Passenger local	From -0.02 to -0.25	-0.45
Passenger (crossing demand)	> than local	-0.40

Table 5-4 Comparison between Reference and Modelled Cost Elasticities for Road Freight Demand

Trip Purpose	Reference Elasticities	Modelled Elasticities
Freight Local traffic	From -0.14 to -2.50	From -0.43 to -1.7
Freight Crossing traffic	From -1.10 to -1.80	-0.95

5.2.2 Differentiation Scenarios

The Brenner corridor model was applied to test several alternative scenarios of differentiated road tolls for passenger and freight. In principle, the differentiation schemes can be defined according to:

- The variable used to differentiate tolls (e.g. vehicle size, emissions category);
- The level of differentiation (i.e. the difference between each toll level);
- The size of the tolls (i.e. for a given relative difference between each toll level, the absolute values can be larger or smaller).

A huge number of scenarios can be defined when all the three sources of differentiation are combined. In order to identify a manageable and meaningful number of tests, the procedure adopted consisted of different steps.

In the first step each source of differentiation was analysed separately. Namely five scenarios were defined for each attribute of differentiation: EURO category, freight vehicle size, passenger vehicle occupancy, road type. The five scenarios concerning each attribute consisted of different levels of differentiation. For instance, summarises the five scenarios concerning the differentiation by EURO category. In the table, value 1 stands for the original toll level. In the Business as Usual (BAU) scenario tolls are not differentiated; in the other tests, differences are introduced either by increasing the tolls (e.g. 1.3 means 30% a higher toll) or by decreasing the toll (e.g. 0.75 means a 25% lower toll).

Table 5-5 Example of First Step Scenarios: Single Source of Differentiation

	BAU	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5
CARS						
EURO 1	1	1.3	1.6	2	1.4	2
EURO 2	1	1.2	1.4	1.66	1.2	1.5
EURO 3	1	1.1	1.2	1.33	1	1
EURO 4	1	1	1	1	0.75	0.5
TRUCKS						
EURO 1	1	1.3	1.6	2	1.4	2
EURO 2	1	1.2	1.4	1.66	1.2	1.5
EURO 3	1	1.1	1.2	1.33	1	1
EURO 4	1	1	1	1	0.75	0.5



The outcome of such first scenarios was then taken into account for a second wave of scenarios, where more criteria were tested at the same time. For instance, tolls were differentiated by road type and vehicle size. The combinations of sources of differentiation were selected according to the results of the first set of scenarios, trying to design reasonable and effective differentiation schemes. Table 5-6 reports an example of a scheme where more criteria are used at the same time.

In the third step, a different approach was used: some targets were set and a differentiation scheme able to meet the targets was searched. Of course, the lessons from the previous steps provided useful indications about the most promising schemes, so the number of modelling runs required could be reduced. The targets defined were the following:

- Minimising the travel times on the corridor;
- Minimising the emissions on the corridor.

The final step was focused on the analysis of how a given differentiation scheme can result in diverse impacts when the composition of the demand is changed. The rationale for these tests was twofold. On the one hand, the composition of the demand in the matrix was the result of an estimation process, where several assumptions were needed. Therefore, the size of the different segments is not certain. From this point of view, testing alternative segmentations can be interpreted as a sort of uncertainty analysis. On the other hand, it is expected that in the medium and longer terms, impacts tolls differentiation are extended to the composition of demand. In particular, vehicle fleet could change: the renewal of vehicles could be accelerated and the share of light and heavy trucks could be modified. From this point of view, testing alternative segmentations can be interpreted as the analysis of how the short term impacts the model is able to simulate can change in the longer terms. Given the objectives of this third step, the changes to the demand segmentation was chosen to represent likely effects of the differentiation schemes (e.g. a higher share of more recent EURO categories) but also to test alternative compositions of the demand (e.g. more or less large trucks in the fleet).

Table 5-6 Example of Second Step Scenarios: Multiple Sources of Differentiation for Trucks

Road Type	EURO Category	Vehicle Size	Toll Bau	Toll Test
State Road	EURO 1	<3.5 tons	0	0.975
		3.5 - 16 tons	0	1.3
		>16tons	0	1.3
	EURO 2	<3.5 tons	0	0.9
		3.5 - 16 tons	0	1.2
		>16tons	0	1.2
	EURO 3	<3.5 tons	0	0.825
		3.5 - 16 tons	0	1.1
		>16tons	0	1.1
	EURO 4	<3.5 tons	0	0.75
		3.5 - 16 tons	0	1
		>16tons	0	1
Road Type	EURO Category	Vehicle Size	Toll Bau	Toll Test
Motorway	EURO 1	<3.5 tons	1	1.0725
		3.5 - 16 tons	1	1.43
		>16tons	1	1.43
	EURO 2	<3.5 tons	1	0.99
		3.5 - 16 tons	1	1.32
		>16tons	1	1.32
	EURO 3	<3.5 tons	1	0.9075
		3.5 - 16 tons	1	1.21
		>16tons	1	1.21
	EURO 4	<3.5 tons	1	0.825
		3.5 - 16 tons	1	1.1
		>16tons	1	1.1



5.2.3 Results of Scenarios Based on Single Differentiation Criteria

A first group of scenarios dealt with differentiated motorway tolls on the basis of vehicles emissions class (Figure 5-2). According to the simulations, providing disincentives for “dirty” vehicles generates effects especially for heavy vehicles, which react more significantly than car drivers to higher tolls. In all tested scenarios, an “environmental” differentiation of charges leads to an increase in both time and money spent from travellers on the network, as well as in the motorway revenues⁴⁴. In other words, if tolls differentiation is applied with the aim of making polluting vehicles paying more than cleaner one, the effect is to shift part of the traffic on ordinary roads, with an overall worsening of congestion. The motorway operator would gain from such schemes as the elasticity of demand is lower than 1. It may be noted that the impacts on times, costs and emissions are not large: the scale of the figures below is on purpose such as one may grasp how limited changes are.

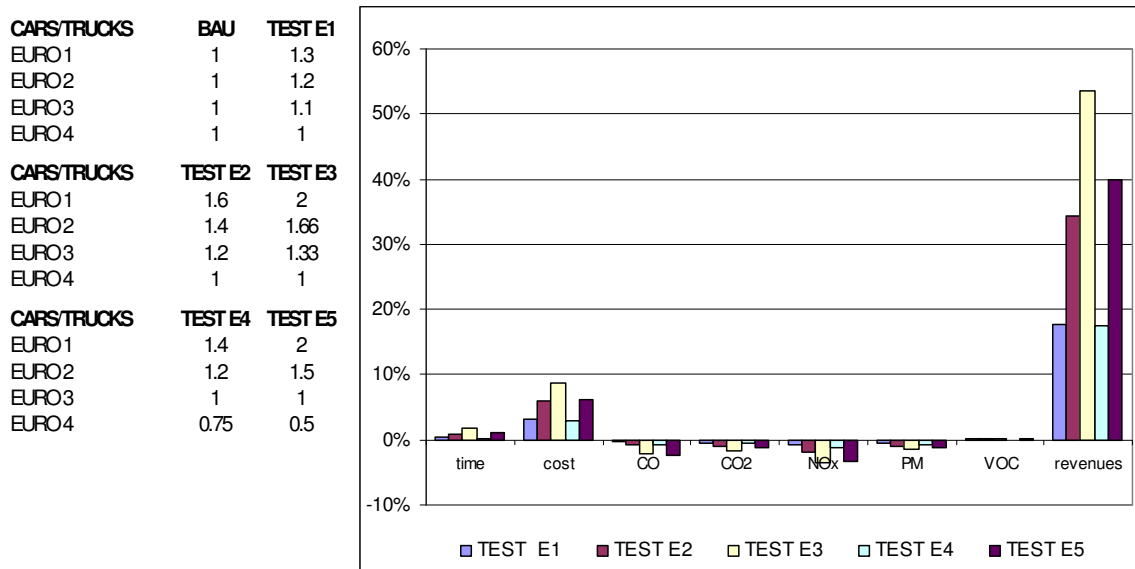


Figure 5-2 Summary Results of the Differentiation Scenarios According to the EURO Category

While first three scenarios (E1, E2 and E3) introduce a system of disincentives for pollutant vehicles, the last two tests (E4 and E5) verify the effects of schemes including also a rebate for the cleanest ones. The first and third scenario lead to the same results, and in general there is no evidence supporting the hypothesis that the presence of an incentive for Euro 4 vehicles could yield desirable effects under the perspective of travellers or of the motorway operator.

With respect to the composition of traffic flows, it can be noted how such toll schemes leads to a noteworthy modal shift only for tourists. In the third test, a remarkable share of this category, whose weight upon the whole of travellers amounts to 7 per cent, shifts from car to other transportation modes as train (+1.5 percent) and bus/coach (+4.4 percent).

A second group of tests considered a toll scheme arising from discriminating trucks on the basis of their deadweight and car travellers according to whether they transport a passenger or not (Figure 5-3). Results suggest that coupling discounted tolls for light vehicles with slightly higher tolls for the heaviest vehicles (Test S5) can give rise to positive effects: travel times in the area are reduced as traffic on ordinary road is decreased without any effect on the revenues of the motorway operator. Increasing tolls for heavy vehicles produces higher revenues for the motorway operator but traffic conditions are worsened.

The opposite policy for trucks (Test S4) leads to undesired effects in terms of congestion on the network, emissions and private revenues, which decrease in comparison with the BAU scenario. This

44 All results presented in this chapter make reference to the morning peak time



result is due to the fact that the increase in tolls for light lorries, whose demand elasticity is higher relative to large trucks, is more than balanced by their shift to the state road. Regarding car travellers, the effects on congestion of a toll scheme based on different charges for those ones who transport at least a passenger are not significant. In general, they are larger if the toll system provides a disincentive for lone drivers (Test S1-S3), rather than if it schedules an incentive for those who transport a passenger (Test S4).

It is interesting to note that, even in the scenario for which the discrimination between the motorists with and without a passenger is higher (Test S5), the modal shift of travellers is moderate. Considering all travellers categories, in fact, this toll scheme provides only a 0.5 increase in the number of cars with at least a passenger other than the driver.

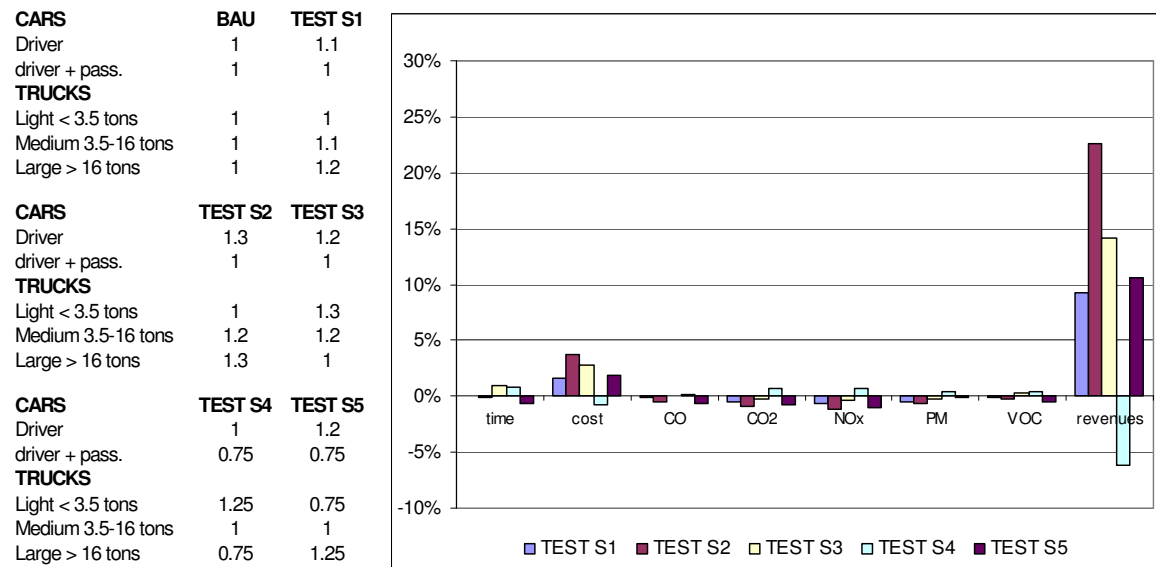


Figure 5-3 Summary Results of the Differentiation Scenarios According the Vehicle Size/Occupancy

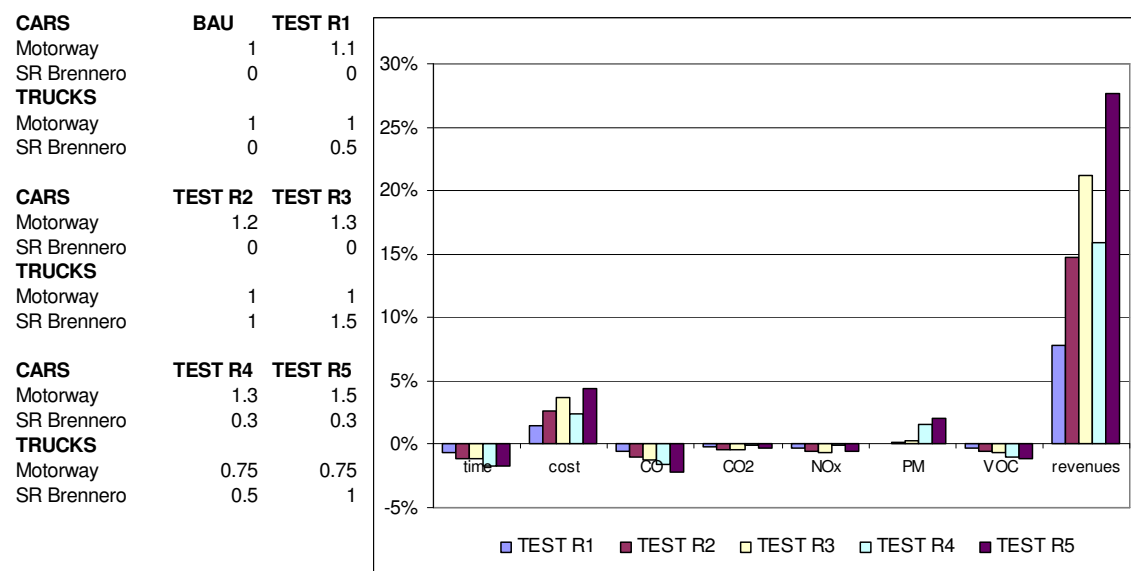


Figure 5-4 Summary Results of the Differentiation Scenarios according the Road Type



The third set of scenarios extend tolls also on the state road (Figure 5-4). A first group of three tests increases the charge on car travellers on the motorway, without any tolls on the state road. Conversely, trucks have to pay a toll on the state road, while the price of the highway does not change. As a result of such schemes, we have to deal with two complementary effects. On the one hand some car travellers shift to the state road because now the motorway is more expensive. This shift leads to savings in time spent on the network since, on the other hand, truck drivers are now induced to leave the state road for the motorway, with positive effects in terms of traffic congestion on the ordinary network.

Also trucks get benefits, even more remarkable compared with the ones obtained by motorists, from their shift in terms of time spent, as a share of car travellers move to the state road and then the motorway is less congested. Total travel costs increase on the whole. Revenues increase for the motorway operator, and in these scenario a share of profits originates from charges on the state road.

Tests R4 and R5 provide a toll scheme in which also car travellers have to pay a fee on the state road, while hauliers receive a discount on current motorway charge. Results show that the presence of a toll on the state road reduces the route shift of car travellers. In comparison with the third scenario, some of them prefer to choose other transport modes instead of using the car.

In these two scenarios the route shift for trucks from the ordinary road to the motorway is larger compared with the one obtained in tests R2 and R3, even though in the latter the relative cost of the motorway with respect to the state road is higher. This evidence suggests that the toll level on the motorway is the leading driver of route choice for the road freight vehicles. Therefore, a toll scheme based on a combination of incentives (on motorway) and disincentives (on the ordinary network), like tests R4 and R5, seems more effective, in terms of traffic reallocation, than a policy only based on a larger toll on roads (like in tests R2 and R3). Discounting tolls for trucks on the motorway when the state road is charged seems also not detrimental for the motorway operator. In fact, the revenues deriving from trucks decrease noteworthy (respectively -20.3 and -19.3 percent with respect to the base case). But this loss is more than balanced by the gains originated by higher tolls for car travellers and, above all, tolls on the state road.

It's worth to note that the best scenario, under the motorway operator perspective, is the last one in which, in spite of a remarkable decrease in the revenues from hauliers, the total revenues increase 22.5 percent. At the same time, however this scenario gives rise to a strong rise in car travellers costs (+7.8 percent).

All in all, the simulations suggest that there may be a trade-off between objectives. For instance, the better scheme for improving travel time on the network can be obtained discounting the motorway tolls, which is however not welcome by motorway operators unless also roads are charged, but this sharply increases travel costs for all road users. Also, applying motorway tolls proportional to the level of emissions can give rise to undesired effects in terms of congestion for travellers, because of the shift of some traffic on the state road.

5.2.4 Results of Scenarios Based On A Mix Of Differentiation Criteria

With the aim of analysing the possibility of balancing the impacts of the alternative schemes, the second group of tests concerned a mix of various differentiation criteria. In total, eight scenarios have been defined, where vehicles are charged according to their EURO category as well as their size (freight vehicles only) and tolls are introduced also on the state road. Table 5-7 provides a summary description of the scenarios, in terms of changes with respect to the previous one.

Figure 5-5 reports the main aggregate results obtained simulating the eight mixed scenarios. In the first scenario charges vary among vehicles according to their EURO class and the level of tolls is different between car travellers and hauliers since, as we have seen before, the demand elasticity of trucks is higher compared with the motorists' one. The test introduces also an incentive for light lorries and a disincentive for the largest ones. On the state road, hauliers have to pay a fee, but they receive a discount on the highway. Concerning lorries and compared with the current tax scheme, the price of the motorway has risen just for the largest and most pollutant (Euro1 and 2 class) ones.



As a result, total time spent by travellers on the network decreases (-1.2 percent with respect to the base case), in consequence of a strong reduction of travel time spent by truck drivers (-5 percent), while the time gains for car travellers are not significant. Total network costs increases 4 percent, with a larger variation for motorists (+5.9 percent) and a smaller one for trucks (+0.3 percent). With respect to environmental parameters, this toll scheme leads to positive results for all pollutant emissions but PM, which level grows due to the strong shift of trucks from the state road to the motorway and the consequent rise of average speed. A 23.8 percent rise in private revenues results from both highway and state road charges.

The second scenario M2 introduces a fee on the state road also for car travellers, while trucks do not receive a discount on the highway anymore. This change relative to the previous test leads to substantial modifications of the results. The motorists' shift from the highway to the state road is now less noteworthy because of the new toll. This implies a higher gain in terms of time saved (-1.1 percent) for car travellers. The shift of trucks from the state road to the motorway is much lower, as their gains in term of total time spent on the network (-4 percent).

On the whole, time savings (-1.6 percent) are counterbalanced by the rise in costs incurred both by car (+6.6 percent) and trucks (+4.5 percent). Concerning pollutant emissions, the toll scheme provides an improved scenario, in which also PM level reduces. Also in terms of revenues for the motorway operator, this test leads to a better result (+38.3 percent) compared with the first one.

Table 5-7 Summary Description of the Mixed Scenarios

Scenario	EURO Category	Vehicle Size	Road Type
TEST 1	Disincentives for all pollutant vehicles. Larger difference for cars than for trucks.	Discounted tolls for light vehicles, higher tolls than the current ones for heavy vehicles.	State road tolled for all freight vehicles (50% of current motorway charge). 25% discount on the motorway for all trucks.
TEST 2	No changes with respect to test 1.	No changes with respect to test 1.	State road tolled also for cars (30% of current motorway charge). No discount for trucks on the motorway.
TEST 3	25% discount for EURO 4 cars.	No changes with respect to test 1.	The toll for trucks on the state road increases (100% of current motorway charge).
TEST 4	No changes with respect to test 3.	Rise in the discount for light lorries. Heavy lorries are not overcharged anymore.	No changes with respect to test 3.
TEST 5	EURO 2 cars are not overcharged anymore.	No changes with respect to test 4.	No changes with respect to test 3.
TEST 6	10% discount for EURO 2 cars with respect to the current charge.	Light lorries are not discounted anymore.	25% discount on the motorway for all trucks.
TEST 7	20% discount for EURO 2 cars with respect to the current charge.	Light lorries receive a 25% discount.	State road is overcharged for cars (40% of current motorway toll). The motorway is 10% overcharged for trucks.
TEST 8	EURO 3 cars are less overcharged with respect to the previous scenario. 10% discount for EURO 2 cars with respect to the current charge.	No changes with respect to test 7.	No changes with respect to test 7.

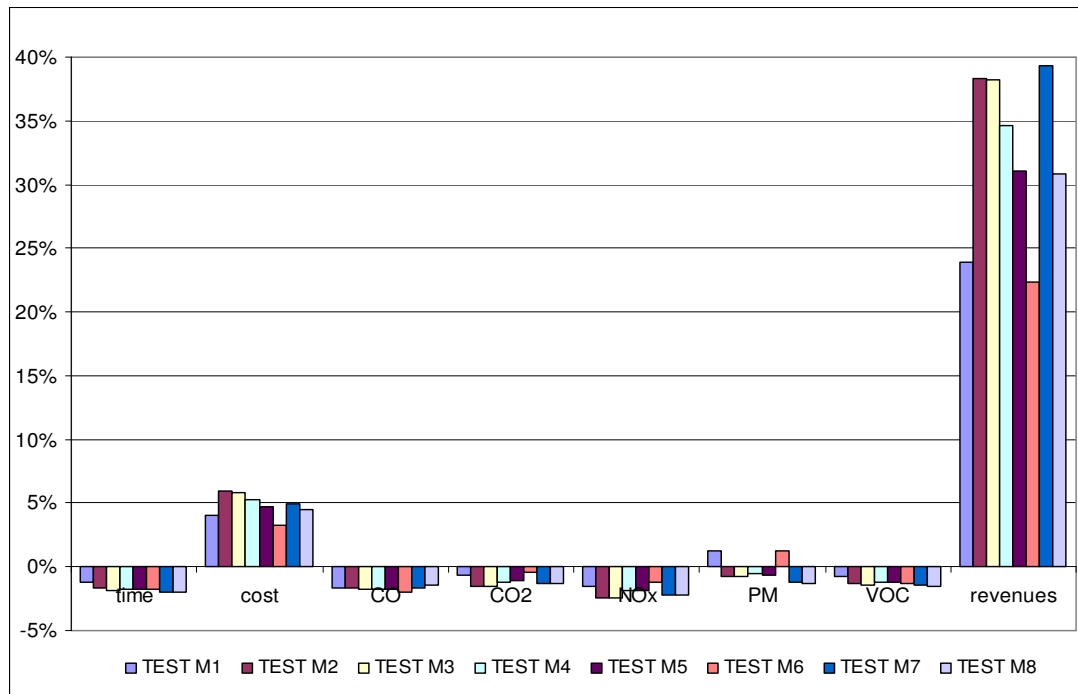


Figure 5-5 Summary Results of the Mixed Scenarios

Even though these two tests have shown positive results in terms of improved average speed, total travel costs are well higher the current level especially for car travellers. The third scenario attempts to reckon with this issue, providing a discount on the highway for the “cleanest” cars. At the same time, trucks tolls on the state road are increased in order to stimulate their shift to the highway. With respect to the previous scenario, savings in travel time are improved (-1.8 percent) by the stronger shift of trucks from the state road to the motorway. However, the effect of the new toll scheme on total costs incurred by travellers is very low and their expenditure on the network still increases by 6.2 percent. This result can be explained by the small number of new and less pollutant cars on the network. In general, total costs, emissions and private revenues continue to vary in the same manner as in the previous simulation.

Recalling what we have seen about a toll scheme based on vehicles size, providing incentives for light lorries seems to be the most effective policy under the viewpoint of traffic flows reallocation between the state road and the motorway. Therefore, the frame of the policy can either provide for a system of incentives and disincentives, as in the first three mixed scenarios, or just an incentive (a disincentive) for the lightest (larger) ones. The, fourth test modifies the structure of the toll scheme, increasing the discount for light lorries and removing the overcharged toll for the larger ones.

With respect to the previous scenario, nothing changes for car travellers. Concerning the truck drivers, within this toll scheme a stronger shift from the state road to the motorway can be observed, due to the fact that light lorries have a greater incentive to shift while, at the same time, the cost of the highway for the larger ones has reduced. However, compared with the third scenario, this change in traffic flows allocation does not lead to significant variation in terms of time saved. Total network costs increase by 5.2 percent, less than in the third scenario, because of the decrease in revenues resulting from freight vehicles. In general, the earnings of the motorway operator still grows noteworthy (+34.7 percent) with respect to the current scenario.

As the increase in total network costs is still remarkable, the fifth test decreases the charge relative to EURO 3 car class. Compared with the fourth scenario, the rest of the toll scheme does not change. Results are in line with expectations, but with no remarkable differences with respect to previous scenarios: in terms of time spent on the network, this simulation leads to a reduction of about 1.7



percent, the same as before. The rise in network costs is a bit lower (+4.8 percent), due to the toll reduction for some car travellers and, for the same reason, the motorway operator revenues also increase less than in the previous scenarios (31.1 percent). It could be noted that also environmental results are not significantly affected by the variants experimented.

The sixth scenario provides for a greater discount for EURO 2 car class and, considering trucks, it does not distinguish anymore among size categories but grants a discounted charge for all lorries on the motorway. Time savings are remarkable, especially for trucks (-4.9 percent), whose shift from the state road to the motorway is stronger in respect to the previous scenario. At the same time, the increase in network costs is smaller (+3.3 percent). Therefore, within the mixed scenarios, the sixth one leads to the best result under car travellers perspective, since time saved is large and the increase in cost is weaker compared with other tests. However, the improvement in emissions' reduction is less relevant and the PM level even grows. A 22.3 percent rise in the revenues represents the gains for the motorway operator, still significant although lower than in other scenarios. Even though the outcome of the previous scenario is quite positive for road users as a whole, benefits are quite unbalanced between passengers and freight. Trucks enjoy a benefit in terms of time spent on the network without suffering from an increase in total costs, while time saved by car travellers is low (-1.1 percent) and the raise of their costs is significant (+4.9 percent). At the same time the environmental results are not satisfying, Test M7 and M8 try to address these aspects

In the seventh scenario the charge on EURO 2 cars is reduced, while the charge on the motorway and on the state road increases, respectively, for trucks and motorists. Again, light lorries receive a discount. With respect to the previous scenario, environmental impacts are actually improved as pollutant emissions are all reduced including PM emissions. This result is obtained without worsening significantly other indicators: time saved by car travellers is slightly higher (-1.4 percent), while the increase in costs is constant (+4.9 percent). The overcharge of the motorway for medium size and large trucks leads to a strong reduction in time spent (-4.5 percent), even if a strong rise in costs (+4.9 percent) can be observed. This toll scheme also leads to relevant result from the network operator point of view, since his revenues increase strongly (+39.3 percent).

The last scenario (Test M8), provides a change in the previous toll scheme, attempting to decrease car costs. The charge for EURO 2 cars is therefore reduced. Compared with the previous test the time saved is constant, but the increase in network costs is less remarkable (+4.5 percent on the whole). And the emissions reduction is comparable with the one resulting from Test M7. Revenues of the motorway operator are lower, but still noteworthy (+30.8 percent).

5.2.5 Optimisation Scenarios

As explained above, mixed scenarios have been arranged trying to obtain balanced results for all subjects: car users, motorway operator, the environment. However, assuming that specific targets are defined for a tolls differentiation policy, another group of tests has been carried out searching from the scheme able to minimize or maximise some specific variables. In particular, two objectives have been defined: reducing the time spent on the network and reducing pollutant emissions.

A first group composed of four tests makes an attempt of minimizing the environmental impact of traffic on tolled network. Figure 5-6 summarises the outcomes of the tests. In all scenarios what change is only the charge on cars by EURO class and on trucks by size: other charges are the same provided by Test M8 as this test proved effective from several point of views.

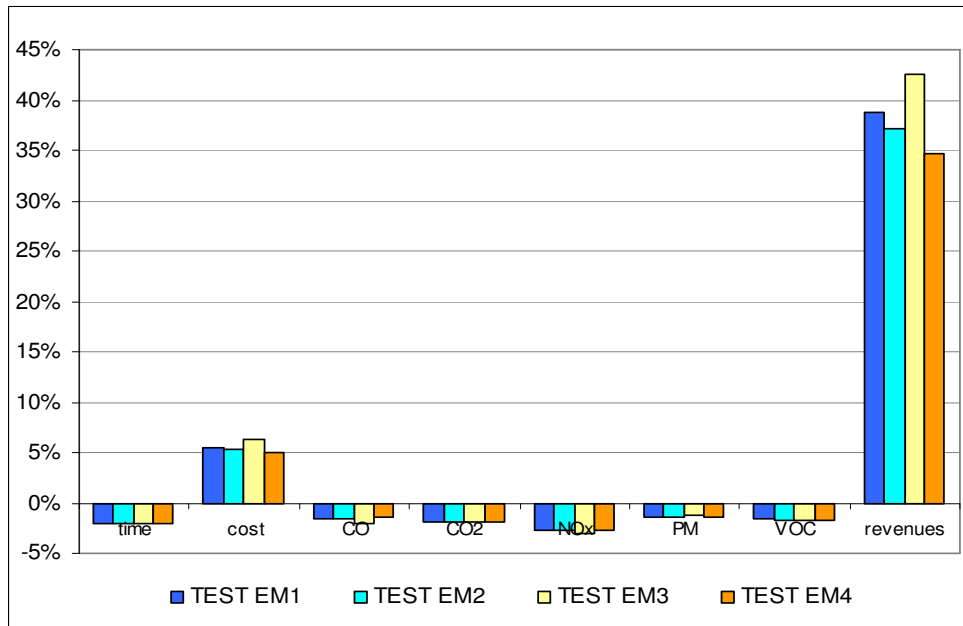


Figure 5-6 Summary Results of Optimisation Scenarios for Minimising Emissions

The first scenario provides a higher toll for EURO 3 cars and a lower one for EURO 2 class. Light lorries receive a discount, while large one are overcharged. In fact, as we have seen in the fifth toll scheme based on vehicles size, the trucks shift from the state road to the motorway leads to a decrease in all kinds of emissions but CO and, when this shift is sizeable, PM. As a general result, the opposite is true for car travellers: a shift from the highway to the state road implies a lower level of pollutant emissions. Compared with Test M8 the reduction in first scenario emissions is stronger. Trucks CO emissions increase by 2 percent, but this growth is more than balanced by the reduction in cars pollution and as a whole also CO reduces (-1.6 percent).

The second test makes an attempt of reducing costs supported by the hauliers through the increase in the incentive for light lorries. With respect to the previous scenario, the trucks shift from the state road to the highway is slightly more relevant but it does not seem to generate significant effects on pollutant emissions.

Keeping into account this evidence, the third test lets unchanged the toll scheme by size and overcharges fees on all EURO categories. The aim of this test consists in stimulating car travellers road shift. Predictably, this scenario leads to a higher decrease in pollutant emissions, especially concerning CO, which primarily depend on cars rather than on trucks.

In terms of environmental impact, the results arising from this charge scheme can be compared with the ones referred to Test E3, which anyhow provided a higher rise in travellers costs (8.7 percent). In fact, the main issue related to “environmental” toll schemes regards the trade off between network costs and environmental improvement. If an increase in time-saving is consistent with a reduction of pollutant emissions, the same does not hold in the case of travellers costs. All these three scenarios provide a relevant rise in costs suffered both by motorists and trucks drivers.

In order to reckon with this issue, the last test (Test EM4) imposes a decrease, with respect to the third one, on the cars charges classified by EURO class. Results are, of course, less positive in terms of environmental improvement and essentially comparable with the ones provided by the first test. However, from travellers perspective this scenario leads to a rise in costs still remarkable (+5 percent), but lower compared with the one provided by Test 1 (+5.5 percent). In general, concerning emissions, up to a given limit a reduction is consistent with an increase of the motorway revenues and with a decrease of congestion. However, improvement of the environmental effects cannot be obtained without large costs for travellers.



Another group of tests deals with the issue of time savings maximisation. Under this perspective, the best results have been obtained in the pursuit of pollutant emissions minimisation, even though these scenarios were not satisfactory from travellers' point of view because of their relevant costs.

Generally speaking, a positive result in terms of time spent on the network can be achieved by stimulating trucks shift from the state road to the motorway. In this sense, an effective toll scheme should provide incentives for light lorries, which demand elasticity is higher compared with larger ones. On the other hand, if car travellers moves from the motor way to the state road, they can benefit from the less congestion due to trucks shift. Combining these two behaviour represents the best policy in order to achieve significant results in time-saving terms. Figure 5-7 summarises the outcomes of the tests.

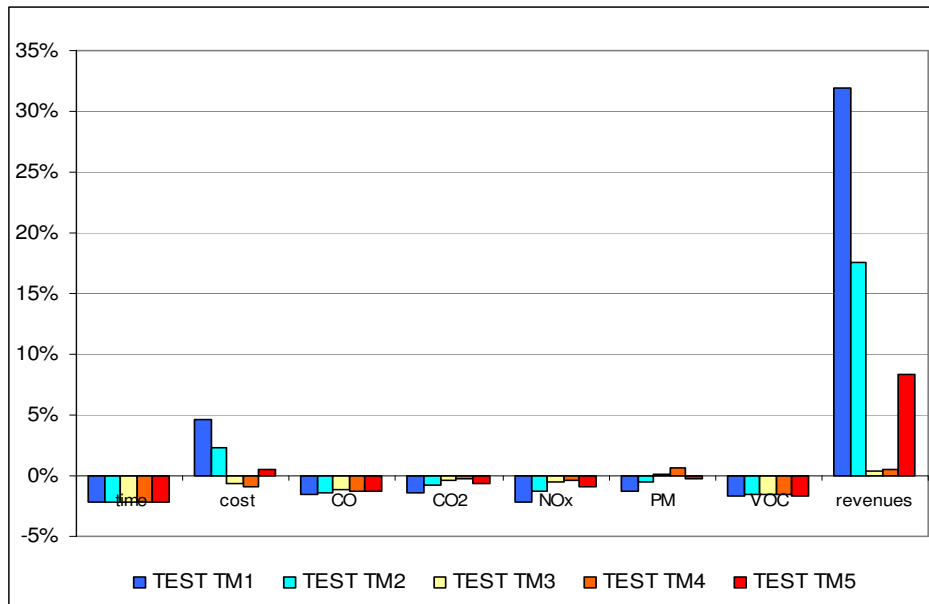


Figure 5-7 Summary Results of Optimisation Scenarios for Maximising Time-Savings

The following tests modify the structure of the toll system regarding tolls on the state road, while other charges are, again, the same provided by Test M8. With respect to the latter, the first scenario provides a higher fee for car travellers on the state road. Time spent on the network by motorists decrease (-1.6 percent), both on the state road and on the motorway. It could be noted that also a shift from car to other transport modes is observed particularly for tourism (-2.5 percent) and other purposes (-1.4 percent). Lorries reduce the time spent on the network as well (-4.4 percent) but, altogether, the rise in total costs is relevant (+4.6 percent).

The second test provides for a decrease of the charge on the state road paid by car travellers, in order to reduce costs and, at the same time, to preserve the gains in terms of time spent on the network. The evidence arising for such a toll scheme seems to provide positive effects, since time savings are not significantly diminished (-2.1 percent), while the increase in costs is lower (+2.3 percent).

The two following tests decrease again the charge paid by both car travellers and truck drivers. The reduction in time spent is constant (-2.1 percent) and benefits are always higher for lorries (-5 percent) compared with car travellers (-1.5 percent). As time spent on the network, also travellers costs reduce, while private revenues slightly increase.

The toll scenario in this last two cases provided a 25 percent discount for all car travellers on the motorway. The fifth test tries to provide a mix between the first and the last two scenarios, in order to improve the results for travellers, without affecting too much the private revenues of the network operator. Both truck drivers and motorists receive a 20 percent discount on the motorway, while the toll is 10 percent overcharged for big trucks. Obtained results split the benefits between travellers and



the network operator. The gain of the former in terms of time spent is still there (-2.2 percent), while the increase in total costs is low (+0.5 percent). The latter benefits from the increase of revenues (+8.3 percent).

As a general result, once again, the design of each scenario has to deal with the trade-off between costs for travellers and profits for the network operator. In all scenarios the attempt to achieve positive results in terms of time saved lead to an improvement in the environmental impact of pollutant emissions. This evidence is also suggested by the previous group of test, which were oriented towards emissions reduction. In that case, however, benefits in terms of time and environment coincided with a high increase in network costs and, as a consequence, in network operator. In this second group of scenarios, to the contrary, both travellers and the network operator can reach a satisfactory result. The rise in costs suffered by the former is, in Test TM5, very small compared with other scenarios. Concerning private revenues, they are still higher than in the BAU scenario (+8.3 percent), even though many other toll schemes provided better results from network operator perspective.

5.2.6 Toll Differentiation and Future Scenarios

In the majority of tested scenarios, the toll schemes involve, in some measure, the class emission of the vehicles and the size of the road freight vehicles. It should be noted that a toll differentiation scheme is expected to lead to two different effects. For instance, if tolls are increased for more polluting vehicles, in the short run the revenues of the motorway operator are supposed to grow, because the elasticity is lower than 1 so that the toll increment is not fully balanced by the route or modal shift of travellers. However, in the long run drivers could decide to renovate the fleet. Then, if the charge scheme provides benefits for “clean” cars, the revenues will presumably decrease. So, the question is: how sensitive are the results obtained in the tests to the change of the fleet composition? A group of tests reckoned with this issue.

Table 5-8 shows how the composition of the fleet of car and trucks is simulated to change in the various tests. It can be noted that the total number of trucks is not constant across scenarios, even at the same year: what has been kept fixed is the amount of tonnes transported. According to the share of heavy and light trucks in the fleet, the same number of tonnes requires a different number of trucks. Furthermore, also changes of the average load factor have been assumed.

Results of the tests are summarised in Figure 5-8. The BAU 2005 column in the figure above represents the base scenario at the year 2005. Test M8, as we have seen before, indicates the results arising from a mixed test based upon a strong discrimination between “clean” and “dirty” vehicles, especially concerning cars. For each variable (time, cost, etc.), the result obtained for this scenario, considered as the most preferable emerged from the previous tests, has been set to 100 arbitrarily and the results of the other tests are expressed as ratio with respect to such a value.

The test M8 2020 describes the situation predicted in 2020 with the same toll scheme as the one provided by test M8 but with an increase of total traffic on the network. All other tests assume the traffic at the year 2020 and let change the fleet structure, with a substantial reduction in the number of “dirty” vehicles. In fact, even without the incentive of higher motorway tolls, a large reduction of the share of “dirty” vehicles in the fleet is expected in the long run. The base case for this fleet renewal is the projection of the REMOVE model (test REMOVE). In the other tests, the composition of the fleet is changed both in terms of Euro category and in term of share of light and heavy vehicles.

An increase in the overall traffic without a change of the fleet (test M8 2020) would lead, of course, to a rise in traffic congestion, in costs suffered by travellers and, as a consequence, in private revenues. But in the long run the fleet will be renewed. The scenario REMOVE assumes the REMOVE projections for the year 2002, which depict a strong change in fleet composition: 85 percent of cars belong to EURO 4 class (right now this share is about 9 percent), while less pollutant trucks represents the 40 percent of the whole fleet. Results show that this change implies undesired results under the perspective of the network operator. A decrease of about 26 percent with respect to the presumed 2020 scenario leads to earnings even lower compared with current ones. Predictably, reduction in emissions is remarkable and travellers costs reduce as well. Traffic congestion increases as a result of the shift of lorries from the state road to the motorway, due to the less average cost of the latter.



Table 5-9 Tested Changes of the Fleet Composition at the Year 2020

Vehicles	EURO Category	BAU	2020 EXP	TREMOVE	TRT	TRT V2	TRT V3
Trucks							
<3.5 tons	EURO 1	7%	7%	1%	1%	0%	0%
	EURO 2	9%	9%	5%	5%	2%	0%
	EURO 3	17%	17%	14%	22%	12%	2%
	EURO 4	0%	0%	13%	22%	35%	7%
	TOT <3.5 tons	33%	33%	33%	50%	50%	10%
3.5 - 16 tons	EURO 1	8%	8%	1%	0%	0%	0%
	EURO 2	13%	13%	6%	2%	1%	1%
	EURO 3	14%	14%	16%	11%	6%	5%
	EURO 4	3%	3%	15%	11%	18%	14%
	TOT 3.5-16 tons	38%	38%	38%	25%	25%	21%
Vehicles							
EURO Category							
BAU							
2020 EXP							
TREMOVE							
TRT							
TRT V2							
TRT V3							
>16tons	EURO 1	15%	15%	1%	0%	0%	1%
	EURO 2	5%	5%	4%	2%	1%	4%
	EURO 3	8%	8%	12%	11%	6%	17%
	EURO 4	0%	0%	11%	11%	17%	48%
	TOT >16 tons	29%	29%	29%	25%	25%	69%
TOT. Trucks		9.499	12.008	11.946	13.976	13.738	6.745
Cars							
	EURO 1	36%	36%	1%	0.5%	0.5%	0.5%
	EURO 2	31%	31%	5%	2.5%	2.5%	2.5%
	EURO 3	24%	24%	9%	5%	5%	5%
	EURO 4	9%	9%	85%	92%	92%	92%
	TOT. Cars		68.108	77.060	75.693	75.131	74.619

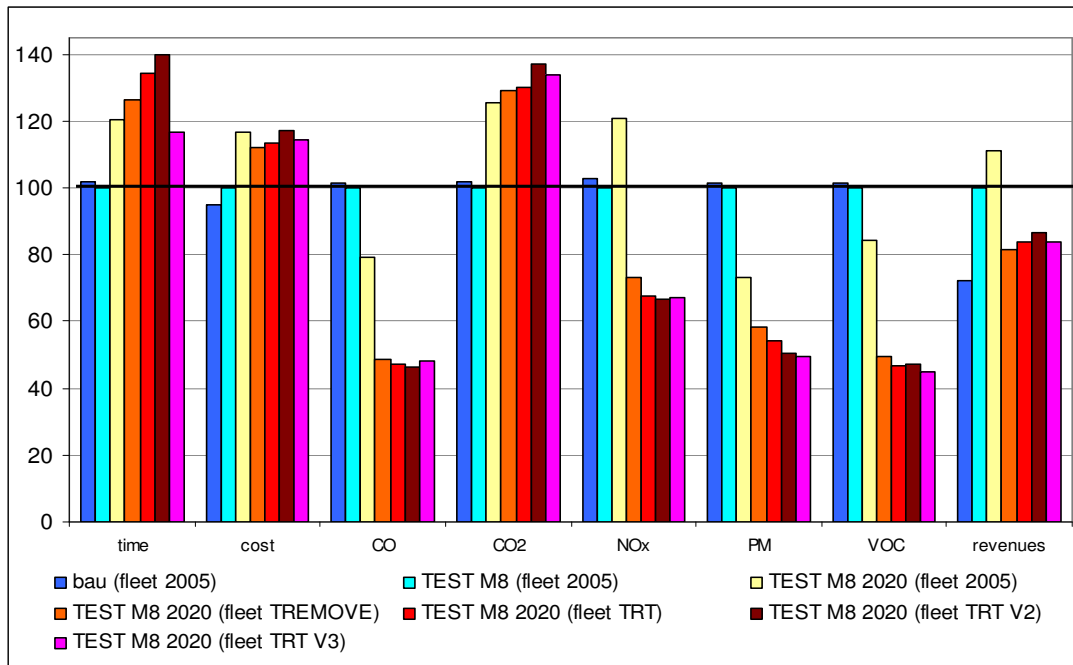


Figure 5-8 Summary Results of Scenarios with Changes of the Fleet Composition



It may be assumed that individuals and firms will react to higher tolls, so that the fleet composition could be different from the TREMOVE forecasts. The TRT scenario assumes a very high share of EURO 4 cars (92 percent). For the trucks, the percentage of cleaner vehicles on the whole rises to 44 percent and the composition of the fleet by size changes as well. At the same time, the 50 percent of vehicles is assumed to be composed by light lorries (the current shares amounts to 33 percent), as a consequence of the toll scheme that provides incentives for small vehicles. Since the model keeps constant the total amount of transported tons, an increase in the share of light lorries on the whole fleet implies a rise in the number of vehicles as well. With respect to the previous scenario, results are slightly less negative from the network operator point of view. His revenues decreases by 24.3 percent with respect to the scenario M-8 even if there are more “clean” vehicles and light lorries, which receive discounts on the network. In fact, the higher number of light lorries leads to an increase in the total amount of tolls paid. Consequently, the earnings for the motorway operator derived from trucks go up 15 percent. At the same time, a higher congestion is observed with respect to the TREMOVE scenario, but the most remarkable result is that total transport costs for truck are higher than in the TREMOVE scenario. This means that the strategy of using more light vehicles would be not productive for the road freight transport sector as a whole. However, the idea behind this scenario is that a different composition of the fleet comes from several independent individual decisions. Of course, such decisions would be made after a scrutiny of all conditions: tolls, investment costs, operating costs, load factors, etc. Exploring this complex matter is out of the domain of this exercise. This scenario should be regarded as a sensitivity test: what happens with a different fleet composition.

In TRT V2 test, the truck fleet composition changes again, as the share of EURO 4 lorries amounts to 70 percent on the whole, while in terms of vehicle size, the same shares of TRT test are used. Trucks shift strongly from the state road to the motorway and this behaviour leads to an increase in total costs suffered by truck drivers. As a consequence of the rise in charges paid by lorries, the decrease in the network operator revenues is lower (-22 percent) compared with the one arising from the previous scenario.

The last test, TRT V3, leaves unchanged the structure of fleets in terms of emissions categories with respect to test TRT V2, but modifies the composition by vehicle size. The proportion of large trucks on the whole fleet becomes higher (69 percent).. Furthermore the load factor is improved by 15%. The rationale for this scenario is that hauliers strategy in reaction to the higher tolls for heavy trucks may be an optimisation of loads on such trucks, using a lower number of vehicles, rather than splitting loads on many light vehicles. Of course in these tests the total amount of trucks is significantly lower compared with other scenarios. Results show a strong reduction of traffic congestion on the state road due to the fact that a share of light lorries, for which the state road is sometime more attractive than the motorway, have been replaced with large trucks. Generally speaking, results are not very different from the ones obtained in the TREMOVE scenario.

The outcomes of the last three scenarios suggest that even quite large modifications of the fleet composition in terms of vehicle size do not modify significantly aggregated results. At the same time, the evidence arising from this group of tests seems to show that a toll scheme based on differentiated charges by EURO class may endanger the network operator revenues in the longer terms even if in the short term this scheme leads to remarkable, positive results.

5.2.7 Social Impact of Different Scenarios

So far, scenarios have been primarily analysed for their effects on the various target variables (travel times, costs, emissions, revenues of operator). In most cases, trade-off effects have been shown: improvements on the side are offset by worsening on other sides. One may ask which combination is the “best” one. Furthermore, the evidence from the tests shows that only limited emissions and travel time reductions can be achieved using toll differentiation schemes. So one may ask whether there is a real payoff for the higher travel costs. In order to address these questions, under a cost-benefit analysis perspective, the evaluation of a set of scenarios has been carried out using shadow prices of travel time and pollutant emissions. In this way, different outcomes could be added to each other.

It should be remarked, however, that we have not performed a real cost-benefit analysis since, for instance, implementation costs have not been considered, costs and benefits have not been evaluated



over a period of time using a discount rate, etc. What we have done is just to use shadow prices to obtain commensurable values and add times, costs and emissions.

The shadow prices used are reported in Table 5-10. The values of travel times for freight are derived from values in Euro/ton*hour estimated in the SCENES project⁴⁵. The values of travel times for passengers have been estimated using results of direct surveys carried out by TRT in Italy. The marginal costs of polluting emissions are estimations made for the ASTRA-Italia project⁴⁶ starting from the INFRAS-IWW values⁴⁷.

Table 5-10 Shadow Prices used for the Estimation of the Economic Benefit of Scenarios

	VOT*	CO**	CO2**	NOx**	PM**	VOC**
Cars	11.7	3.1	87.2	6 863.2	173 276.5	1 073.7
Trucks	20.9	2.1	87.2	6 863.2	173 276.5	1 073.7

*Euro per hour

**Euro per ton

The following figures show the results of the scenarios in terms of total benefits enjoyed by the society in comparison to the BAU scenario. Then, positive values imply a gain in social welfare (lower costs), while negative values represent a loss (higher costs).

Outcome of this analysis shows the existence of a clear trade-off between the social cost and the income of the motorway operator (not considered in the balance since it is a transfer and it is already accounted within total travel costs). None of the scenarios when a simple differentiation scheme is applied comes up with a positive results: costs are always higher than in the BAU case. This is caused by the significantly higher travel costs while the reduction of travel times and emissions, when existing, are too limited to offset the monetary expenditure.

In mixed scenarios we often obtained better results in terms of less traffic congestion and pollutant emissions. However, as we can see from Figure 5-9, considering shadow prices of time and pollution, the costs of this toll schemes always exceed its benefits. Even Test M8, which has been used as an “optimal” scenario, provides a negative result. The same result applies for those scenarios aimed at reducing emissions.

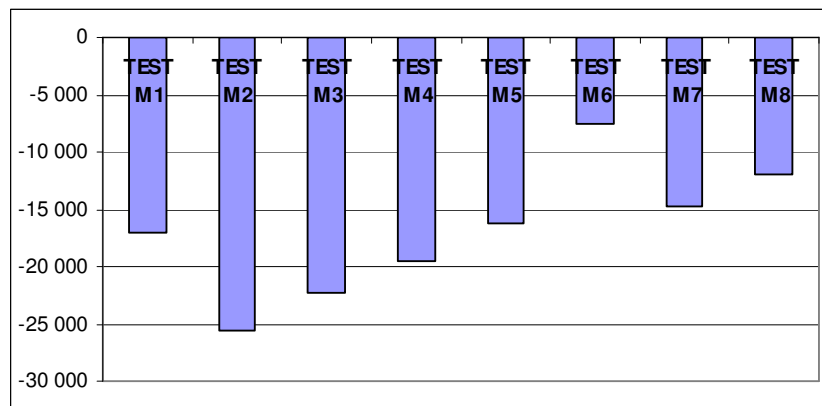


Figure 5-9 Net Economic Benefit of Mixed Tolling Scenarios

45 ME&P et. al., 2000, SCENES European Transport Forecasting and Appended Module: Technical description, Deliverable D4 of SCENES, Funded by European Commission 4th Framework Programme, Cambridge, UK.

46 Centro Studi Federtrasporto, 2002, Bollettino economico sul settore dei trasporti - Fisco e pedaggi per ridurre i costi del trasporto: la metodologia, n. 12, Roma.

47 INFRAS-IWW, 2000, External costs of transport, Zurich/Karlsruhe.



A time-saving oriented toll differentiation implies, on the contrary, the possibility to reach positive results in terms of social welfare (Figure 5-10). The first test of this kind leads again to a negative result, due to the rise in costs paid by travellers (+4.6 percent). Other toll schemes have positive effects in terms of social welfare as benefits exceed costs. It can be noted that in all this group of four scenarios where benefits exceed costs, also the operator revenues are at least equal to the original level or even higher. This result does not depend on larger travel time savings but on lighter tolls: discounts are used as well as surcharges.

It may worth to mention that benefits from travel time savings have been computed, as usual, by applying the reference value of time to the sum of saved times. As a whole this sum is of thousands of hours, but if a single trip is taken into account, in many cases only few minutes are saved. Although current practice recommend to consider also marginal travel time savings (see Lyons 2006), one may be dubious that such limited differences do have relevance for travellers.

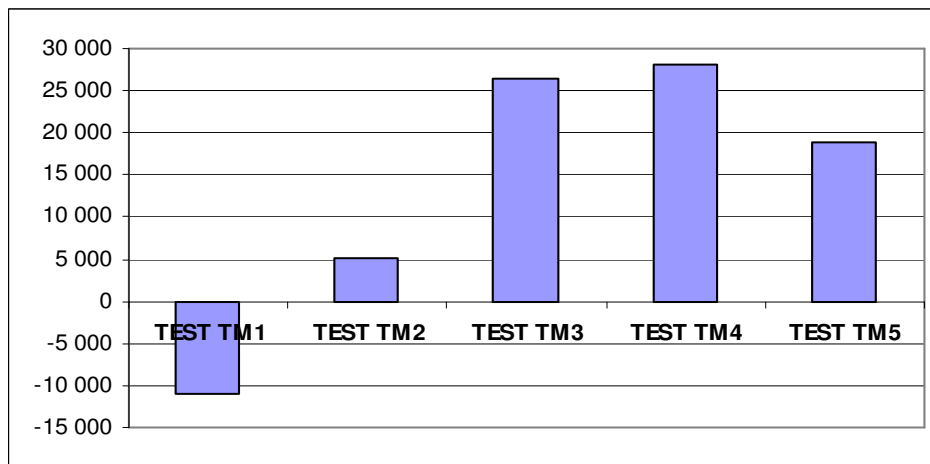


Figure 5-10 Net Economic Benefit of “Time Saving Oriented” Tolling Scenarios

5.3 PADANA REGION MOTORWAY MODEL

5.3.1 Characteristics of the Model

The Padana Region Motorway model has been elaborated in order to test the impacts of further toll differentiation on the complex motorway network existing in its study area, which comprehends Lombardia, Emilia Romagna and Veneto Regions.

The Padana Region is one of the main gates for both passenger and freight traffic and his motorway network is composed by the following motorway existing and in project:

- A4 Milano – Venezia,
- A1 Milano - Bologna ,
- A22, Brennero - Modena,
- A21 Piacenza – Brescia,
- A13 Padova – Bologna,
- the Cremona –Mantova axis (in project),
- the Brescia – Bergamo – Milano axis (in project),
- the Pedemontana axis (in project),
- The Tirreno - Brennero axis (in project).

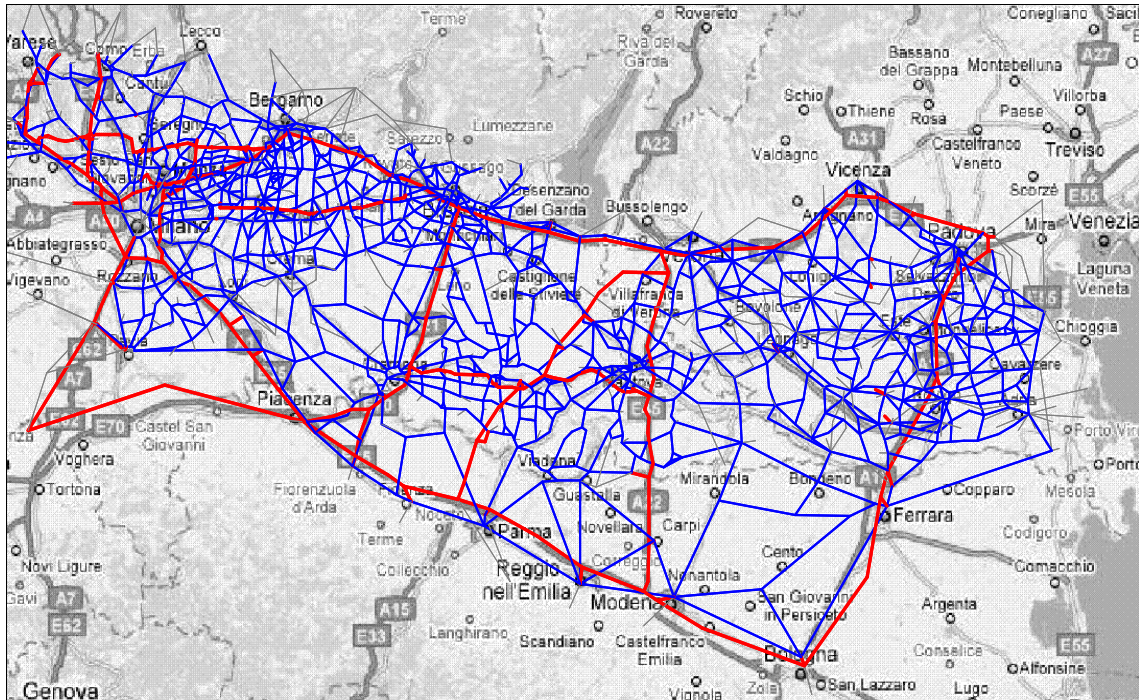


Figure 5-11 The Padana Region Motorway Model Network

The region comprehends areas where population and activities are intensively located, so that the road network is intensively used for (relatively) short-distance trips within the study area. The network of national roads is also consistently developed beside the motorway network, and can be considered as an alternative route (of course especially for local trips).

The Padana Region Motorway model has been the results of the update of an existing road transport model of the Italian section concerning this area. The model is implemented using the Meplan software package.

The model simulates route choice for both passenger and freight demand, expressed in terms of vehicles. None of the other modes is considered as alternative to road transport. As explained above, the study area is crossed by a complex road network, described in a detailed way in the model (see Figure 5-11). As a consequence, the zoning system includes a consistent number of zones defined with the objective of simulating both local and long distance traffic.

For the purpose of this study, the model has been updated introducing vehicle differentiation for both freight and passenger, in order to permit the introduction of differentiated toll. The adopted scheme has been drawn from the Brenner model structure.

Vehicle Types

Several types of freight road vehicles and passenger cars are modelled according to different dimensions: size and standard EURO. As far as the latter is concerned, for both car and trucks there are four categories:

- EURO-I or less,
- EURO-II,
- EURO-III,
- EURO-IV



In terms of size, the following categories of freight vehicles are considered:

- <3.5 tons;
- 3.5-16 tons;
- >16 tons.

These groups are consistent to the MEET and COPERT classification and allowed us to use known databases (such as Copert 4) to split the fleets.

As a result, passenger demand is segmented according to the standard EURO of the vehicle used for the trip, while for freight demand the combination of size and standard EURO is considered. In the end, 4 segments are used for passenger and $4 \times 3 = 12$ segments for freight demand.

Origin/Destination Matrix

The Origin/Destination matrix was estimated on the basis of the existing road matrices for car and trucks, distributed among the different categories according to the fleet composition registered in the study area (ACI – Autoritratto 2005).

The toll differentiation tests have been implemented at the year 2020, when all the new motorway projects are supposed to be available. Different matrices concerning various configurations of the vehicle fleet have been produced in order to simulate the effect of its evolution on the toll analysis.

5.3.2 Differentiation Scenarios

The Padana Region Motorway model was applied to test several alternative scenarios of differentiated road tolls for passenger and freight, replicating as much as possible the differentiation schemes applied for the Brenner model.

As described above, the sources of differentiation considered have been:

- The variable used to differentiate tolls (e.g. vehicle size, emissions category);
- The level of differentiation (i.e. the difference between each toll level);
- The size of the tolls (i.e. for a given relative difference between each toll level, the absolute values can be larger or smaller), adopting the same selection procedure of the Brenner model in order to identify a manageable and meaningful number of tests.

5.3.3 Results on Scenarios based on Single Differentiation Criteria

A first group of scenarios dealt with differentiate motorway tolls on the basis of vehicles emissions class (Figure 5-12). As already mentioned for the Brenner transport model, the simulation results where disincentives for “dirty” vehicles are applied generate effects especially for heavy vehicles, which react more significantly than car drivers to higher tolls.

All tested scenarios produce an increase of the whole set of indicators analysed: in particular, the time spent from travellers on the network and the transport emissions are consistently growing with respect to the results of the Brenner model. The reason of this discrepancy can be found in the different characteristics of the study areas: in the Brenner case a not very congested corridor, in the Padana region a complex road network still closed to the capacity limit in its basic configuration. As explained above, the effect of tolls differentiation based on the pollution emission level of vehicles is to shift part of the traffic from motorway on ordinary road, with an overall worsening of congestion. In the Padana Region Motorway model this effect is additional to the already congested basic solution, which leads to more relevant increase concerning the time spent on the network and to worse condition for transport emissions.

As well, the cost increase is almost half of the observed in the Brenner model, probably because of the existence of a more consistent network of ordinary road as alternative option with respect to the tolled



motorway. As a consequence, the motorway operator revenues increases are lower than in the Brenner model case, but still ranging from +10% to +35%.

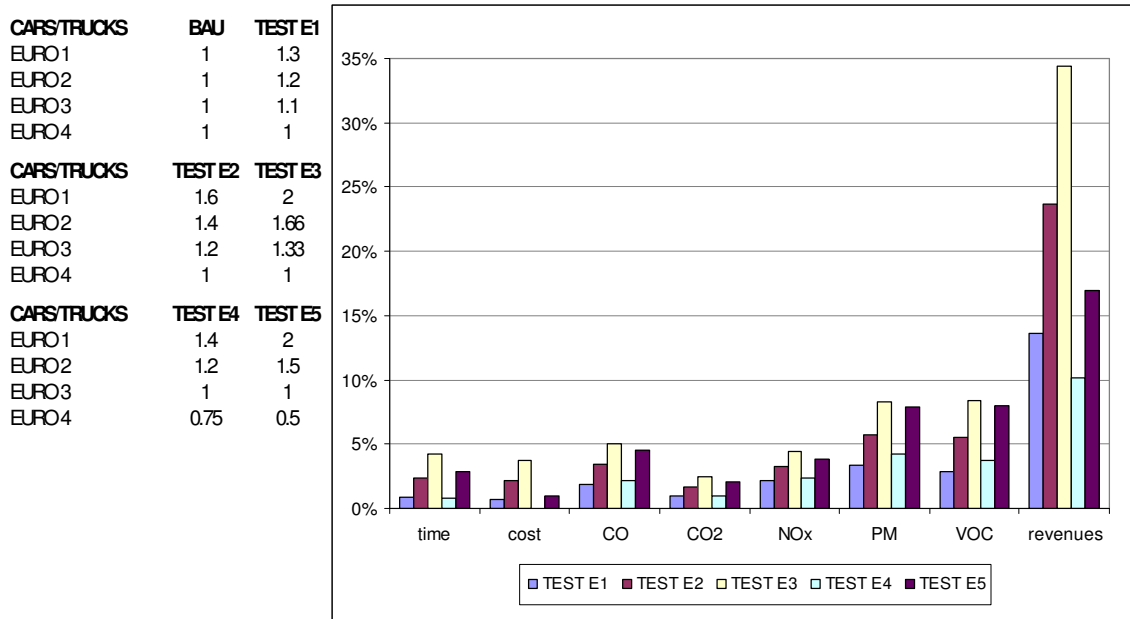


Figure 5-12 Summary Results of the Differentiation Scenarios According the EURO Category in the Padana Region Motorway Model

The second group of tests considered a toll scheme arising from discriminating trucks on the basis of their deadweight (Figure 5-13). Results confirm that in the Padana Region Motorway model trucks have more alternative roads than in the Brenner model, which produces a shift from the motorway network with a consequent decrease of cost in all the scenarios. The effect of coupling discounted tolls for light vehicles with slightly higher tolls for the heaviest vehicles (Test 5) is in contrast with what has been observed for the Brenner model: travel times are almost unchanged, transport emissions increase and the effect on the revenues of the motorway operator is a slight reduction. Similar effect (with the exception of transport emissions which slightly decrease) can be observed for the opposite policy for trucks (Test 4). In general, most of the scenarios are not satisfying from the emissions point of view and show unchanged values for the time spent on the network, as a results of the balancing trend which shift passenger from ordinary road to motorway and trucks in the opposite direction.

The last group of scenarios based on single differentiation criteria was focused on the management of the road network, balancing the tolling scheme on motorway and the network of main state road. Figure 5-14 shows the motorway network and the main state roads network, where the charges have been modelled.



CARS	BAU	TEST S1
cars	1	1

TRUCKS	BAU	TEST S1
Light < 3.5 tons	1	1
Medium 3.5-16 tons	1	1.1
Large > 16 tons	1	1.2

CARS	TEST S2	TEST S3
cars	1	1

TRUCKS	TEST S2	TEST S3
Light < 3.5 tons	1	1.3
Medium 3.5-16 tons	1.2	1.2
Large > 16 tons	1.3	1

CARS	TEST S4	TEST S5
cars	1	1

TRUCKS	TEST S4	TEST S5
Light < 3.5 tons	1.25	0.75
Medium 3.5-16 tons	1	1
Large > 16 tons	0.75	1.25

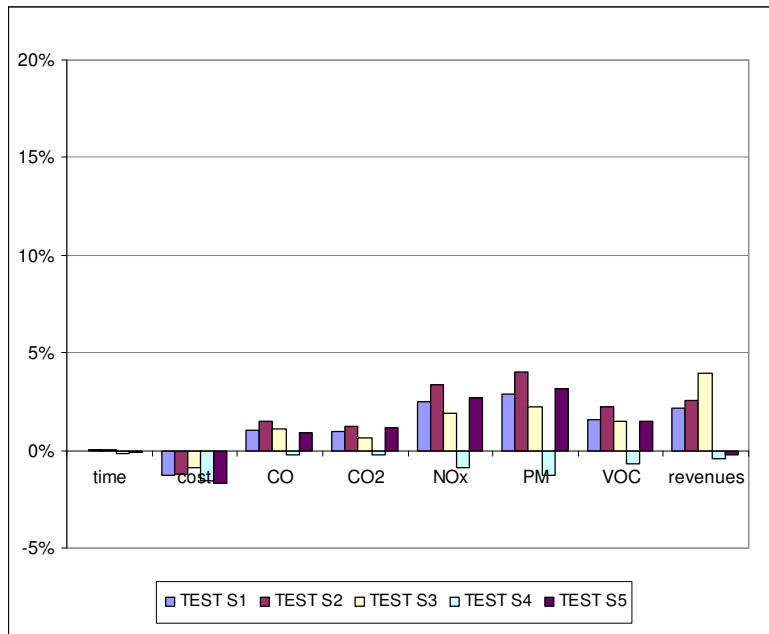


Figure 5-13 Summary Results of the Differentiation Scenarios According the Vehicle Size/Occupancy in the Padana Region Motorway Model

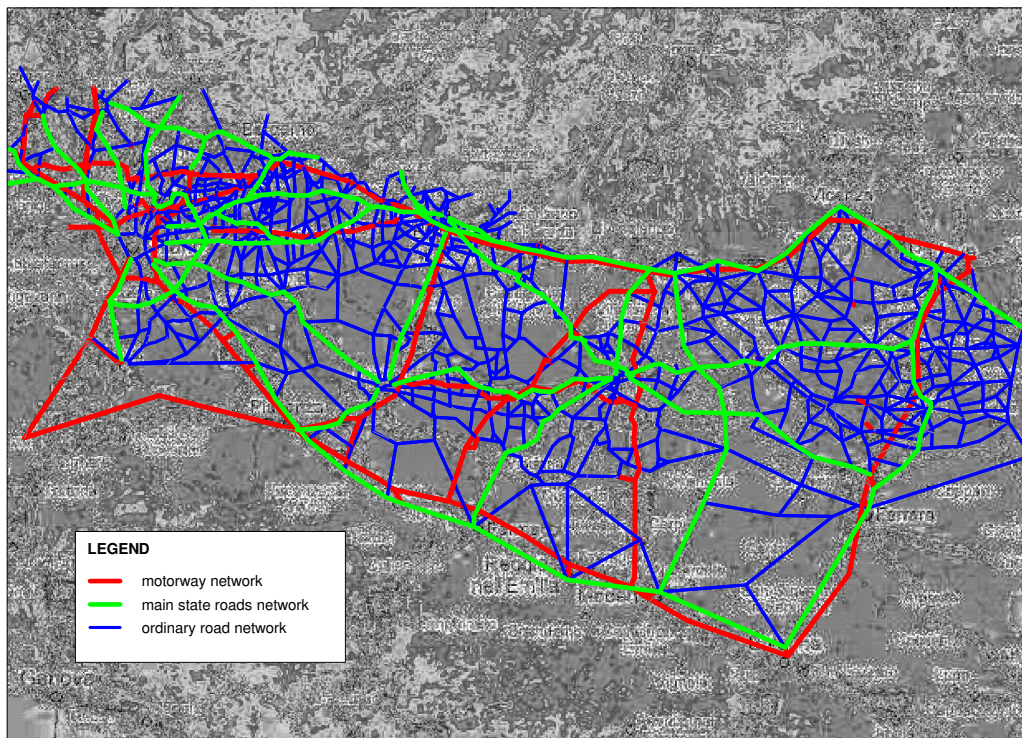


Figure 5-14 Motorway Network and Main State Roads Network in the Padana Region Motorway Model

The effect of the first group of tests - where the charge on car travellers on the motorway is increased without any tolls on the state road, while trucks have to pay a toll on the state road, the price of the highway remaining unchanged - is similar to the reaction observed in the Brenner model (Figure 5-15).



On one hand car travellers shift to the state road because of the increased toll on the motorway, on the other hand truck drivers are induced to leave the state road for the motorway: these shifts lead to savings in time spent on the network for both car and trucks. Unfortunately the positive effect on time (which is more consistent than in the Brenner model because the network starts from a congested configuration) does not produce positive effects on transport emissions, which increase for all the pollutants in any scenario considered. Total travel costs are almost unchanged for these three scenarios (from -0.8% to +0.6%) while revenues increase for the motorway operator as effect of the increased toll, with a small share of profits originated from trucks on the state road.

Tests 4 and 5 provide a toll scheme in which also car travellers have to pay a fee on the state road, while trucks receive a discount on current motorway charge. In the Padana Region Motorway model the results of these tests is similar to the previous analysed, except for the increase of cost (and consequently in revenues for the motorway operator) which is more consistent. Once more, the fact that the whole network is already congested in its basic configuration could cause similar effects in terms of shift from the motorway to the state roads (and vice versa) even if with different toll level applied. The structure of the model, which does not simulate the choice between different transport modes, could also explain the different results with respect to the Brenner model (where part of the demand is shifted to other transport modes).

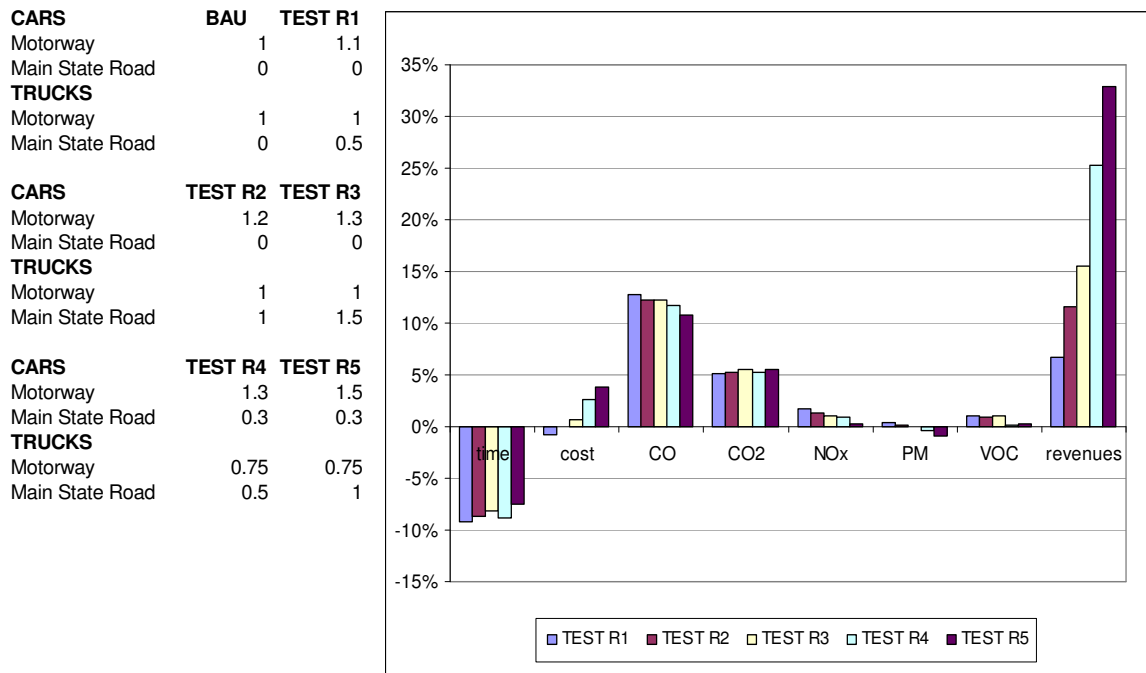


Figure 5-15 Summary Results of the Differentiation Scenarios According the Road Type in the Padana Region Motorway Model

All in all, the simulations suggest that there may be a trade-off between objectives. For instance, the better scheme for improving travel time on the network can be obtained with the management of motorway tolls and roads charging, but this seems to increase travel costs and transport emissions. Also, applying motorway tolls proportional to the level of emissions can give rise to undesired effects in terms of congestion for travellers.

5.3.4 Results of Scenarios based on a Mix of Differentiation Criteria

The following steps in the toll differentiation analysis concerned to test a mix of various differentiation criteria. First of all, several scenarios have been selected from the ones defined for the Brenner model, taking into account the observed discrepancies in the results. Then, on the basis of the analysis of these results, additional test have been made in order to obtain balanced results for all subjects: car users, motorway operator, the environment. In total, five scenarios have been defined, where vehicles



REPORT ON MOTORWAY TOLL DIFFERENTIATION

are charged according to their EURO category as well as their size (freight vehicles only) and tolls are introduced also on the state road.

The results of the tests are shown in Figure 5-16. In the first mixed test, charges on motorway vary among vehicles according to their EURO class in a differentiated way for car and trucks, an incentive is introduced for light lorries and a disincentive for the largest ones. Concerning road management, hauliers have to pay a fee on the state road, but they receive a discount on the highway. As a result, the price of the motorway for lorries has risen just for the largest and most pollutant in comparison to the current tax scheme, while car increase are consistent for all the Euro class, except for Euro 4.

As a result, total time spent by travellers on the network decreases (-7.7% with respect to the base case). Total network costs are almost unchanged (in contrast with the Brenner model where the same scenario caused an increase by 4%), as result of a small decrease for car and a correspondent increase for trucks. With respect to environmental parameters, this toll scheme leads to negative results, with a consistent increase for CO₂ and CO, due to the shift of cars from the motorway to the state road and the rise of average speed for trucks on the motorway. A 12% rise in private revenues (half than in the Brenner model result) is obtained considering both highway and state road charges.

Table 5-11 Summary Description of the Mixed Scenarios

Scenario	EURO Category	Vehicle Size	Road Type
Test M1	<ul style="list-style-type: none"> • Current toll for the EURO4 vehicles, • Higher tolls for older categories. • Larger difference for cars than for trucks 	<ul style="list-style-type: none"> • Discounted tolls for light vehicles, • higher tolls than the current charge for heavy vehicles 	<ul style="list-style-type: none"> • State road tolled for all freight vehicles (50% of current motorway charge) and discounted motorway toll (75%) • Car toll not introduced on state road and unchanged for motorway (100%)
Test M2	<ul style="list-style-type: none"> • Discounted toll for car EURO4 and EURO 3, • Higher tolls for older categories • (Larger difference for cars than for trucks) 	<ul style="list-style-type: none"> • Unchanged for all categories 	<ul style="list-style-type: none"> • State road tolled for all freight vehicles (100% of current motorway charge) and discounted motorway toll (75%) • Car toll introduced on state road (30%) and unchanged for motorway (100%)
Test M3	<ul style="list-style-type: none"> • Discounted toll for car EURO4 and EURO 3, • Higher tolls for older categories • (For EURO 1 Larger difference for cars than for trucks) 	<ul style="list-style-type: none"> • Discounted tolls for light vehicles, • unchanged tolls for medium-heavy vehicles 	<ul style="list-style-type: none"> • State road tolled for all freight vehicles (100% of current motorway charge) and increased motorway toll (110%) • Car toll introduced on state road (40%) and unchanged for motorway (100%)
Test M4	<ul style="list-style-type: none"> • Discounted toll for car EURO4 and EURO 3, • Higher tolls for older categories • (For EURO 1 Larger difference for cars than for trucks) 	<ul style="list-style-type: none"> • Discounted tolls for light vehicles, • higher tolls than the current charge for heavy vehicles 	<ul style="list-style-type: none"> • State road tolled for all freight vehicles (50% of current motorway charge) and discounted motorway toll (75%) • Car toll introduced on state road (20%) and unchanged for motorway (100%)
Test M5	<ul style="list-style-type: none"> • Discounted toll for car EURO4 and EURO 3, • Higher tolls for older categories • (For EURO 1 Larger difference for cars than for trucks) 	<ul style="list-style-type: none"> • higher tolls than the current charge for light vehicles, • Discounted tolls for heavy vehicles 	<ul style="list-style-type: none"> • State road tolled for all freight vehicles (50% of current motorway charge) and discounted motorway toll (75%) • Car toll introduced on state road (20%) and unchanged for motorway (100%)

The test M2 provides a discount for EURO 3 and 4 car class and, considering trucks, it does not distinguish anymore among size categories and reduce the toll for all lorries on the motorway. On the



other hand, a charge is introduced on the state roads for both car and trucks, which is respectively 30% and 100% of the original tolls on motorway: as a results, trucks tariffs are higher on state roads than on motorway. In this case, time savings are slightly higher with respect to the first scenario (-8.8%) and still more consistent than the Brenner model results (where the same scenario was simulated). This effect is due to a stronger shift of trucks from the state road to the motorway (and of car in the vice-versa direction) with respect to the previous scenario. At the same time, the increase in network costs is now visible but still small as amount (+2.4 percent). However, a slight reduction in emissions is observed for all pollutants, even if CO₂ and CO still to present increase around 5-10%. According to the effect observed on total cost, the revenues for the motorway operator show a 23%, more significant than in other scenarios.

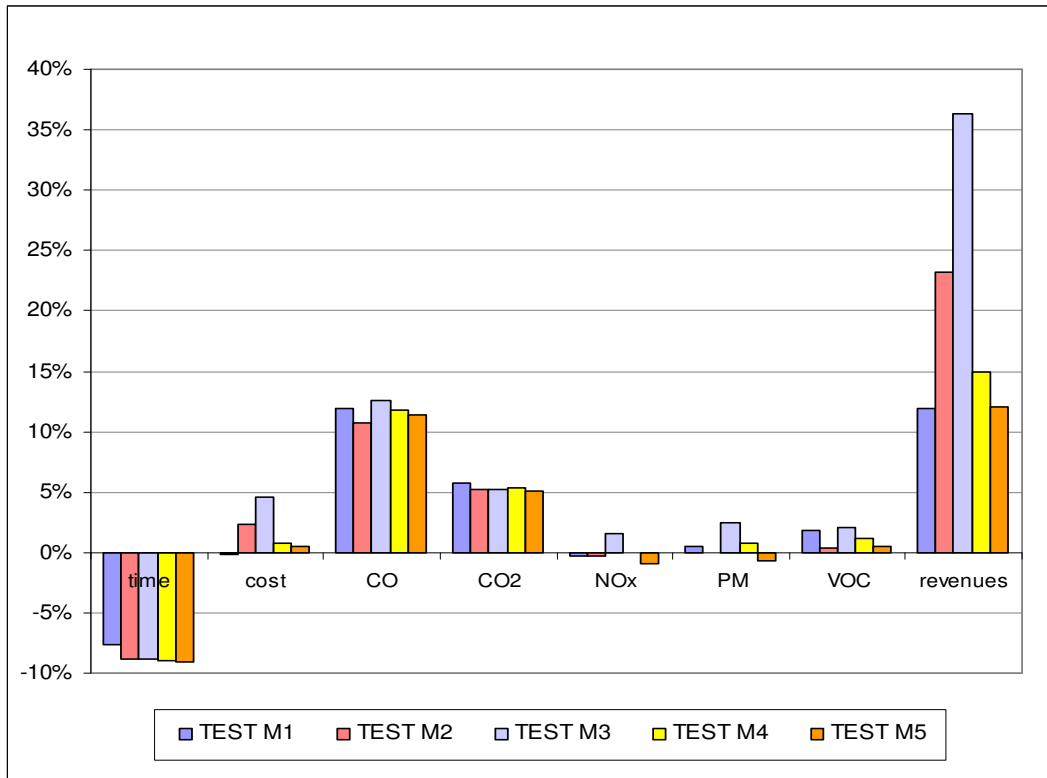


Figure 5-16 Summary Results of the Mixed Scenarios in the Padana Region Motorway Model

Scenario M3 decreases car motorway costs and reduces the charge for EURO 2 class, while an increase of car state road tariff is implemented. Concerning trucks, the discount on motorway is applied only for light duty vehicles, while a general increase is planned for the other lorries. Compared with the previous test, the time saved is the same, but the increase in network costs is more remarkable (+4.6 percent on the whole) and consequently the revenues of the motorway operator are increased (+36%). Also from the emission point of view the results are not satisfying, presenting the worst level of pollutants among the scenarios analysed so far.

Looking at the results of these three scenarios in comparison with the observed effects in the Brenner model, is possible to confirm the different reactions due to the structure of the models:

- Time savings are always more significant in the Padana Region Motorway model, where the shifts between motorway and state roads allow to reach better condition in traffic flows, while in the Brenner model the improvements are probably smaller because the network is not particularly congested in its basic solution;



- Thanks to the lower level of congestion of the network, the Brenner model generally shows positive effects in transport emissions, while the other model is often increasing the level of the pollutants;
- The hierarchy among the scenarios for total cost (and consequently revenues for the operator) is not consistent among the two models: the existence of a larger network of ordinary road (not tolled) as alternative option explains this effect.

Starting from the results of these scenarios, two additional tests have been implemented. Both the additional test start from the test M1, with few changes in order to improve the results for the aspects analysed.

The test M4 was focused on decreasing car toll on motorway, introducing discount for Euro 3 and Euro 4 classes with respect to the previous scenario. On the other hand, a charge on state roads is introduced for cars, calculated as 20% of the original tolls on motorway. As a results, the share of passengers moving from the motorways to the state roads is reduced, with positive effects on time saving (-9% instead of -7.7%). Transport emissions are also slightly decreased, while total cost show a small increase (+0.8%) which should anyway be acceptable for the users. Consequently, also revenues for the operator is increased by 15% instead of 12%.

One more step for improving results has been made applying a different toll scheme for truck based on their size: in fact, it was already noted that in this model the effect of coupling discounted tolls for light vehicles with slightly higher tolls for the heaviest vehicles produces similar results than the opposite policy (increasing motorway tolls for lighter vehicles), except for transport emissions which are lower in the latter case. So, test M5 applied this “reverse policy” in terms of vehicle size: slightly higher tolls for light vehicles coupled with discounted tolls for the heaviest vehicles on the motorway. The results is in line with the expectation: total cost (and revenues) are slightly decreased with respect to the other variation test (+0.5% and +12% respectively), as well as transport emissions. Time saving is unchanged with respect to the improvement already obtained with the first variation test.

It is also interesting to note that in all mixed scenarios but test M3, the traffic on the not-tolled network is reduced in terms of PCUs. Cars using such network increase by about 5-7 percent, while truck are reduced of about 15%. This suggests that the differentiation schemes can give rise to a better distribution of traffic on the network, reducing the share of freight vehicles on many roads.

5.3.5 Toll Differentiation and Future Scenarios

As already observed for the Brenner model, the toll differentiation based on vehicles emissions class is expected to lead to two different effects: in the short run the revenues of the motorway operator are supposed to grow, but in the long run drivers could decide to renovate the fleet (which is anyway supposed to develop among the years). Then, if the charge scheme provides benefits for “clean” cars, the revenues could develop in a different way. A group of tests reckoned with this issue.

The results in Figure 5-17 show that the modification of the fleet does not affect significantly the network operator revenues. This results is in contrast with what we observed in the Brenner model, where revenues increased with respect to the BAU at 2005 but not in comparison with the extrapolation of the chosen scheme at the year 2020 assuming that the fleet composition of the year 2005 is maintained. The reasons for this stability are the following. On the one hand, when the share of cleaner vehicles is increased, the motorway becomes more attractive (as such vehicles pay a lower toll). Therefore more traffic shift from road to motorways and revenues are increased even if the average tariff is lower. On the other hand, like in the Brenner case, if the tolling scheme lead to changes on the average size of the fleet, the higher number of vehicles on the motorway prevent a significant change of revenues.

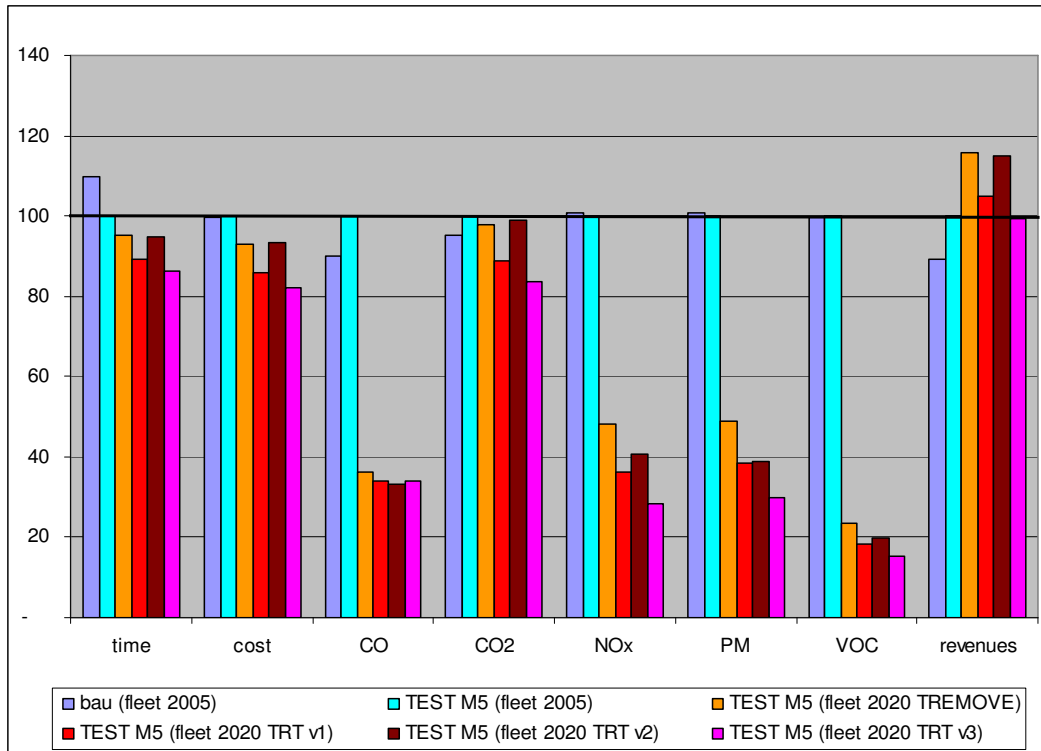


Figure 5-17 Summary Results of the Toll Differentiation with Future Expectation in the Padana Region Motorway Model

5.3.6 Social Impact of Different Scenarios

As for the Brenner corridor, also for the Centropadane model an economic analysis has been carried out, in order to compare all scenarios among them in terms of social welfare.

Toll schemes based on a discrimination among vehicles according to their EURO class leads to negative results in terms of social welfare. The shift of both cars and trucks from the motorway to the state road implies an increase in time spent on the network, since the level of congestion is higher, in total costs suffered by travellers and also in pollutant emissions, especially because of lorries.

Differentiating charges by vehicles size, on the contrary, produces positive effects on social welfare in all tested scenarios but the second one. The social expenditure arising from an increase in emissions level is more than balanced by savings in terms of total network costs and, in some cases, also by a small decrease in time spent.

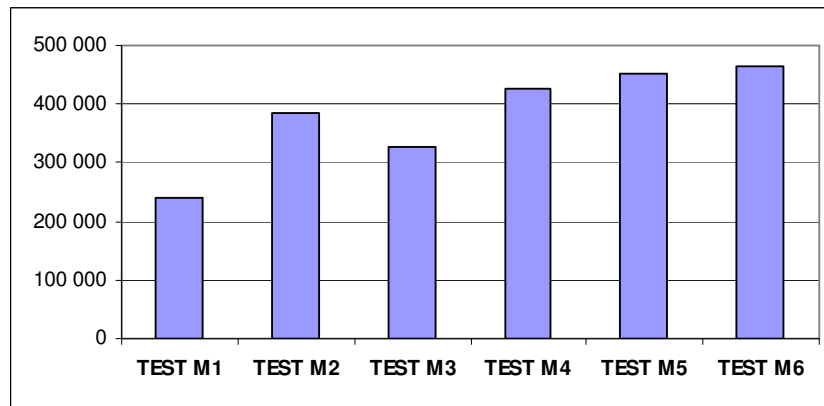


Figure 5-18 Net Economic Benefit of Mixed Tolling Scenarios

Positive results are even stronger if we analyse the evidence arising from those scenarios in which the toll differentiation involved both the motorway and the state road. The shift of trucks from the latter to the former leads to a remarkable increase in time saved, while the rise in network costs and in pollutant emissions (especially concerning CO) are, in terms of social welfare, more than compensated by the first effect.

Mixed scenarios, as it can be observe from Figure 5-18, lead to positive results as well. Again, the social costs of a significant increase in the level of emissions is more than balanced by substantial gains in terms of time spent by travellers on the network.

It is interesting to note that, in contrast with the evidence arising from the Brenner model, in the Padana region tolls differentiation can give rise to social benefit and, at the same time, network operator earnings can rise noteworthy.

5.4 CONCLUSIONS FROM THE SCENARIO SIMULATION BY THE BRENNER AND PADANA REGION MODELS

Testing different toll schemes on the Brenner corridor and in the Padana region leads to some interesting results. In particular, the following points seem to be relevant:

- The impacts of the differentiation schemes are not the same in the Brenner model and in the Padana region model. This suggests that the context of application of the tolling scheme is very relevant.
- In the Brenner corridor, where congestion is limited and a large share of traffic consists of heavy trucks crossing the whole study area, the impact of differentiation schemes on the level of services and the environment is low. At the same time, the motorway operator is able to increase revenues even significantly. In the Padana region, where a more complex and congested network exists and demand includes many more local trips, level of services can be improved but the revenues of the network operator are less certain and require that also part of the road network (in addition to motorways) is tolled, which is politically challenging.
- Both models suggest that a trade-off between objectives does exist: improving levels of service can reduce motorway operators revenues while higher revenues can well be produced without gains for the road users.
- Even when travel times can be reduced in non negligible amounts, like in the Padana region, the rise of charges and, as a consequence, of total costs for travellers exceeds the benefits. In the Brenner context, scenarios oriented towards the minimisation of time spent can come up with benefits exceeding costs only if discounts are used, which might be undesirable from the motorway operator perspective.



- It seems impossible to reduce significantly emissions using differentiation tolls. If more polluting vehicles are overcharged they just shift on road and more elaborated schemes are able to produce only limited savings of pollution in the Brenner corridor, while in the Padana region even such a small result is not visible.
- Since in the Brenner corridor travel times cannot be improved, the only significant benefit from the social point of view can spring from a proper use of the revenues of the motorway operator, e.g. for developing alternative modes or boosting the renewal of the fleet.
- Toll schemes that provide for high charges on pollutant vehicles lead to remarkable, positive results from the network operator perspective. However, if such a policy ensures remarkable gains in the short term, changes in the fleet structure could imply, in the long term, significant losses for the network operator. Instead, discounting tolls for “cleaner” vehicles seems a good strategy to minimise undesired effects on future earnings.

5.5 MODELLED PERFORMANCE OF UK MOTORWAY TOLLS

There has been considerable interest in Motorway tolling in the UK in recent years – although there is as yet only one tolled motorway (the M6Toll road to the north of Birmingham) in the UK. This interest has resulted in numerous studies of the effect of putting tolls on motorways. Early studies such as that by Mauchan and Bonsall (1995) were followed by much larger studies under the umbrella of the Department for Transport’s Multimodal Studies programme (DfT, 2002) and the National Road Charging Feasibility Study (DfT, 2005). Some studies in preparation for the M6Toll have also been published although commercial sensitivities have resulted in them revealing little detail. Our current concern is with *differentiated* charges on motorways and this immediately limits the volume of relevant material.

Mauchan and Bonsall’s (1995) study used a fixed-matrix SATURN assignment model to assess the effect of charges on the West Yorkshire motorway network. The main aim of the study was to examine the effect of different forms of motorway toll on traffic diversion to the non-motorway network. Two types of differentiation were tested (i) a simple per-km charge was compared with a flat rate charge irrespective of distance travelled which effectively penalised traffic using the motorways to travel short distances, and (ii) tolls imposed on all motorways were compared with those imposed only on “strategic” motorways – thereby favouring the local traffic. The tests showed (i) that per-km charges (in the range 3 to 12 cents per km) created much more diversion to non-motorway roads than did flat-rate tolls yielding the same overall revenue (the per distance charges typically caused increases of up to 25% in the flow on major non-motorway roads - five to ten times as much as was caused by the flat charges), and (ii) that tolls on “strategic” motorways caused about 25% less diversion to non-motorway roads than was caused by charges levied on all motorways - even though the latter produced somewhat lower overall revenue. In both cases the diversion to non-motorway roads was felt both on the major roads and, via a knock-on effect, on the minor roads. One may conclude from this study that differentiation by type of traffic (long-distance v. short distance) and by type of motorway (strategic v. general purpose) can have a profound effect on the impacts on the surrounding network.

The multimodal Studies programme (DfT, 2002), examined a range of very interesting charging strategies, including several options for motorway charges, and drew some important conclusions (such as that charges imposed solely on motorways had deleterious impacts on other traffic on non-motorway roads, that motorway charges could help “lock-in” the benefits of capacity increases, and that their performance could be enhanced if accompanied by the introduction of tolls on non-motorway roads or appropriate traffic control measures) but since, with one exception, the studies did not explore the performance of *differentiated* motorway charges, these conclusions may perhaps be out of scope for this report. The exception is provided by the ORBIT study, which tested the effect of link-specific tolls and found that overall benefits could, according to the model, be increased by allowing some links to have negative tolls. We interpret this result as indicating that benefit is to be obtained by charging people different amounts for using the same link depending on their *overall* route (e.g. a negative charge on an interurban stretch of motorway, particularly if combined with positive tolls on motorway access /egress links, would indicate that benefit is gained by dissuading traffic which uses motorways for short distances while not penalising traffic which uses it for longer distances).



The UK Department for Transport's National Road pricing Feasibility Study (DfT, 2005) included model-based analysis of a range of different road charging strategies. Although none of the tests looked exclusively at motorway charges, some of the results are of relevance to the topic of differentiated motorway charges. The tests, which were run using the National Transport Model, indicated that the benefits of charging, principally congestion relief, would be considerably increased if the charges were varied according to the amount of local congestion. Marginal Social Cost (MSC) charges differentiated only by type of road (the types being: motorways and dual-carriageway roads; trunk and principal single carriageway roads; urban roads of class B and C together with rural roads of class B; and rural roads of class C together with all unclassified roads) reduced congestion by 14% on interurban roads and by 3% on urban roads (compared, respectively, to reductions of 34% and 48% achievable by MSC charges varying by area and time of day as well as by type of road). Other results from the study showed that over 60% about of the benefit from a National Road Pricing Scheme would come from charges within urban areas and that more than 50% of it would come from charging in London and the major conurbations but that a case might be made for extending the scheme to cover the whole country because the incremental cost of running such a scheme would be reduced. Supplementary modelling also demonstrated the environmental case for having different charges for different types of vehicle – with the highest charges being applied to the largest vehicles. We may conclude from this study that the social benefits (congestion relief and reductions in externalities) of imposing a uniform per-kilometre charge on all motorways are minimal but that significant benefits are to be gained, in the context of a national charging scheme, from the introduction of motorway charges which, in order to reflect the amount of congestion and the contribution to externalities caused by different types of vehicles indifferent conditions, are differentiated by location, time of day and vehicle type.

As part of an ongoing study to motorists' demand for toll roads on behalf of the UK Department for Transport, Wardman et al (2007) reported the results of Stated Preference experiments exploring the demand for the M6 Toll Road under different pricing strategies. Respondents were offered the choice of three parallel routes - the current (free) M6, the M6 Toll Road, and the A50 (non- motorway) route – under a range of different scenarios. The results, based on 3,031 choices, point to a number of conclusions but those of relevance to this paper are:

- that preference for the M6 Toll Road route increases with journey length;
- that the preference for the M6 Toll Road is most marked among females, people over 65 and people in multi-occupancy vehicles;
- that people are prepared to pay for the improved driving conditions offered by the M6 toll route motorway at a rate which exceeds the simple value of the time saved; and
- that people are prepared to pay less to use the M6 Toll Road when travel information sources indicate that the M6 is flowing freely.

We interpret these findings as indicating that revenue to the M6 Toll Road operator could be maximised by varying the toll according to the level of congestion on the M6 but that, although the willingness of long distance traffic, older drivers and females to pay higher tolls, is interesting, it is probably impossible to capitalise on except via targeted marketing (the imposition of higher tolls on such groups is likely to be impossible outside a model!).

The M6 Toll Road opened in December 2003 (with fixed tolls, during daylight hours only, of £2 for cars and light vans and £10 for large vehicles – those whose height at first axle exceeds 1.3 m). Traffic data on the Toll Road and on other roads in the area collected during the first year of operation (Atkins, 2005) shows that traffic growth in the corridor was above the national average and that significant volumes of traffic were using the Toll Road. Interestingly, the statistics have shown that usage of the Toll Road is most marked among cars and light vans - a fact picked up by the toll operators who, after 9 months of operation, increased the charge for small vehicles to £3 and reduced that for large vehicles to £6. It seems that the M6 Toll Road is an example of a motorway toll regime where the price differentiation is based on willingness to pay.



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