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

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I Introduction

The principle of marginal cost based pricing has been discussed in the European transport policy since the 60s. In 1971 the Commission submitted a proposal for a Council Decision on the introduction of a *Common System of Charging for the Use of Infrastructure*[1]. A common system was proposed, based on marginal social cost and budgetary equilibrium. The proposal suggested a common system, which should apply to rail, road and inland waterways. Interim reports followed up and the definition of the marginal social cost included the cost of use (i.e. maintenance), congestion and other external costs as noise, air pollution, and accidents[2]. However, other more urgent questions came in the forefront and the discussion faded away.

All the same, a number of economists continuously developed the ideas, knowing that the principle is one of the fundamental principles of economics (Jansson(1984), Newbery(1989), Small (1989)). However, it was not economists that pushed the principle back on track again. The environmental lobby discovered, and accepted, the principle of pricing environmental damages in the early 90s (e.g. Kågesson(1993)). They forcefully, and successfully, lobbied for the principle. 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 then probably a shift to rail transport.

A number of reports where produced on the topic of external cost of different modes of transport (e.g. OECD(1994), UIC(1994)). The question was 'hot' and rediscovered and the theoretical background was not always clear. Very often, the result was based on average cost estimates with a rough classification of internal and external cost. These well-intended studies often presented the result by mode, or rough sub categories of

[1] Accompanied by a Memorandum (O.J No C 62, 22 June 1971) providing detailed background.
[2]COM(75)493

modes (passenger car and goods vehicle etc). The marginal cost principle was regarded as a weapon on the battlefield between modes of transport.

While the movement in the 90s put the principle back on track, the recent development has put us on the *right* track. More and more studies explicitly estimate the *external marginal cost* with clear theoretical backing. We have gone from top-down to bottom-up approaches; from macro-studies to micro-studies. Two interesting outcomes emerges; new estimates are often lower than the result form previous studies, and the cost differs greatly between different vehicles, times of day etc.

These new results have a number of implications for transport policy. The lower general level with a higher degree of differentiation highlights the intra modal efficiency. Instead of huge shifts between modes, the outcome will be an adjustment within a mode. The lower level of the cost raises the question about cost recovery; marginal cost pricing may not cover the total cost. On the other hand, adding proper scarcity prices/congestion pricing revenues would be raised that push the balance towards, or beyond, cost recovery. Even if we incorporate other goals than efficiency in our pricing policy, marginal cost will always be the base. Optimal deviation from the first best marginal cost prices will start from information on the marginal cost. Without proper knowledge of the pure marginal cost no other policy can be efficient implemented.

II Recent progress in the measurement of external costs

What do we know about marginal cost of transport? We focus on the short run marginal cost and only repeat what others have said, along the optimal expansion path the short run and long run marginal costs are the same. In the following, we divide the discussion into traditional subcategories, (II.i) infrastructure cost, (II.ii) congestion cost, (II.iii) accident cost and (II.vi) environmental cost.

II.i Infrastructure cost

The question we want to have an answer on may be phrased: '*what is the extra cost imposed on the Swedish road authority if an additional truck from Denmark with a gross laden weight of 40 tonne and 4 axles run 1400 km across Sweden*'. If we know the answer, it would be appropriate to ask the Danish truck operator to pay a price equal to the cost.

We separate the question of the maintenance of the network from question of the expansion of the network. The first is about wear-and-tear of the infrastructure; let it be roads, railways or airfields, while the second question has its duality in congestion pricing and will be discussed in the next section.

II.i.a Production function

There is a rich body of literature in traditionally economics on production functions and on cost functions. Empirical cost functions are regularly published in economic journals but literature on cost functions purely for the infrastructure use is rare. The reason for this situation can be found in the fact that there was no interest and no need – for example for pricing purposes – to analyse such cost and cost causation relationships. However, the situation has changed.

In studies on wear-and-tear cost, we clearly see the movement from the top-down approach to the bottom-up approach; from the use of aggregate data on spending and total gross tonne kilometre in the whole country country, to detailed information on costs and traffic by segments of the infrastructure.

Johansson and Nilsson (2001) show clearly how this bottom-up method can be used when analysing the marginal cost related to wear-and-tear of rolling stock on the rail infrastructure. The vertical separation of the rail industry into a track authority and one or more operators has its implication for the data availability; cost related to infrastructure is accounted for separately from train operation costs. In addition, a large part of the information is booked on a disaggregated level, i.e. track unit. For each track unit, information can be found not only about maintenance spending, but also about traffic, length, number of switches, bridges, the quality of the track etc. This micro information makes studies possible in a much better way, than has been possible previously with aggregated time-series data. When modern econometrics is employed on these micro dataset the explanatory power of the model is high.

However, not all costs are recorded by segment and a part of the costs are classified as common costs. Some of these costs are truly common and should not be allocated, while others should be allocated to the track unit using different keys. The result from analysis of Swedish and Finnish data suggests that the average costs for maintaining tracks in those two countries decrease with traffic load. Higher traffic volumes imply lower average and marginal maintenance cost. This is analogous with the familiar u-shape of the cost curve. As both the Finnish and the Swedish data indicate a decreasing cost activity the revenues will fall short of the 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: Estimates of 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	0.009	0.009	0.012	0.018
Secondary/non-electrified	0.097	0.099	0.026	0.040

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

II.i.b Reinvestments

The approach taken above is suitable for *current* maintenance cost. For *reinvestments*, extremely long time series are needed to be able to find a pattern in the reinvestment cost. Instead, an alternative shortcut, originally developed by Newbery (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 Danish truck change the present value of the future reinvestment cost?*

The key relationship to understand is how the traffic load will affect the pavement cycle. After some mathematical calculations, it is found that the marginal cost is a product of the average cost and an elasticity, which expresses the change in lifetime of the pavement as the traffic load changes. The assumption by Newbery implied that the elasticity was one, and consequently the marginal cost equals the average cost.

Road engineers seldom, or never, 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 that can be used to derive marginal costs will be revealed from engineers.

In a Swedish long term pavement performance project, run by road engineers for 8 years, lifetime functions have been estimated (Wågberg 2001). Similar approaches have been taken in other countries and in European Union research (PARIS). We only need to assume a certain 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. Two observations can be made; the Danish operator should pay a higher share of the average pavement cost if he uses the low quality secondary network than if he uses the high quality main network. Secondly, the charges will not recover the total cost of pavement.

Table 2: Lifetime elasticity (or cost recovery rate)

Standard axles per day And direction (Q/365)		*Strong road base* 50	75	100	125	150	175	*Weak road base* 200
Low traffic volume	*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*
High traffic volume	*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)

II.i.c Forth power rule and other costs

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 research on the applicability of the forth power rule is lacking.

Finally, a cost component that often is forgotten in estimates of the wear-and-tear is the increased vehicle and comfort cost of subsequent road users as the road deteriorates. In principle this has been explored (Newbery 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. Modern estimates on these costs are lacking.

II.i.d Conclusion

It is clear that the most important recent progress in estimate on the marginal cost of infrastructure use is the move from a top-down to a bottom-up approach. This has been facilitated by a new structure of infrastructure management that records data of infrastructure cost in a better way. However, much can still be done to improve the quality of information, but to our experience, it is more a question of save and store the right data, than to initiate huge new data collections. With micro data at hand, econometric techniques are available to estimate the marginal cost of wear-and-tear. For some cost components, models that mix engineering and economic knowledge are used.

The econometric approach taken for railways is also suitable for roads and other infrastructure facilities. However, information on road maintenance cost is often not well allocated to single road links, which makes the analysis more challenging. The principle for reinvestment cost can easily be applied to all modes of transport.

The structure of the cost, both for rail and road, shows a similar pattern; we find higher costs on low standard networks and lower costs on high standard networks and secondly, the marginal cost will fall short of the average cost. The study on rail track costs suggests that the similarities between countries are considerable but not complete. It would be heroic to generalize the result from two countries up in north; more studies have to be carried out, but the blueprint exists. 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 problem at harbours.

II.ii Congestion cost

In a large Swedish project on the marginal cost of transport, congestion cost is ruled out from the research. It is said; *'we know what we need to know of the marginal cost of road* *congestion and slot allocation of rail tracks – it is a political question to decide on implementation'*[3]. Although this statement may be too strong, it encapsulates the main findings. Congestion pricing is not about estimate the external marginal cost – the principle has been known for long – 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.

II.ii.a <u>Scarcity cost</u>

Let us assume that a Swedish train operator plans to run a line from Sweden, passing the new Öresund bridge, entering into Denmark and ending his line at a Danish town. We have examined the infrastructure damage cost above, the additional question we need to ask is *'what is the extra cost this train will impose on the Danish rail authority and operators due to scarce capacity?'*

To be able to introduce the new line, the operator need to have slots on the tracks he intend to pass. If slots are available, the operator should be allowed to run the line 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 the operators that want to run on the tracks; we can imagine a number of different systems, decisions by the Danish rail authority, or by a club of operators or even lottery.

All of these systems could generate an efficient allocation of slots, mainly by chance. A more 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 Danish 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.

[3] Source: WWW.VTI.SE/TEK

This is in fact the scarcity cost irrespectively of how the track capacity is allocated; we do not need to introduce auctions to find this cost, in principle. However, with an administrative procedure we are not certain that the operator with the lowest willingness-to-pay has to leave the track and consequently, we are not certain that the scarcity cost is minimized. In addition, we have problem to estimate the willingness-to-pay of the train that has to leave the track. With an auction, the operator will reveal this himself.

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 will 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. This problem can be solved, but it is another story.

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. Regardless of the auctioning principle, the idea of scarcity cost is the same for these other modes.

II.ii.b 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 the other road users as the number of cars increases. For many years, studies have been carried out using engineering based volume delay curves that depicts the change in speed as the number, and composition, of vehicles increases. The reduced speed for all users is valued with a value of time 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 the 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. We can assume that users in reality will be cleverer than researchers in finding new behaviours. This is at the core of the pricing principle - let the user find the way and make the best trade offs.

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, the fact that we have higher congestion costs in urban areas than in non-urban areas is of course a result of the restriction on the possible expansion of the road capacity. It is no predetermined rule that the revenues should be invested in the same mode of transport. Clever use of the revenues is at the backbone of a successful congestion pricing implementation.

II.ii.c Conclusions.

In principle, the results of congestion or scarcity cost have been around for a long time. Auctioning of slots for railtracks, airfields or harbours will reveal the information on the scarcity cost. Without the auctioning method this information has to be assessed in other ways, and we are not certain that the scarcity cost is minimized, but the principle is the same The cost will give information on where the capacity needs to be expanded and the revenues from pricing the scarcity cost, or auctioning, will give revenues to the infrastructure operator.

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 pricing are increasing the welfare, the revenue has to be spend in a clever way and it is no predetermined rule that says it should be introduced to expand the capacity of the same mode.

Congestion pricing is ready for introduction as far as the knowledge on marginal cost is concern. The recent developments are more about acceptability of pricing schemes and packages.

II.iii Accident cost

The principles of external marginal accident cost are complicated, the theory is only recently developed, it is difficult to find the relevant empirical functions and the principle includes ethical questions (see Lindberg 2001). The question we try to answer could be; *'what is the extra accident cost if a Swedish HGV travels on the German autobahn from Travemünde to Frankfurt?* First, we discuss the marginal accident cost and in a second step the *external* marginal accident cost.

II.iii.a Marginal accident cost

The marginal accident cost is analogous to congestion cost discussed above. As the HGV driver enters the traffic flow on autobahn, he increases (or changes) the cost of all others with a small amount; for the accident cost as an increased (or changed) risk and for congestion cost as increased travel time. All these small cost increases are summed over all affected users to find the total change in cost due to the entrance of Swedish HGVs on the autobahn.

Previous studies on accident cost have taken a top-down approach and estimated the average cost of accidents. This assumes that the risk is constant as more vehicles enter the road. However, recent research based on micro data suggests that the risk is often *decreasing* with more vehicles. Decreasing risk is compatible with an increasing number of accidents, but the number of accidents does not increase in proportion to the increased traffic volume.

The consequence is that the marginal accident cost will fall below the average accident cost. 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.

The issue of the valuation of accidents is also 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)).

II.iii.b <u>The external marginal accident cost</u>

The HGV driver will not consider the whole of the marginal cost in his decisions. This highlights the other aspect of the marginal accident cost, the problem of internal and external cost components. In congested traffic, all users have to reduce the speed and the cost the user considers in his decision is the average cost. In accidents, only the victim bears the cost (in the absences of liability systems). As the own vehicle becomes safer, the user internalise less of the cost himself. The table below summarise recent data for Swedish HGVs, which shows that as the vehicle becomes heavier we expect the user to bear a smaller part of the cost.

Table 3: Internal and External Cost per goods vehicle accident in Sweden 1999 by weight class (kEuro/Accident)

Weight Class	Internal Cost IC (kEuro)	External Cost - other vehicles EVC (kEuro)	External Cost – unprot. user EUC (kEuro)	System External cost ECC (kEuro)	Total External Cost TEC (kEuro)	Total Cost TC (kEuro)	*PROP (θ*
3.5 – 12	11.5	26.9	0.0	4.9	31.9	43.4	*0.30*
12 – 15	4.6	24.5	1.0	6.1	31.6	36.2	*0.15*
15 – 19	4.7	63.3	0.9	8.1	72.3	77.0	*0.07*
19 – 23	3.5	37.0	0.0	5.5	42.5	45.9	*0.09*
23 –27	5.9	42.6	0.4	6.1	49.1	55.0	*0.12*
27 – 31	3.4	43.8	4.5	6.0	54.2	57.6	*0.07*
Above 31	2.8	86.0	0.0	10.5	96.5	99.3	*0.03*
All	5.3	43.9	1.4	6.3	51.5	56.8	*0.10*
HGV >12t	4.6	45.7	1.5	6.4	53.7	58.3	*0.09*

Source: Lindberg (2002b).

The cost for an average HGV accident is 58.3 k€. The majority of the cost (53.7 k€) is external cost and the HGV users own cost is limited to 4.6 k€, or 9%. The external cost contains costs for unprotected road users (1,5 k€), other vehicle users, mainly passenger car users (45.7 k€), and so called system external costs (6.4 k€), primarily medical cost and lost production paid by the society at large and not paid by the users.

The result of the two parts, the marginal accident cost and the internalisation of the average cost, are summarised for the heavier vehicles in the table below. The risk function is based on individual heavy goods vehicles driving on an average road network. The marginal cost increases with vehicle weight. However, the result is only robust for vehicles above 15 tonne.

Table 4: External Marginal Cost by Weight Class (€/100vkm)

Weight Class	***Marginal cost***
15 – 19	**0.62**
19 – 23	**0.75**
23 – 27	**0.81**
27 – 31	**1.61**
Above 31 t	**3.20**

The existence of a liability system will transfers the cost burden from the victim to the responsible user and will affect the proportion of internalisation. In Sweden, the sums that are transferred are so small that they hardly affect the outcome of the costs above.

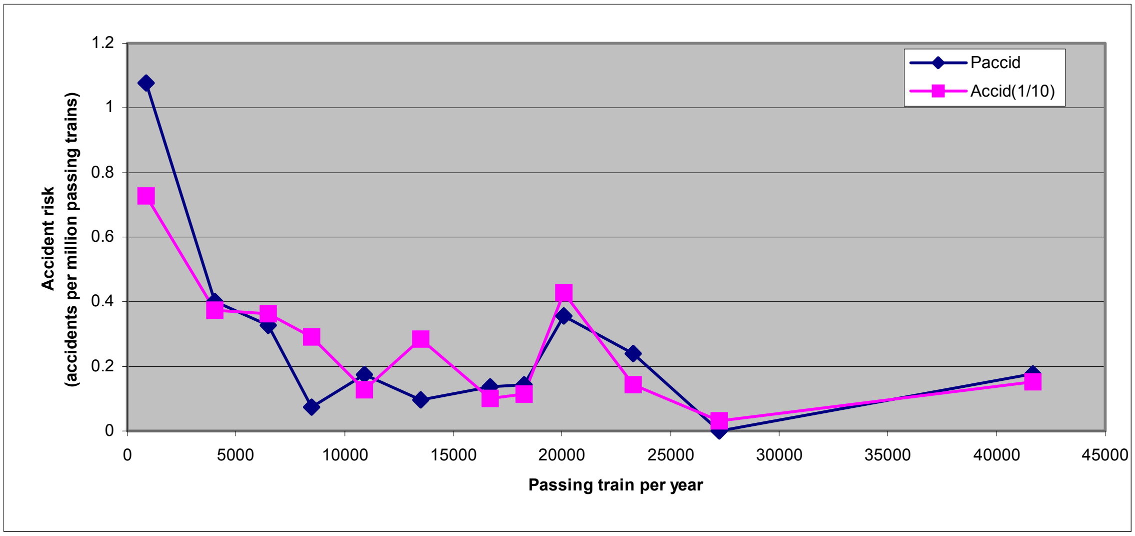
II.iii.c Rail-Road accidents

The recent theoretical developments solve the issue of multi-modal accidents. In fact, a micro economic theory does not distinguish between modes of transport, it is applicable to all types of accidents. A long time question has been the marginal cost in relation to road-rail collision accidents at level crossings.

Following the two step approach above, we need to find the relationship between the number of passing trains and the risk if we look for the marginal cost for the trains, and the relationship between the number of passing cars and the risk to find the cost for cars. In a second step, we need to find who bears the cost.

In a Swedish study (Lindberg 2002c) the accident risk at 8000 road-rail level crossings are examined. The study uses information on protection device, road type, number of passing cars and passing trains. It is assumed that the road user bears all the accident cost. The effect of both road and rail traffic are significant and the protection devices have the expected sign. The accident probability will decline if full or half barriers are installed. The result shows that the risk declines with an increasing number of passing trains. Once again, the marginal cost is below the average cost.

Figure 1: Accident risk, all accidents (ACCID, divided with 10) and personal injury accidents only PACCID 1995-1999[4]



The detailed approach makes it possible to estimate an external marginal accident cost by protection device (se table below). A highly differentiated pricing scheme would use this information and employ a specific cost for each track unit. In addition, as the worst level crossings are rebuilt the cost should decline.

Table 5: 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 S:t Andrew cross'	0.102
Open crossing with light	0.097
Open crossing with S:t Andrew cross	0.184
No protection device	0.006

Exchange rate 9.4 SEK/€

4 Crossings are grouped by number of passing trains. The first eleven groups have an interval of 2500 passing train. The number of observations in each group are 3382; 2229; 941; 652; 419; 459; 264; 77; 28; 36; 23. The twelfth and last group contains crossings with 30000-75000 passing trains (108 obs).

II.iii.d Conclusions

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.

The empirical developments of the estimates on external marginal accident cost mirrors the development of the infrastructure cost. The state-of-the-art approach is based on detailed databases on individual vehicles or crossings. The marginal cost falls short of the average cost and the estimates can be differentiated in detailed subgroups. However, more studies on the risk function have to be carried out before the marginal cost can be differentiated both on vehicle and on road type.

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. The existence of externalities does also influence the behaviour of the driver. Furthermore, the liability system may transfer the responsibility for the cost from the victim to the injurer, the non-injured part in an accident. If we assume that, the injurer internalise this cost, the type of liability system and level of fines and compensation will affect the external marginal cost.

II.iv Environmental cost

The development in estimate of environmental cost follows the mainstream in marginal cost estimates. The approach is going from a top-down approach, leading to an average cost to a bottom-up approach. Friedrich and Bickel (2001) notice 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). On the other hand, 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 readily be included in road pricing schemes.

The common bottom-up approach used in Europe is the impact pathway approach clearly described in Friedrich and Bickel (2001). The approach 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.

Figure 2: The impact pathway approach

Emissions
▼
Transport and Chemical conversion
▼
Concentration and Deposition
▼
Response of Receptors
▼
Physical Impact
▼
Change in Utility
▼
Welfare Losses
▼
Costs

Source: based on Friedrich and Bickel (2001)

The emissions are estimated for individual transport technologies, which are closely specified with respect to vehicle technology, location of the transport activity, type of fuel used, and the emissions due to production, maintenance and disposal of vehicles and infrastructure. 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. Finally, a number of steps lead to the economic valuation. The approach is the same as has been the accepted method in accident valuation above, the willingness-to-pay approach.

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).

Table 6: 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.

The introduction of the EURO I, EURO II and EURO III emission standards reduces the damage cost per vehicle kilometre by 65%, 75% and 90% compared to an uncontrolled diesel car. Other detailed results are available.

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 certain vehicle technology will not be the same as the average effect.

Some of the studies carried out with the method still derive average costs, although on a very detailed level.

II.iv.a <u>Conclusions</u>

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. Questions can be raised on some of the functions that have been transferred from other countries (US) but it describes the state-of-the-art. The long term research on the method (ExternE was presented in 1995) has given result.

In the same way as the other cost categories, estimates of the environmental cost has moved from a top-down approach to a bottom-up approach. The result, as we have seen for other cost categories, is a much more differentiated cost structure. Preliminary conclusions suggest that the method also give lower cost estimates then with top down approaches.

II.v Summary of recent progresses

It is evident for all cost components that the recent progress are centred on a healthy shift from top-down approaches to bottom-up approaches; from macro-studies to micro-studies.

A restructuring in the infrastructure sector where infrastructure cost is better recorded has helped the development. However, much still has to be done to ensure an efficient use of data. In addition, the improved computer capacity makes micro-studies of large datasets possible and developments in econometrics has improved the result.

Two interesting outcomes can be found for all cost categories; new estimates generate lower marginal cost than previously thought and, secondly, the cost differs greatly between different vehicles, times of day etc.

It looks as if proper marginal cost analysis turns out to give costs below the average cost in many cases. 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. 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, the studies are carried out with information that is more detailed, which makes it possible to examine detailed subcategories of vehicles etc.

Another conclusion from some of the cost categories is that the marginal cost is higher on the low standard network. This is intuitively an obvious conclusion, but runs unfortunately often contrary to the current pricing practice.

III Implications for transport pricing reforms.

The clear development towards more detailed assessments of the cost has implications for the pricing policy. The transport policy should move from a macro perspective to a micro perspective. More emphasis should be given to intra-model efficiency than to inter-model efficiency. Pricing reforms should improve the overall efficiency of the transportation system. Given the huge differences in marginal cost between, for example, different technologies of road vehicles, a pricing regime that encourage 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 (1999/62/EC) 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/scarcity pricing will generate revenues that will improve the cost recovery result. However, in other areas cost recovery will be difficult to achieve with only marginal cost pricing. Nevertheless, the knowledge on marginal cost is vital. All efficient deviations to ensure cost recovery takes as its starting point the estimate of the marginal cost.

The willingness-to-pay valuation approach is now almost universally accepted and used in a number of marginal cost studies.

For environmental cost, we have a common methodology that has been applied for all modes of transport in a number of countries. Although, uncertainty remains, it is a proper base for pricing reforms. Congestion pricing is not anymore about estimation of the marginal cost, it is more about acceptability and packaging of road pricing schemes. Scarcity pricing is suitable for rail networks, airfields and harbours. Methods exists for auctioning of slots that will increase the efficiency of the slot allocation process, reveal the scarcity cost, give revenues for capacity expansion and information on where the capacity expansion is needed. For the ware-and-tear of infrastructure, econometric methods are available as more disaggregated databases can be constructed. In this area, more studies should be carried out to ensure generalization of the approaches. Finally, accident cost is one of the most difficult areas and more studies have to be conducted around the functional form of the accident risk.

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 lead to a convergence also of the more difficult marginal cost categories in the near future.

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