Recent progress in the measurement of external costs and implications for transport pricing reforms

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The external cost of transport has been discussed in the European transport policy since the 60s. However, it was not until the mid-90s that the European Commission decided on a pricing policy for the transport sector. This policy has stimulated a wide array of new research on the external cost of transport. A survey of some of the most recent studies in the area displays a clear picture; the latest studies are clearly focused on the marginal external cost and based on detailed bottom-up methods. The paper summarise the methods used to estimate some of the components of the marginal cost of transport - marginal infrastructure cost, congestion and scarcity cost, accident and environmental cost. The survey displays the huge variation in the estimates that follows from the use of more detailed databases. While this may be perceived as a problem for blunt pricing policies the paper suggests that it highlights the need for a more refined pricing policy in the transport sector.

1. Introduction

The principle of marginal cost based pricing has been discussed in the European transport policy since the 60s[2]. Already 1971 the Commission submitted a first proposal for a decision on a *Common System of Charging for the Use of Infrastructure*[3]. This proposal prescribed marginal social cost pricing and budgetary equilibrium and covered rail, road and inland waterways. The scope of the marginal social cost included the cost of use (i.e. maintenance),

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[1] An earlier version of this paper was presented at the second seminar of the IMPRINT-EUROPE Thematic Network: "Implementing Reform on Transport Pricing: Identifying Mode-Specific Issues", Brussels, 14th/15th May 2002.
[2] See for example COM(64)389 and COM(68)567.
[3] COM(71)268

congestion and other external costs as noise, air pollution, and accidents[4]. However, no final decision was taken.

Irrespectively of the policy failure at that time, economists continuously developed the ideas (e.g. Jansson (1984), Newbery (1989), Small (1989)). Nevertheless, it was not economists that pushed the principle back on the policy arena again. Environmental NGOs discovered, and finally accepted, the principle of pricing environmental damages in the early 90s. They forcefully, and successfully, lobbied for the principle (e.g. Kågesson (1993)). One of the appetizers for the environmental movement to embrace the marginal cost idea was that the principle called for higher prices for road transport, and a shift to environmental more friendly modes of transport.

A number of reports where produced in the early 90s on the topic of external cost of transport (OECD(1994), UIC(1994)). The question was 'hot' and rediscovered and the theoretical background was not always clear. The result was often based on average cost estimates with a rough classification of internal and external cost. These studies often presented the result by mode, or rough sub categories of modes. The marginal cost principle was regarded as a weapon on the battlefield between modes of transport. At the end of this period the Commission presented a Green Paper 'Towards Fair and Efficient Pricing in Transport' (COM(95)691). While the main theme of the Green Paper was about marginal cost pricing it also played with budgetary equilibrium ideas.

The latest policy development has stimulated a wide array of new research on the external cost of transport. This paper summarise the most recent developments in the measurement of marginal external cost[5] and discusses the possible consequences for the transport policy this development may lead to.

2. Recent progress in the measurement of external costs

What do we know about marginal cost of transport? While the movement in the early 90s put the principle back on track, the recent development has put the issue on the '*marginal cost*' track. More and more studies explicitly estimate the *external marginal cost* with a clear theoretical background. The paper focus on the short run marginal cost and only note that along the optimal expansion path the short run and long run marginal costs are the same. In the following, we divide the presentation into traditional subcategories, (2.1) infrastructure cost, (2.2) congestion and scarcity cost, (2.3) accident cost and (2.4) environmental cost.

2.1 Infrastructure cost

The short-run marginal infrastructure cost related to an additional vehicle on the road comprises three components; the increase in cost inflicted on other vehicles (road damage externality), the increased wear of the road leading to routine maintenance (marginal cost of road wear) and thirdly, the damage to the road leading to periodic maintenance in the future (marginal cost of road damage). In principle the same classification holds for other modes of transport.

[4] Defined in COM(75)493

[5] Prepared for the second seminar of the IMPRINT-EUROPE Thematic Network: "Implementing Reform on Transport Pricing: Identifying Mode-Specific issues", Brussels, 14th/15th May 2002.

Associated with the two last categories the question we want to have an answer on may be phrased: '*what is the extra cost imposed on the road authority in region A if an additional truck with a gross laden weight of 40 tonne and 4 axles run 1400 km across the region*'. If we know the answer, it would be appropriate to demand the truck operator to pay a price equal to the cost. Maintenance is produced in mainly two different forms, routine maintenance and periodic maintenance.

Routine maintenance

There is a rich body of literature in traditionally economics on production functions and on cost functions but literature on cost functions purely for the infrastructure use is rare. The reason has been a limited interest and need – for example for pricing purposes – to analyse infrastructure cost and cost causation relationships. However, the situation has changed. The vertical separation of the rail industry into a track authority and one or more operators has its implication for pricing policy and data availability; infrastructure use are charges independently and cost related to infrastructure is accounted for separately from train operation costs. The development of kilometre charging for heavy vehicles in Europe will further increase the demand on such studies.

Johansson and Nilsson (2001) use this opportunity and collect information by some 250 track units, i.e. segments of rail tracks. For each track unit, information on (routine) maintenance expenditure, traffic volume, number of switches, quality of the track etc is collected for Swedish and Finnish railways. Not all expenditures are recorded by segment and a part of the costs are classified as common costs. Some of these costs are truly common, while others probably should have been allocated to the track unit with a better accounting system.

The authors employ the Translog function of Berndt and Christensen (1972) and derive marginal cost estimates. The result suggests that the average costs for maintaining tracks in those two countries decrease with traffic load. This is analogous with the familiar u-shape of a production cost curve. As both the Finnish and the Swedish data indicate a decreasing cost activity the revenues will fall short of total cost. The rate of cost recovery is estimated to 17% in Finland and 12% in Sweden, in the latter case a larger part of the costs has been perceived as common costs, and therefore not allocated to track unit.

Table 1. Marginal cost in €/100 gross ton km for Swedish and Finnish railroads

Country	**Sweden**		**Finland**	
Year	**1995**	**2000**	**1995**	**2000**
ALL tracks	0.012	0.013	0.016	0.024
Main/electrified tracks	0.009	0.009	0.012	0.018
Secondary/non-electrified tracks	0.097	0.099	0.026	0.040

Based on Johansson and Nilsson (2001). Exchange rate: 9.40 €/SEK.

Similar approaches have been tried in the road sector based on longitudinal observations (Link et.al. (2002), Li et.al. (2001) and Martin (1994)). Some of these studies also cover the periodic maintenance. However, the general lesson is that the data availability is much more problematic in the road sector. Maintenance expenditures are seldom recorded by road segment but more often by regions. This increases the necessary effort to construct a disaggregated database or increases the challenge for the econometric analysis to disentangle the different elements that causes regional maintenance expenditures to vary. One outcome would be to synthesis the data as Ghaeli et.al. (2000) or, as proposed here, disentangle the estimates for routine maintenance and periodic maintenance. However, this separation demands that the correlation between routine and periodic maintenance expenditures are understood and taken into account.

Periodic maintenance

The approach taken above is suitable for routine maintenance cost. For periodic maintenance, extremely long time series are needed to be able to find the necessary pattern. Instead, an alternative shortcut, originally developed by Newbery (1988a, 1988b and 1989) for the road sector, can be employed. The upper layer of infrastructure, tracks or pavement, has to be renewed within certain intervals. The cost for all future maintenance cycles can be expressed as a present value, i.e. the future cost is discounted and summarised. Our initial question can be rephrased; *will the entrance of the truck change the present value of the future periodic maintenance cost of the road authority?*

The key relationship to understand is how the traffic load will affect the pavement cycle. Under some general assumptions it can be proven (Lindberg (2002a)) that the marginal cost related to periodic maintenance for an average road is primarily a product of the average cost (AC) and an elasticity (ε), which expresses the changed lifetime of the pavement as the traffic load changes. The average cost is defined as the reinvestment cost (C) per passing vehicle (Q) over the pavements lifetime (T).

$$\mathrm{MC}_{\mathrm{Average}} = -\varepsilon\,\mathrm{AC} \qquad (1)$$

where:

$\varepsilon = \frac{dT}{dQ}\frac{Q}{T}$ Deterioration elasticity

$\mathrm{AC} = \frac{C}{QT}$ Average cost

Road engineers seldom have been interested in the marginal cost of transport, but they certainly have been interested in the lifetime of a pavement and what affects the lifetime. One important conclusion, highlighted by Turvey (2001), is that if the economist rephrases the question, much knowledge will be revealed from engineers. In a long term pavement performance project in Sweden lifetime functions have been estimated based on cracking (Wågberg 2001). Similar approaches have been taken in other countries and in European Union research (PARIS). If we assume a terminal value of a quality index, when we believe the road needs to be repaved, the change in time when this terminal value is reached due to changes in traffic load will decide the elasticity. The table below shows some of the result for Sweden. The elasticity increases (in absolute number) as the road strength weakens and as the total traffic load on the road increases[6]. Two observations can be made; the truck operator should pay a higher share of the average cost of pavement if he uses the low quality secondary

[6] The assumption by Newbery(1989) implied that the elasticity was one, and consequently the marginal cost equals the average cost.

network than if he uses the high quality main network. Secondly, a charge equal to marginal cost will not recover the total cost of pavement. The approach taken can readily be applied on periodic maintenance of rail tracks although we have not found any such study.

Table 2. Lifetime elasticity

Standard axles per day and direction	**Strong road base**					**Weak road base**	
	50	**75**	**100**	**125**	**150**	**175**	**200**
200	-	-	-	-	-	-	-0,21
300	-	-	-	-	-0,30	-0,40	-0,47
400	-	-	-0,21	-0,37	-0,47	-0,55	-0,60
500	-	-	-0,37	-0,49	-0,58	-0,64	-0,68
600	-	-0,30	-0,47	-0,58	-0,65	-0,70	-0,74
700	-0,10	-0,40	-0,55	-0,64	-0,70	-0,74	-0,77
800	-0,21	-0,47	-0,60	-0,68	-0,74	-0,77	-0,80
900	-0,30	-0,53	-0,65	-0,72	-0,77	-0,80	-0,82

- = not allowed combination , The road base strength is measured in surface curvature index (SCI).

Source: Lindberg (2002a)

The table above is based on standard axles. A measure of standard axles per vehicle has to be applied to derive a cost per vehicle. The common knowledge is to apply the so called forth power rule to estimate the cost for different vehicle categories with different axle loads. The rule emerges from the AASHO-Road-Test, which derived within an engineering experiment a relationship between road damage and axle weight. The fourth power rule indicates that doubling the axle weight increases road damages by a factor of 16 ($=2^4$). This rule is almost universally applied and it decided the structure of the European Union regulation on heavy goods vehicle taxation (COM(99)62)). However, basic new research on the applicability of the forth power rule is lacking.

User cost

Finally, a cost component that often is forgotten in estimates of the wear-and-tear is the increased vehicle cost and discomfort for subsequent road users as the road deteriorates. Consequently, we should add a third question; *what is the present value of the changed road user cost to all subsequent road users as a result of the damage caused by the tuck?* In principle this has been explored (Newbery 1988a, 1988b, 1989) and it has been shown that it is both a negative effect, the increased roughness, and a positive effect, the shorter lifetime give the users a new surface earlier. Under some circumstance these effects cancel out.

An alternative approach, sometimes advocated, to estimate the marginal infrastructure related cost of road use is to apply already existing Pavement Management Systems (e.g. Gronau (1994)). Such systems cover all three cost components discussed above. However, these models are not developed for the purpose of estimating marginal effects. It is not certain that the functions have been properly specified to truly capture the marginal effect of increase number of vehicles, and only that effect.

2.2 Congestion and scarcity cost

A Swedish research project on marginal cost of transport suggests that ‘we know what we need to know of the marginal cost of road congestion and slot allocation of rail tracks – it is now a question of implementation’[7]. Although this statement may be too strong, it encapsulates the main findings. Research on congestion pricing is not about the external marginal cost – the principle has been known for long (Walters 1961) – but to design policy packages and pricing schemes that can be successfully implemented. Nevertheless, this is the right place to examine some of the features of congestion and scarcity costs.

Scarcity cost

Let us assume that a train operator plans to run a new line. The marginal infrastructure cost was presented above and the additional question we need to ask is *‘what is the extra cost this train operator will impose on the rail authority and other operators due to scarce capacity?’*

To be able to introduce the new line, the operator needs slots on the tracks he intends to pass. If slots are available, the operator should be allowed to run the line for free, given that he pays for the rail damage cost and other externalities. Presumably, not all tracks will be free at the time he wants to run the train. Someone has to allocate the slots between interested operators. A promising method is to auction the slots; the bidder that will pay the highest price will have the right to use the track. The bidder with the lowest willingness-to-pay has to leave the scene. The cost for the rail sector due to the entrances of the new operator is the value of the train that cannot run anymore, i.e. the willingness-to-pay of the train that left the track. The auctioning principle has been proven to work in rather complicated networks in field experiments (Nilsson 1999, 2002). The same principle can be introduced at airports or harbours.

As the scarcity price increases on certain links of the rail network, the rail authority will have information on where to expand the capacity and, indeed, the authority may have revenues to finance such investments. It has of course to be ensured that the track authority does not use his market power to restrict the capacity in order to increase the revenues form scarcity pricing.

Congestion cost

For road transport the estimate of the scarcity, or congestion cost, is somewhat different. In this mode, it is not a question of a limited number of slots. It is a question of decreasing quality of service for other road users as the number of cars increases. For many years, studies have been carried out using volume delay functions that depicts the change in speed as the number of vehicles increases. The reduced speed for all users is valued and the average cost born by the road user is subtracted. The remaining cost is the external congestion cost that could be introduced in a road-pricing scheme.

The main problem in estimating congestion cost is to anticipate the reaction of the users; while it is relatively simple to estimate the external congestion cost at the current traffic load the cost at the optimal traffic load, that will be the result of a road pricing scheme, is much more difficult to assess. The researcher has to have a good knowledge on the reactions of users. A speculative assumption is that we in the near future, when road pricing scheme has

[7] Source: www.vti.se/tek

been introduced more widely (London, Stockholm), will find that the elasticity is underestimated because users find unexpected ways to adapt to the pricing scheme.
The revenues from congestion pricing scheme will give information on where the transport system should be expanded; in the same way as the revenues from slot auctioning. However, it is no predetermined rule that the revenues from scarcity or congestion pricing should be invested in the same mode of transport. Clever use of the revenues is at the backbone of a successful implementation.

2.3 Accident cost

A part of the traffic accident problem can be explained by the fact that the user, in his decision, does not consider all costs related to an accident - a part of the accident cost is external to the user. Two important principles are included in this external marginal cost component; first, the term *external* suggest that we are only interested in the cost not already borne by the user and, secondly, the term *marginal* suggest that we examine the change in cost at the margin when the user takes a decision. We consider here the decision to make a trip; the external marginal accident cost is related to distance (kilometre). The question we try to answer could be; '*what is the extra accident cost imposed on other road users and society at large if a HGV travels on the German autobahn from Travemünde to Frankfurt?*
The external accident cost has been discussed by Vickrey (1968), Newbery (1988c) and Jansson (1994). These studies focus on the external marginal cost related to cars as a homogenous unit. If heterogeneity is taken into account the external marginal accident cost will depend on four elements as discussed by Lindberg (2002b): the cost of an accident (a+b+c)[8], the accident risk (r), the proportion of the cost already born by the examined user (θ) and the risk elasticity (E). The latter expresses the change in risk as the traffic volume changes. Each of these elements raises questions on their own when the marginal cost shall be estimated.

$$MC = r(1-\theta+E)(a+b)+rc(1+E) \qquad (2)$$

The most important element in the cost of an accident is the risk value, or value of statistical life. The issue of the valuation of accidents is complicated. However, nowadays the CVM method is an accepted method to find values on the so-called risk value, i.e. the users' willingness-to-pay for a small risk reduction. This is often transferred to a value of statistical life but has nothing to do with a valuation of the life per se. While the use of this value today is in the mainstream, it should be noted that the method has some internal problems, which need to be solved in the future (see Beattie (1998) and Carthy (1999)).
While accident statistics may be good in many cases, although underreporting has to be considered separately, the possibility of finding information on exposure (e.g. kilometre driven) is in general *very* poor. The problem of finding a measure of exposure also means that the possibility to estimate accident functions, and consequently to be able to say something about the relationship between accident risk and traffic volume (the elasticity), is limited. Nevertheless, research suggests that the risk is almost constant or even decreasing but that it varies with traffic flow (Vitaliano et.al (1991), Dickerson et.al. (2000)). Decreasing risk is

[8] a = private accident cost to the users, b= risk value of relatives and friends, c = system external cost such a medical cost financed with general taxes.

compatible with an increasing number of accidents, but the number of accidents does not increase in proportion to the increased traffic volume.

The possible reasons why the risk declines has its implications for pricing. One reason could be that reduced speed is the duality of the increased safety; the cost is then captured in the congestion cost. The other reason is that people protect themselves in ways that we do not observe. For example, unprotected road users may take other routes or choose the car instead of the bicycle as the traffic volume increases. The cost for this behaviour is a part of the marginal accident cost, but is not estimated.

To find the marginal *external* accident cost it is necessary to make a distinction between cost internal to the examined user and costs that are external. The latter consists of (minor) cost born by the rest of society (some medical cost etc) and the dominant cost of imposing an accident risk on other users. It is often assumed that the user understands his own risk and consequently already bears the value related to his own risk of being a victim.

The external accident cost of heavy goods vehicles is a focal point for many of the interesting problems on accident externalities. In the table below the internal and external average accident cost per kilometre and weight class are summarised form a recent study (Lindberg (2002b)). The latter includes the cost for the non-truck part in the accident as well as the system external medical cost etc. The average external cost per kilometre varies from 0.02 €/vkm for the lightest class up to 0.099 €/vkm for the heaviest vehicles. An important observation is the falling part of internal cost as the weight increases. For the first weight class the proportion internal cost is 0.27 and for the heaviest the proportion is only 0.03. To neglect this split into internal and external will thus overestimate the external accident cost for lighter vehicles.

The risk declines with increasing distance for a single weight class (elasticity -0.63 - -0.91), which means that the marginal cost is below the average cost. The external marginal accident cost varies from 0.006 €/vkm to 0.033 €/vkm with an average between 0.008 and 0.011 €/vkm for trucks above 12 tonnes. The study focuses on driven distance by individual vehicles. This is different from the traffic volume on a single road. It can be expected that vehicles driven longer distances drive more on interurban roads, have a more experienced driver and may be better maintained. The analysis may therefore understate the risk resulting from an equi-proportionate increase in traffic on all roads.

Table 3. External marginal accident cost, HGVs, Sweden 1999.

Weight tonne	**Internal Cost (€/vkm)**	**External Cost (€/vkm)**	**Proportion internal (θ)**	**External Marginal Cost (€/vkm)**
3.5 – 11.9	0.007	0.020	0.27	n.a
12 – 14.9	0.005	0.032	0.13	n.a
15 – 18.9	0.004	0.065	0.06	0.006 - 0.010
19 – 22.9	0.003	0.031	0.08	0.007 – 0.009
23 – 26.9	0.006	0.048	0.11	0.008 – 0.012
27 – 30.9	0.003	0.050	0.06	0.015 – 0.017
31 -	0.003	0.099	0.03	0.030 – 0.033
Above 12t	0.004	0.047	0.08	0.008 – 0.011

The recent developments solve the issue of multi-modal accidents. A long time question has been the allocation of cost in relation to road-rail collision accidents at level crossings.

Lindberg (2002b) estimates an external marginal accident cost by protection device for road-rail level crossings. A highly differentiated pricing scheme would use this information and employ a specific cost for each track unit.

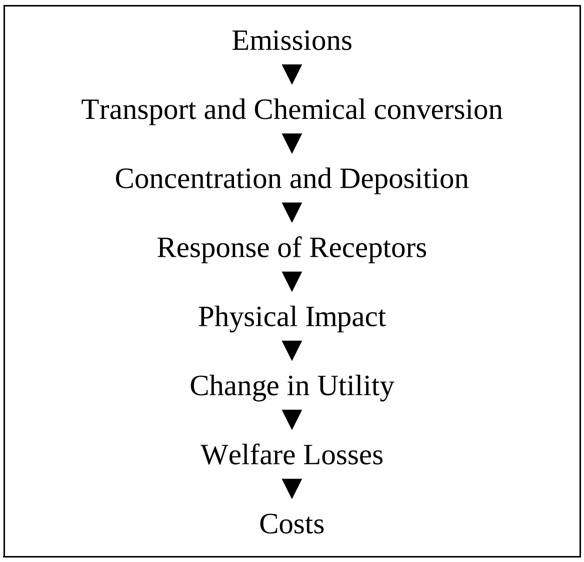
Table 4. Marginal accident cost for trains at road-rail level crossings (€/train passage)

Crossing type	€/passing train
ALL	0.032
Full barriers	0.036
Half barriers	0.087
All barriers	0.059
Open crossing w. light or St Andrew cross	0.102
Open crossing with light	0.097
Open crossing with St Andrew cross	0.184
No protection device	0.006

Exchange rate 9.4 SEK/€

2.4 Environmental cost

The development in estimate of environmental cost follows the mainstream in marginal cost estimates going from top-down to bottom-up. Friedrich and Bickel (2001) highlight that the top-down approach only can be used to address general issues like *'is train transport in general and average more environmentally friendly than road transport'* (p1). The bottom-up approach can be used to develop detailed environmental regulations and pricing. The question asked is; *'what is the environmental damage of a car with the EURO I technology driving in Brussels centre at lunchtime?* If we know the answer, the cost can be included in road pricing schemes.



Source: based on Friedrich and Bickel (2001)

Figure 1. The impact pathway approach

The common bottom-up approach used in Europe is the impact pathway approach, which has been developed within a series of research projects financed by the European Commission (ExternE). The approach includes a sequence of events that links the emissions to the impact and subsequent valuation.

The emissions are estimated for individual transport technologies, which are closely specified with respect to vehicle technology, location of the transport activity and type of fuel used. The model deals with the physical transport by wind of the emitted pollutants and chemical transformation. The output from this stage includes concentration and deposition of both the emitted components and secondary pollutants formed in the atmosphere. The next step includes the dose-response function, which transfers the dose, or exposure, to physical impacts and health impacts. The final step leads to the economic valuation.

The method is applied to all modes of transport and for railways, also the upstream effects of the energy generation processes are calculated. The method has been tested in a number of European Union countries and could clearly be transferred between countries (Belgium, Finland, France, Germany, Greece, The Netherlands and United Kingdom).

The huge amount of input functions certainly means that some of them are not well suited for a certain application. Continuously development of local knowledge is necessary. The dose-response functions come in a variety of forms, they may be linear or non-linear and contain thresholds or not. The shape of the function has implications for the result; if the function is strongly non-linear or includes threshold values the marginal effect of a certain vehicle technology will not be the same as the average effect. Not all environmental effects have been quantified with dose-response functions. While global warming is included with an abatement cost value no such values are included for acidification or eutrophication.

Table 5. Damage cost in €/100 vkm

Country and town/area	Petrol cars EURO II	Diesel cars, EURO II
Belgium, rural	0.22	0.45
Belgium, Brussels	0.84	3.31
Finland, Helsinki	0.31	1.00
German, Stuttgart	0.44	1.33
German, Güstrow-Neustrelitz	0.14	0.25
Greece, Athens centre	1.53	6.52
Greece, rural2	0.26	0.47
Netherlands, Groningen	0.17	0.41
Netherlands, Amsterdam	0.54	2.46
United Kingdom, London	1.10	4.46
United Kingdom, rural	0.14	0.29

Source: Friedrich and Bickel (2001) p 209-210.

3. Conclusions and implications for transport pricing reforms.

The structure of the marginal infrastructure cost, both for rail and road, shows a similar pattern; higher costs on low standard networks and lower costs on high standard networks. In addition, the estimates are found on the decreasing part of a production cost curve implying that the marginal cost will fall short of the average cost. The study on rail track costs suggests that similarities between countries are considerable but not complete. Few published studies are carried out on airfield wear-and-tear and we cannot judge on the magnitude and structure of this cost component. For inland waterways and maritime transport the infrastructure maintenance cost is small and is mainly a question at harbours.

In principle, the results of congestion or scarcity cost have been around for a long time. Auctioning of slots for rail tracks, airfields or harbours will reveal the information on the scarcity cost. In the road sector, the applied principle has been around for even longer. The latest development is more about detailed transportation models that capture more of the adjustment process than any new methods. In the same way as for scarcity costs, the congestion cost gives information on necessary expansion of the transportation capacity. To ensure that congestion and scarcity pricing are increasing the welfare, the revenue has to be used in a clever way and it is no predetermined rule that says it should be introduced to expand the capacity of the same mode.

The principle of external marginal accident cost is complicated and some issues still have to be resolved. However, many answers have been given in the most recent development but more studies on the risk function have to be carried out before the marginal cost can be differentiated by vehicle and by road type with certainty. We know that the potential victims may react to the increased risk with a costly risk avoiding behaviour. The cost of this risk avoiding behaviour should thus be added. Finally, we should not only concentrate on the external marginal cost when internalisation of accident costs is discussed. Internalisation can result in an optimal traffic volume under an in-optimal behaviour.

A huge amount of European Union research effort has gone into the development of the impact pathway approach and the ExternE model. The result is a common methodology that has been applied in almost 10 different countries and for all modes of transport. The results are robust, although not free from uncertainty, and can be seen as the best estimate availably.

The recent development in the measurement of the external cost of transport is focused around the move from top-down to bottom-up approaches. The use of more detailed databases with more sophisticated methods generates a more differentiated picture of the marginal cost of transport. First, new analysis suggests in many cases that the marginal cost is below the average cost - the familiar u-shaped cost curve is rediscovered. As many previous studies are based on average cost it is evident that the new studies will give a lower cost estimates. Secondly, past policies to curb transport cost have had an effect on the magnitude of the external cost. Modern engine technology emits only a fraction of emissions compared to older vehicles and vehicles tend to become safer and safer over time. Thirdly, it is evident that the cost varies largely between different subgroups of vehicles within the same mode.

This development has implications for the pricing policy. The large variation in cost between subgroups within the same mode suggests that the transport policy should move from a macro perspective to a micro perspective. More emphasis should be given to intra-model efficiency than inter-model efficiency. Given the huge differences in marginal cost between, for example, different technologies of road vehicles, a pricing regime that encourages the use of better technology within a mode is more important than a shift between modes through a rough average cost pricing. If a modal shift will occur within such a differentiated pricing structure, it will be from the dirtiest technology of a mode to the cleanest technology of another mode.

The other, more preliminary conclusion is that the marginal cost is highest on the low standard network. The implication for European road taxation legislation is clear, the

paragraph that limit user charges to only motorways, and similar roads, is a barrier for implementation of marginal costs and will lead to higher overall transportation cost in Europe.
As the marginal cost falls below the average cost in many cases, the question on cost recovery becomes important. First, it should be acknowledge that congestion and scarcity pricing will generate revenues. However, cost recovery will be difficult to achieve with only marginal cost pricing in many cases.
Given the successful result on the research on environmental cost, which was regarded as the most uncertain area for a couple of years ago, the use of proper theory and modern methods will hopefully lead to a convergence also of the more difficult marginal cost categories in the near future.

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