# Policy Implications of European Research on Transport Pricing

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## Abstract

This paper draws on recent European research - and particularly the PETS project - to examine the implications of the valuation of externalities of transport infrastructure use in the context of the European Commission's proposals for pricing based on marginal social costs. The aim is to examine the implications for transport prices, and hence transport demand, by comparing existing variable taxes and charges with forecasts of marginal costs for different passenger and freight modes in 2010. It is found that, whilst marginal cost pricing in urban areas would lead to a major shift from car to public transport, for inter-urban corridors changes in mode split are much smaller and not always favouring public transport.

## 1. Introduction

Externalities from transport are widely recognised as a major problem in Europe. There is growing concern about congestion, noise and air pollution. European transport policy places great emphasis on the expanded use of economic instruments to reduce the problem. In 1995, the Commission issued a Green Paper "Towards Fair and Efficient Pricing in Transport" (CEC, 1995), following which a High Level Group was established to consider how to implement the proposals. This group produced a report (HLG, 1998) the proposals from which were taken forward in the following White Paper (CEC, 1998b), and has since prepared two further papers on how to implement the policy (HLG, 1999a; HLG1999b). At the same time, as part of the 4th Framework Programme, the Commission sponsored a large amount of research on how to implement its pricing policies, on practical and acceptability problems and on what the implications of implementing them would be.

The main questions that are raised in this paper in relation to the impact of pricing are: what are the marginal social costs of the different modes of transport?; how important are air pollution costs in relation to the overall price changes that efficient pricing implies?; if the sum of marginal costs is compared to existing variable taxes and charges, are price increases automatically implied?; and, do these price changes suggest that optimal pricing will result in a shift to more environmentally-friendly modes, or lead to an overall reduction in travel?

The PETS (Pricing European Transport Systems) project undertook a range of case studies for the year 2010 to answer these questions in different European areas: Cross Channel (UK, France and Belgium), Transalpine, Finland, Oslo-Gothenburg, and Lisbon.

## 2. The policy background for transport pricing

It has long been the declared aim of the Commission that pricing policies should be developed that promote economic efficiency. This requires prices that cover marginal social cost. Originally, this was seen mainly in terms of charging for the use of infrastructure according to marginal operation and maintenance costs, but more recently the concern with environmental problems has led to an emphasis on the external costs of transport as well - congestion, accidents and environmental costs.

In 1995 the Commission published a Green Paper entitled "Towards Fair and Efficient Pricing" (CEC, 1995). The basic argument of this paper was as follows: prices should reflect the costs that infrastructure users impose; some costs (environmental, accidents, congestion and infrastructure) at present are only partly covered, or not covered at all; and, these costs could be very large – of the order of 250 billion ECU[1] p.a.

[1] As at 4.1.99, 1 ECU = 1 EURO = 1.15 US dollar.

## 3. Principles for the internalisation of externalities

The well known principle of efficient pricing in a first best world is that the user should bear short run marginal social cost. A particular characteristic of the transport sector is that the user actually directly bears some of the costs in the form of time, and often the provision and running costs of a vehicle. It is thus more appropriate, following Jansson (1997), to speak of charging the "price relevant cost", which is therefore marginal social cost less costs borne directly by the user (e.g. journey time).

For transport infrastructure, the price relevant cost is the sum of short run marginal cost to infrastructure provider (maintenance, operations), marginal cost imposed on other infrastructure users (congestion, accidents, opportunity cost) and marginal cost imposed outside the transport sector (environmental costs – air pollution, global warming and noise).

Some commentators advocate pricing at long run marginal cost, that is allowing for optimal adjustment of the capital stock, and therefore infrastructure capacity to traffic. Of course, if capacity is optimal, the two values are equal and it makes no difference which is measured (Newbery, 1990). Our conclusion was that very often transport infrastructure capacity is non-optimal, and may remain so for decades. In this situation, it is more appropriate to concentrate on using pricing to obtain optimal use of the existing infrastructure and rely on project appraisal methods to guide the adjustment of the capital stock.

Most transport infrastructure is subject to increasing returns to scale, but the costs of land/property acquisition limit expansion, particularly in urban areas. The result is that a surplus is likely on urban roads, whilst deficits are likely on rural roads and public transport (Jansson and Lindberg, 1998). This immediately raises two questions. Firstly, does the resultant pattern of surpluses and deficits overall satisfy public sector budget constraints? Secondly, will the resulting cross subsidisation be seen as equitable? In either case, if the answer is no, we are likely to find ourselves faced with a need for some form of second best pricing.

For scheduled transport services, again the price relevant cost is the sum of short run marginal cost to the producer (but given the possible speed of adjustment it seems reasonable that this should be allowing the vehicle stock/timetable to vary), marginal cost imposed on other users of the service (this may be negative if the result of increased traffic is to lead to better services - the "Mohring" effect; Mohring, 1972), marginal cost imposed outside the sector (although this should already be reflected in appropriate infrastructure use charges).

It may be noted that this approach to the internalisation of externalities focuses solely on the marginal costs of infrastructure use in determining the changes need to existing prices. It neither considers the fixed costs of infrastructure provision, nor the upstream or downstream environmental costs associated with infrastructure or vehicles; these issues lie more firmly within the realm of decision making on aspects such as infrastructure provision and vehicle sales/ disposal taxation. The counterpart of these types of cost on the revenue side, is that fixed charges and taxes are not generally considered in the analysis. These are assumed to remain unchanged from the current situation.

## 4. Overall methodology for the 2010 case studies

In order to demonstrate the application of the internalisation of externality principles discussed above, five strategic corridors in Europe were selected for case study analysis. These five case studies represent a range of core and peripheral regions in Europe, congestion and population density characteristics, and passenger and/or freight transport contexts.

The five case studies were: Cross Channel passenger and freight study, dealing with the corridors London-Paris and London-Brussels, and including rail, air, car and truck, with the road modes crossing the Channel either through the tunnel or by sea (Sansom et al., 1999); Transalpine Freight Study, dealing with international road and rail freight between northern and southern Europe through the Alps (Suter et al., 1999); Finnish passenger and freight study, dealing with road and rail transport in the corridor from Helsinki to the Russian border (Peura et al., 1999); Oslo-Gothenburg passenger study (Jule, 1999); and, Lisbon passenger study, which was particularly concerned with pricing road, rail and ferry routes across the Tagus river in Lisbon (Viegas et al., 1999).

Thus there are three inter-urban passenger studies (Cross Channel, Finland and Oslo-Gothenburg), three inter-urban freight studies (Cross Channel, Transalpine and Finland) and one urban passenger study (Lisbon). Of these, the two in the Nordic countries represent areas of low population density where substantial infrastructure investment is taking place to offer high quality infrastructure services rather than because of shortage of capacity. The Cross Channel and Transalpine case studies are in more congested corridors with higher population and environmentally sensitive areas, but again with relatively high levels of infrastructure investment. That in Lisbon represents a bottleneck for longer distance transport, which has been eased by the provision of a new road and rail bridge, but it still represents a very congested area dominated by local transport.

In each case study, marginal social cost was estimated for the relevant modes and routes and used to forecast the impact of the marginal social cost pricing on demand (given the uncertainty about the valuation of some externalities, high and low valuations were tested). Average vehicle classes for the main passenger and freight modes were modelled in a conventional route and mode choice framework. Clearly, the use of average vehicle classes has limitations, and these are discussed later. To enable comparison between modes, prices are presented in common units - ECU/100 passenger km or ECU/100 tonne km, in 1995 prices and 2010 values.

The use of transport models with detailed network representations enabled the application of prices specific to the geographical context and transport volume context. Furthermore, for externalities which have unit costs that vary with transport demand (e.g. congestion), use of the models in an iterative manner enabled equilibrium transport prices to be determined. With the exception of the Oslo-Gothenburg study, an overall fixed trip matrix was used.

In the following sections, the focus is on the methodology and results from the Cross Channel case study. All five case studies share a common methodological base, but where important differences exist between the Cross Channel case study and the other four case studies, these are highlighted.

## 5. Methodologies for the valuation of externalities

The principal externalities of transport use are congestion, accidents, and the Mohring effect for public transport ,noise , air pollution and global warming.

For each externality, emphasis was placed on using the most disaggregate data sources available – i.e. wherever possible, there was a general preference for use of "bottom up" as opposed to "top down" approaches. Furthermore, where unit values are related to individual preferences – e.g. value of health, accidents, time – values based on willingness to pay approaches were used. Due to the close relationship with individual incomes, the values were assumed to grow in line with real GDP per capita over time (2.4% p.a. for the Cross Channel case study). Lastly, since the case studies were conducted for 2010, there was a need to forecast likely reductions in emission rates due to factors such as changes in vehicle fleet composition.

Where marginal social costs are reported in the subsequent text, the costs relating to individual links are weighted by route distances in order to yield an overall marginal cost.

For air pollution, the determination of costs specific to vehicle types and geographical contexts has relied heavily on the results of studies exploiting the "impact pathway" approach developed in the ExternE Transport study (Friedrich et al., 1998). This represents the output of what is by far the largest effort ever devoted to the issue in a single European research project. The impact pathway approach was based upon a bottom-up analysis of emissions, dispersion modelling, dose-response functions and monetary valuation of impacts relating to human health, ecosystems, crop losses and damage to construction materials for a range of all the major pollutants, including nitrogen oxides, sulphur dioxide, carbon monoxide, particulates and ozone. The resultant costs were dominated by damage to human health.

The Cross Channel study adapted bottom-up estimates from an application of the impact pathway approach to the corridor from London to Lille (Weinreich et al., 1997), taking into account the geographical context (e.g. population location and density) and vehicle stock characteristics (engine/ fuel or power type, etc.). Due to the impact of European legislation on the vehicle stock and fuel composition, by 2010 the emission rates for road vehicles (weighted by the relative values of pollutants) are forecast as 20% of the 1995 level (DETR, 1999). For rail, traction is electrically powered, the base energy mix (France 70% nuclear, UK 70% fossil fuels) adapted over time according to MacKerron and Pearson (1995).

The starting point for valuation was a value of statistical life of 0.98 million ECU at 1994 prices, used in accident analysis (Hopkin and Simpson, 1995). This was adapted to reflect years of life lost in the case of mortality, and years of reduced quality of life for morbidity.

For global warming, damage cost estimates incorporating equity weighting to take account of the disproportionate burden likely to be imposed on developing countries were adopted from Eyre et al. (1997) based on a review contained in Christensen et al. (1998). Uprated to 1995 prices and 2010 values, these range from a value of 85 to 240 ECU per tonne of carbon equivalent, at 3% and 1% discount rates. Since the values represent estimates of damage at the global level, these unit values are obviously not adjusted to circumstances in the case study countries.

For noise, a comparable method to that used for air pollution was implemented, with an emphasis in the case studies on using a bottom-up approach where possible. For the Cross Channel case study, only top-down estimates were available, from INFRAS/IWW (1995). These were adapted on the basis of roadside dispersion modelling carried out for the London to Lille corridor (Weinreich et al., 1997), with further estimates for the other corridors in the study area based upon relative population densities. Values were increased to 2010 values according to real GDP per capita growth.

For accidents, the approach adopted was to estimate the share of accident costs not borne by the individual (directly or via insurance) plus – for road traffic – the increased risk to existing traffic of an increase in traffic volumes (rail and air risk rates were assumed to be invariant with vehicle kms). Unit values were based on willingness to pay approaches (for the Cross Channel study, 0.98 million ECU per fatality; Hopkins and Simpson, 1995). For rail and air transport, there is no apparent downward trend in accident risk rates for the Cross Channel corridor. However, for inter-urban road transport, recent trend changes in risk rates (-2% p.a. fatalities, +3.5% p.a. severe and slight; DETR, 1998) were extrapolated to the year 2010. A sensitivity test was conducted to examine the effect of the inclusion or otherwise of the values held by friends and family; this component is often excluded due to uncertainty as to its value and validity (e.g. Proost and Van Dender, 1999). This element is incorporated in the high valuation of externalities but not the low.

In the case of congestion, the planned provision of road and rail infrastructure in many of the case studies meant that estimates of the 2010 external costs of congestion were insignificant. For the two case studies where road congestion was significant – Cross Channel and Lisbon – the approach used was to estimate marginal external congestion costs from the derivative of the speed-flow curve, the traffic volume and the value of time (Newbery, 1990). To achieve greater accuracy for this highly non-linear cost category, the Cross Channel case study modelled hourly time slices, taking a weighted average of the resulting marginal costs for input into the all-day model. The Lisbon case study applied an alternative approach of running separate peak and off-peak models. In both cases, the model was iterated until a new equilibrium was reached.

For the public transport modes, the Mohring effect, whereby additional traffic provides benefits to existing passengers, will arise if the most efficient form of providing increased capacity is to increase service levels. For the Oslo-Gothenburg case study, increased capacity was provided in the form of larger individual vehicle capacity (no increased service level or Mohring effect), but where vehicle and fixed infrastructure constraints precluded higher capacity vehicles, the Mohring effect was estimated based on the values of time of existing passengers.

## 6. Price changes necessary to achieve internalisation of externalities

In this section the comparison is made between the sum of 2010 price relevant costs, discussed in the previous section, plus marginal infrastructure and operating costs, and the sum of existing variable taxes and charges.

In the case of the Cross Channel case study, for road modes variable taxes and charges include fuel duties, value added tax on fuel (car) and road tolls (French auto-routes).  For passenger rail, no taxes are levied, so that the charge is simply that to the final user.  For air travel, a range of passenger departure taxes exist in each country.

Since it was assumed that increases in road goods traffic would lead to corresponding increases in the vehicle fleet, the annual vehicle registration tax associated with goods vehicles was included for the freight case studies.  Another element of existing prices that conventionally would be excluded from such analysis was the value added tax applicable to passenger travel.  This was included because of the sharp variation between different modes – for example, in the UK value added tax on the retail price of fuel (including the fuel duty) is 17.5%, whereas public transport is exempt from value added tax.  An alternative approach would have been to consider the absence or low level of VAT on public transport as a form of subsidy.

Since the focus of the case studies was on the implications of implementation of marginal social cost pricing, the case studies assume that ideal pricing instruments for reflecting a high degree of differential pricing by time period and location are available in 2010.  Clearly, this level of innovation in instruments has to be justified in the real world by comparison of benefits with costs.

Table 1 sets out the comparison between price relevant costs and taxes and charges for passenger travel in the Cross Channel case study in 2010.  It was assumed that, because of the competitive nature of the market, air prices reflected marginal costs to the producer, but rail marginal producer cost was estimated directly.

Table 2 shows the change in prices implied in all of the passenger case studies.  It is clear that, at the low marginal cost valuations, there is a tendency to over-price all inter-urban passenger modes.  However, the reasons vary across modes; for the public transport modes, the over-pricing is a result of pricing to cover total cost in a situation in which economies of scale and the Mohring effect lead to marginal cost being below average.  In the case of road, over-pricing is the result of substantial fuel taxes, which exceed the low values of external costs.  At the high value of externalities, the degree of over-pricing is substantially reduced, particularly for car and air.

For the urban case study, the results are not surprisingly quite different.  On average, car is under-priced even at the low values of externalities.  The under-pricing of car becomes much more marked at the high valuations.

Table 3 provides the comparison between price relevant costs and taxes and charges for freight modes in the Cross Channel case study, for 2010.

Table 4 shows the change in prices implied in all of the freight case studies. For freight, the picture is more mixed. On the Cross Channel corridor, there is a similar degree of under-pricing for both road and rail freight, although again the reasons are different. For road, the reason is a failure for the already substantial taxes on heavy goods vehicles to cover completely the external costs; for rail, it is the failure to include external costs at all in the price of rail freight on this corridor, which is already believed to be priced on a marginal cost basis because of the fierce competition with road. For Transalpine freight, rail appears roughly appropriately priced, whilst road varied from being over-priced at low valuations to under-priced at high (it should be said that in this case study the high valuations included special allowance for the sensitive nature of the Alpine region).

## 7. Impacts on transport demand

What would be the implications of the above price changes for transport demand? Again, the implications are radically different between urban and inter-urban areas, as Tables 5 and 6 illustrate.

In the Lisbon case study, efficient pricing would lead to a substantial diversion of traffic from car to bus and train. This would have a significant impact on local air pollution in major cities where the problem is most severe. However, a relatively small part of total road traffic is to be found in major cities, so the contribution to the problem of global warming would be much less significant.

Nowhere else is a dramatic change of mode split to be found. In the Finnish case study, there is a diversion of 6-8% of heavy goods vehicle traffic to rail, and of 1-3% of car traffic to bus and rail. On Cross Channel routes a very small proportion of car traffic and a slightly larger proportion of air traffic switches to rail. In terms of freight, at the lower valuations of externalities, there is diversion from rail to road on both Cross Channel and Transalpine routes. At the higher valuations, road traffic is little affected.

Overall it must be concluded that, even at the higher valuations of externalities the degree of change in mode split, and the contribution to air pollution and global warming targets, that can be expected from the transport sector outside urban areas is small.

## 8. Conclusions

We have presented estimates of the marginal costs of air pollution and global warming based on the best estimates now available, but they still show a wide range between high and low values. On both valuations, they are certainly a significant component of the case for changes in price but in no case are they the dominant one.

In terms of the impact on prices, and the resulting shifts in transport demand, the pattern of efficient pricing is by no means universally the popular image of big increases in price on the major polluting modes leading to large shifts in demand to rail and other public transport.

The results of the case studies confirm many well-known and obvious conclusions, but provide some surprises as well. Thus it is well known that inter-urban car transport is typically over priced and urban under-priced, particularly at the peak. This is the consequence of dependence on fuel tax as the major form of charging. It would be more efficient to lower fuel tax and to implement some form of supplementary charge in urban areas. The case for introducing tolls for cars on inter-urban roads appears weak, except where there are particular problems of congestion.

For road freight, the results are more variable, more because of the big variations in tax rates between countries than because of differences in cost, but it appears that on some cases there is a degree of undercharging, and in some cases overcharging. However, this cannot be accurately corrected using existing taxes, as it applies particularly to heavy axle vehicles covering high mileages. Adding to annual vehicle taxes would penalise vehicles used on low mileages, and even fuel duty cannot discriminate sufficiently between vehicle types. Therefore, there is a strong argument for the view of the European Commission that, in addition to urban road pricing there is a case for a new mileage related tax on heavy goods vehicles varying with the characteristics of the vehicle concerned. Such a system would also solve the problem of unfair competition between vehicles based in countries with very different tax rates if it were possible to identify the mileage undertaken in each country and charge accordingly.

For inter-urban public transport, the result was more surprising in that typically existing prices were too high. This was because of following commercial pricing practices in a sector subject both to producer economies of scale and to the Mohring effect. All the flows in the case studies were subject to relatively high rail tariffs. However, for rail this result would certainly not hold throughout Europe. For rail freight the result was more mixed, with charges marginally above marginal social cost in one case study, but excessive subsidies in others.

For inter-urban transport, however, in no case were the changes in mode split from the introduction of efficient pricing very large; the belief that proper allowance for air pollution and global warming would lead to major diversion from road and air to rail does not appear to be supported by empirical analysis. On the other hand, very much more diversion could be expected in urban areas, but more as a result of charging for external costs of congestion and accidents than for air pollution and global warming.

In conclusion, then, the impact of optimal pricing on transport volume and mode split appears likely to achieve a significant improvement in air quality in major congested urban areas, but to make little contribution to more general air pollution or greenhouse gas reduction. However, it should be stressed that in this research we were only concerned with overall traffic levels and mode split. Selective taxes according to vehicle emission characteristics and amount and type of fuel used may have much more significant effects on energy efficiency and air pollution from transport.

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Table 1
Changes in Cross Channel passenger prices (ECU/100 passenger km)

| Component | Car | Train | Aircraft |
|---|---|---|---|
| Producer cost: | | | |
| Infrastructure wear and tear | 0.351 | (1) | (2) |
| Increased PT frequency | - | 16.360 | (2) |
| User cost: | | | |
| Congestion (time delays) | 0.12 | - | - |
| Mohring effect | - | -2.856 | - |
| External costs: | | | |
| Accident cost (low) | 0.164 | 0.012 | 0.001 |
| Accident cost (high) | 0.898 | 0.058 | 0.007 |
| Air pollution | 0.397 | 0.098 | 1.366 |
| Global warming (low) | 0.363 | 0.070 | 0.608 |
| Global warming (high) | 1.035 | 0.197 | 1.718 |
| Noise | 0.794 | 0.319 | N/A |
| Total price relevant cost (low) | 2.189 | 14.002 | 1.976 |
| Total price relevant cost (high) | 3.595 | 14.176 | 3.091 |
| Total taxes and charges | 4.331 | 17.020 | 4.247 |
| Change in charge (low) | -2.142 | -3.018 | -2.272 |
| Change in charge (high) | -0.736 | -2.845 | -1.156 |

Note: (1) included in increased PT frequency; (2) nets out with passenger fare.

Note that for car and aircraft the price relevant cost is computed as the appropriate charge to levy to cover external cost; for train the price relevant cost is computed as the marginal operating plus external cost (i.e. the passenger fare). Thus these figures cannot be compared between the modes.

Table 2
Changes in passenger prices (ECU /100 passenger km)

| Case Study | Cost Estimates | Car | Bus | Train | Air |
|---|---|---|---|---|---|
| Cross Channel | low | -2.14 | - | -3.02 | -2.27 |
| | high | -0.74 | - | -2.85 | -1.16 |
| Finnish | low | -2.24 | -2.96 | -4.06 | - |
| | high | -0.49 | -2.56 | -4.04 | - |
| Oslo-Gothenburg | low | -2.57 | -1.18 | -1.26 | -5.71 |
| | high | -0.80 | -0.51 | -1.22 | -4.54 |
| Lisbon | low | +1.19 | -1.72 | -0.90 | - |
| | high | +3.37 | -1.65 | -0.87 | - |

Table 3
Changes in Cross Channel freight prices (ECU/100 tonne km)

| Component | HGV | Train |
|---|---|---|
| Producer cost: | | |
| Infrastructure wear and tear | 0.939 | (2) |
| Vehicle operating cost | (1) | (2) |
| User cost: | | |
| Congestion (time delays) | 0.054 | - |
| External costs: | | |
| Accident cost (low) | 0.516 | 0.011 |
| Accident cost (high) | 0.883 | 0.054 |
| Air pollution | 0.832 | 0.046 |
| Global warming (low) | 0.255 | 0.032 |
| Global warming (high) | 0.719 | 0.091 |
| Noise | 1.536 | 1.412 |
| Total price relevant cost (low) | 4.132 | 1.502 |
| Total price relevant cost (high) | 4.963 | 1.603 |
| Total taxes and charges | 2.869 | 0.000 |
| Change in charge (low) | 1.263 | 1.502 |
| Change in charge (high) | 2.094 | 1.603 |

Note: (1) nets out with freight charge; (2) nets out with charge.

Table 4
Changes in freight prices (ECU /100 tonne km)

| Case Study | Cost Estimates | HGV | Train |
|---|---|---|---|
| Cross Channel | low | +1.26 | +1.50 |
| | high | +2.09 | +1.60 |
| Finnish | low | +1.13 | -0.27 |
| | high | +1.58 | -0.26 |
| Transalpine | low | -4.80 | +0.28 |
| | high | -1.19 | +2.02 |

Table 5
Changes in passenger demand (% change compared to 2010 base situation)

| Case Study | Cost Estimates | Car | Bus | Train | Air | Total |
|---|---|---|---|---|---|---|
| Cross Channel[1] | low | -0.2 | - | +7.1 | -1.7 | - |
| | high | -0.7 | - | +10.3 | -2.2 | - |
| Finnish[1] | low | -1.4 | +3.7 | +12.1 | - | - |
| | high | -3.2 | +11.4 | +20.7 | - | - |
| Oslo-Gothenburg | low | +21.5 | -10.5 | -8.4 | +6.8 | +14.6 |
| | high | +6.2 | -4.4 | +0.2 | +8.9 | +4.7 |
| Lisbon[1] | low | -29.0 | +22.2 | +29.6 | - | - |
| | high | -36.3 | +25.0 | +32.0 | - | - |

[1] Total passenger demand held fixed in model.

Table 6
Changes in freight demand (% change compared to 2010 base situation)

| Case Study | Cost Estimates | HGV | Train |
|---|---|---|---|
| Cross Channel | low | +1.2 | -3.0 |
| | high | -1.5 | +4.0 |
| Finnish | low | -5.9 | +7.4 |
| | high | -7.9 | +9.7 |
| Transalpine | low | +3.1 | -12.5 |
| | high | +0.1 | -1.7 |