Estimating external cost

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Outline of presentation at IMPRINT seminar

1 October 2003

This paper focus on estimation of marginal environmental and accident cost due to road transport but will also shortly discuss congestion cost. The cost of infrastructure damage is covered by the presentation made by Heike Link.

1 Methods and Recent Estimates

1.1 Methods

In the most recent estimates of the external cost of transport a stronger focus has been given to marginal cost theory (see Bossche et.al. 2002). This means that the costs that researchers try to estimates are both external and marginal to its characteristics. This development, with its stronger base in economic theory, has its implication for the methods used.

Previous estimates have often been based on a top down approach. This approach starts with an estimate of the total (external) cost. The total cost is then allocated to different modes or vehicle categories and finally divided with the traffic volume to express the cost per kilometre driven.

With the aim to estimate external marginal cost the methods have changed to a bottom up approach. The starting point is detailed databases which are analysed basically with econometric methods to derive cost functions and subsequently marginal cost estimates. In addition to the i) *econometric method* we can identify two more bottom up methods; ii) *engineering methods* and the use of iii) *planning models*.

The move towards econometric methods increases the demand on information. The information need to be disaggregated and expressed in monetary units. This has proven to be a critical point in analyses of the transport sector. It is often very difficult to find or construct suitable disaggregated databases with economic information.

As an alternative to the econometric method an engineering method is often used. The reason to favour this method is the observation that physical data more often is collected in the transport sector than economic data. With information on ‘physical functions’, cost functions can be constructed and from this marginal costs can be derived. For accident cost, information on risk functions are used to derive risks and risk elasticities, which is joined with accident cost information to derive marginal external accident cost. The marginal cost of the long term cyclical cost of road maintenance can also be estimated as a product of deterioration elasticities and maintenances cost. Finally, the most common method to estimate environmental costs - the impact pathway approach (IPA) - is a chain of numerous ‘physical functions’ with an economic valuation as a final step.

Although ‘physical functions’ are more readily available in the transport sector it is crucial that they are of good quality. Some of the problem we have faced when constructing detail databases for econometric estimates, such as the quality of traffic information, will probably affect the quality of the ‘physical functions’ too.

Finally, it is tempting to use already developed ‘planning models’ such as HDM to derive marginal costs. However, care has to be taken that the functions used has the right property. Often it seems that traffic volume is used as a proxy for other variables (Thomas (2003)). This may be a defendable simplification when models are used for cost benefit analyses of strategies or projects. However, when conclusions shall be drawn on the changed cost of one more vehicle strange results may result. Nevertheless, it is worth to explore this method further as it will spread the research cost to a wider range of interests in the transport sector.

1.2 Recent estimates

The Swedish Institute for Transport and Communication (SIKA) presents annually a compilation of marginal cost estimates. The table below summarise their recent estimate of the external marginal cost for trucks based on information from the Swedish National Road Administration (SNRA).

Although the information is not up to date for each single component it is a useful starting point for discussions on recent estimates.

Table 1: External cost of trucks, Sweden (€/vkm)

		Wear and tear[1]	*trailer*	*Emissions*[2]	*Noise*[3]	*Accidents*	*Global Warm*	***TOTAL***
Urban	3.5-16t	0,01	0,01	0,12	0,06	0,07	0,04	**0,30**
	>16t	0,02	0,03	0,18	0,31	0,07	0,10	**0,70**
Rural	3.5 - 16t	0,01	0,01	0,04	0,01	0,04	0,05	**0,14**
	>16t	0,02	0,03	0,08	0,03	0,04	0,09	**0,28**

Source: SIKA 2003:6

The cost for wear and tear is split into the cost related to 'truck only' and 'trailer only' in the table. The same cost is used for urban and non-urban roads, which reflects the lack of information of urban road costs. However, a more serious shortcoming is the huge uncertainty in these numbers. The corresponding information presented by the SNRA last year was only 1/3 of these costs. This uncertainty is more surprising as the cost of road wear and tear has been discussed for decades and the information has to be important for any road management organization. The only consolation is that the expected cost is small in relation to other cost components.

The cost of emission and global warming is the most dominant cost component and is based on Swedish methods and values. They usually tend to be high compared to standard European values derived with the impact pathway approach. In section 1.2.1 below we present a recent application of the IPA on Swedish data for comparison. Global warming is a separate problem and SIKA presents the cost in an interval based on CO_2 valuation ranging from 80 to 280 € per tonne CO_2 where the low estimate (used in the table) is the current carbondioxide taxation and the higher number the shadow cost to reach the target set for the Swedish transport sector. The table also presents the external marginal noise cost although the uncertainty around this figures are huge. For heavy trucks the costs are given in an interval for low and high speed (+/- 50% of the average presented in the table - the highest cost is found at low speed). The figures should probably be seen more as an example than a real estimate. The marginal external accident cost is based on older information and new estimates suggest a lower cost which is presented in section 1.2.2 below.

1.2.1 Emissions and global warming[4]

The most common bottom-up approach to assess the environmental cost used in Europe is the impact pathway approach described in Friedrich and Bickel (2001). The approach has been developed within a series of research projects financed by the European Commission (ExternE). The result from these studies tends to give substantial lower cost estimates than the internal Swedish approach[5].

Therefore, VTI together with Bickel et.al. made a Swedish application of the impact pathway model used at IER. The approach includes a sequence of events that links the emissions to the impact and subsequent valuation. The approach is thus dependent upon models for the reactions and dispersion of pollutants as well as knowledge of the effect of the emissions on humans, materials and the natural environments. This of course requires quantified 'physical functions'. For acidification and

[1] SIKA (2003), based on table 5.4 'nya skattningar'.

[2] Urban emission costs refers to one city, Landskrona.

[3] SIKA (2003), table 5.5 'tät tätort'.

[4] Based on Nerhagen et.al. (2003)

[5] ASEK

eutrophication of ecosystems as well as for global warming no quantified relationships are established and consequently, these effects are not accounted for in the IPA. Acidification and eutrophication are of specific interest in Sweden and a crude abatement cost method was applied. The same method is used for global warming where a value of 20 € per tonne CO_2 was used (compare the values use by SIKA above).

Costs are estimated separately for effects due to pollutants with a local dispersion and for pollutants with a regional dispersion. The abatement cost of acidification and eutrophication is separately included as a regional problem. The total cost due to a pollutant is the sum of the local, the regional cost and global warming adjusted for double counting.

Table 2: Environmental costs in urban and non-urban areas, €/vkm, Sweden.

Urban	*Local*	*Regional IPA*	*Regional Acid and nutrif.*	*Global Warming*	*Total*
Bus	0,010	0,028	0,026	0,023	0,087
HGV	0,012	0,027	0,047	0,024	0,110
Diesel car	0,004	0,004	0,004	0,006	0,018
Gasoline car	0,001	0,004	0,005	0,009	0,018
Two-wheelers	0,003	0,004	0,000	0,002	0,009
Non-urban					
Bus	0,002	0,012	0,024	0,012	0,050
HGV	0,003	0,019	0,048	0,021	0,091
Diesel car	0,001	0,002	0,004	0,004	0,010
Gasoline car	0,000	0,002	0,006	0,003	0,012
Two-wheelers	0,001	0,003	0,003	0,002	0,009

A noticeable result, although uncertain, is the importance of the cost related to acidification and eutrophication in the table. For HGV these costs account for 43% in urban areas and 53% in non-urban area. Local dispersion has a much smaller cost impact with 3% in non-urban areas and 11% in urban areas for HGV.

When the IPA approach is complemented with abatement cost the cost for HGVs on non-urban roads is in fact higher than the corresponding Swedish estimates in table 1, if global warming is excluded from the comparison. In urban areas the recent estimate is still lower than the values presented in table 1. However, the figures in table 1 is based on one city while the figures in table 2 is a Swedish average with, probably, lower population density.

Abatement costs only arise after a certain threshold level and for acid deposition this limit is only passed by HGV and gasoline cars. This abatement cost component is thus only included for these categories. How this result should be interpreted in practice needs further investigation.

The costs for emissions on urban roads have been calculated for different vehicle categories in every urban area in Sweden. In the project we have also calculated the cost for two specific urban areas in Sweden; Stockholm and Skellefteå. Stockholm is in middle of Sweden and Skellefteå in the north, both at the Baltic Sea coast. For Stockholm and Skellefteå the cost calculations where made for two aggregated vehicle categories; diesel vehicles and gasoline vehicles. For comparison the same categorization is used for all urban areas in Sweden in the table below.

Table 3: Environmental cost for gasoline vehicles (left) and diesel vehicles (right) in different cities, Sweden, €/vkm.

	Gasoline			Diesel		
	Urban	*Stockholm*	*Skellefteå*	*Urban*	*Stockholm*	*Skellefteå*
Local	0,001	0,001	0,000	0,006	0,012	0,005
Regional	0,009	0,011	0,003 [6]	0,029	0,025	0,007
Global warm	0,009	0,009	0,009	0,012	0,012	0,012
Total	0,018	0,021	0,012	0,048	0,049	0,024
Comp. w. average	100%	118%	66%	100%	103%	50%

A general result is that the costs for the (non-reactive) pollutants that have local impact change by the differences in population density. Twice as many people will be exposed to the pollutants emitted per km in Stockholm as in Skellefteå. However, the cost estimate is lower than average for Skellefteå although they have a slightly higher population density than the average for urban areas.

For the pollutants with regional dispersion the same result doesn't emerge. For ozone the cost estimate is the same irrespective of where the emissions occur as the calculation of ozone formation is based on EMEP country-to-grid matrices, so the results for a country are mainly the same. For particles and the cancerogenic substances considered[7] the costs is lower both for Stockholm and Skellefteå compared to the average, which is probably due to the geographical location of these two cities, close to the Baltic Sea. Lower cost estimates for regional impacts for NO_2 and acid deposition and the higher cost for SO_2 regional for gasoline cars in Stockholm are related to a number of factors such as differences in geographical location, background concentrations, air chemistry etc.

1.2.2 Accidents

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; 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. The external marginal accident cost has two distinct characteristics: i) a division between internal and external cost and ii) a congestion like effect. We consider here the decision to make a trip; the external marginal accident cost is related to distance (kilometre).

The external marginal accident cost will depend on four elements: the cost of an accident, the accident risk, the proportion of the cost already born by the examined user and the risk elasticity. The latter expresses the change in risk as the traffic volume changes.

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)).

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[6] Excluding the highly uncertain abatement cost estimate

[7] CO and NMVOC

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, the majority of studies which link accident risk with traffic volume suggest that the risk declines with increasing 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.

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 here assumed that the user understands his own risk and consequently already bears the value related to his own risk of being a victim. This assumption, in addition to the low risk elasticity we find, explains why the cost is lower than previously thought.

<u>Accident cost of HGVs</u>

The external accident cost of HGV is a focal point for many of the interesting problems on accident externalities. Thanks to two unique databases, one on accidents and one on driven distances, an UNITE study tries to estimate the marginal external accident cost for a number of different weight classes of HGVs (Lindberg (2002b)).

The study focuses on driven distance by individual vehicles. This is different from the traffic volume on a single road. We may expect that vehicles driven longer distances drive more on interurban roads, have a more experienced driver and may be better maintained. Our analysis may therefore understate the risk resulting from an equi-proportionate increase in traffic on all roads.

The case study has two basic data sources, information on all individual accidents during 1999 from the Swedish National Road Administration and information on the distance driven during 1999 for 78 000 HGVs above 3.5 tonne from the Swedish Vehicle Inspection Authority. The complete database consists of 3 940 accidents including 83 fatalities, 254 severe injuries, and 1 035 slight injuries. This is 5.8% of all the (reported) accidents in Sweden during 1999. In general, HGV accidents are more severe than the average road accident (14% of the fatalities) even if they include less passengers and unprotected users (bicyclist, moped users (1.2%) or pedestrians (2.6%)).

The average accident risk per goods vehicle is presented in the table below. This risk is (almost) strictly increasing with weight class. However, the accident risk per vehicle kilometre does not show the same clear pattern. This less clear relationship between risk and weight when risk per vehicle kilometre is studied could be due to differences in the type of exposure; heavier vehicles operate predominantly on rural roads.

Table 4: Accident risk per registered vehicle and per kilometre by Weight Class, Sweden 1999

Weight Class	*Tonne Min*	*Tonne Max*	*Accidents during 1999*	*Accidents per vehicle*	*Accidents per million vehicle kilometre*
1	3.5	11.9	204	0,01	0,63
2	12	14.9	70	0,02	1,00
3	15	18.9	225	0,03	0,90
4	19	22.9	212	0,05	0,72
5	23	26.9	754	0,06	0,98
6	27	30.9	517	0,08	0,91
7	31		74	0,06	1,03
All			2055	0,04	0,84
ALL>12			*1854*	*0,05*	*0,87*

The average cost of a goods vehicle accident was 57.000 Euro with 13.000 Euro per accident for weight class 1 and 94.000 Euro per accident for weight class 6. In the table below the average accident cost per kilometre and weight class are presented. The cost varies from 0.027 €/vkm for light vehicles and 0.102 €/vkm for the heaviest class with an average of 0,051 for HGVs (above 12 tonne). This average cost has been spit into internal and external cost where 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. The average for all trucks is 0.043 €/vkm and for HGVs 0.047 €/vkm.

An important observation is the falling part of internal cost as the weight increases. For weight class 1 the proportion internal cost is 27% and for weight class 7 the proportion is only 3%. To neglect this split into internal and external will thus overestimate the external accident cost for lighter vehicles.

Table 5: Total accident cost per kilometre, internal accident cost and external accident cost per kilometre (€/vkm) and proportion internal cost in Sweden 1999 by weight class.

Weight Class	*Tonne Min*	*Tonne Max*	*Total Cost (€/vkm)*	*Internal Cost (€/vkm)*	*External Cost (€/vkm)*	*Proportion internal*
1	3.5	11.9	0,027	0,007	0,020	0,27
2	12	14.9	0,036	0,005	0,032	0,13
3	15	18.9	0,069	0,004	0,065	0,06
4	19	22.9	0,033	0,003	0,031	0,08
5	23	26.9	0,054	0,006	0,048	0,11
6	27	30.9	0,053	0,003	0,050	0,06
7	31		0,102	0,003	0,099	0,03
All			0,048	0,004	0,043	0,09
ALL>12			0,051	0,004	0,047	0,08

The risk seems to decline with increasing distance for a single weight class which means that the marginal cost is below the average cost. In the table below the elasticity is presented for each weight class. The elasticity expresses the change in risk (in percentage) as the traffic volume increases with 1%. The number is indeed low and more research has to be done around this type of estimates.

If this elasticity is applied on the external cost per kilometre we can estimate the marginal external (only) cost. This marginal cost varies from 0.002 €/vkm to 0.033 €/vkm with an average of 0.011 €/vkm for HGVs. However, with an assumption that the user internalise the average internal cost an additional external effect will occur reflecting the reduced cost for users of the same weight class as the accident risk for this group declines. With the strong reduction in risk this effect will be a subsidy which will increase as the proportion internal cost rises. This question requires some more research before firm conclusions can be drawn.

Table 6: Risk elasticity, marginal external cost, adjusted internal cost and marginal external cost (€/vkm)

Weight Class	*Tonne Min*	*Tonne Max*	*Elasticity*	*MC External only (€/vkm)*	*Adj internal cost (€/vkm)*	*MC External only and adjusted Internal cost (€/vkm)*
1	3.5	11.9	-0,91	0,002	-0,006	(-0,004)
2	12	14.9	-0,90	0,003	-0,004	(-0,001)
3	15	18.9	-0,86	0,010	-0,004	0,006
4	19	22.9	-0,72	0,009	-0,002	0,007
5	23	26.9	-0,75	0,012	-0,004	0,008
6	27	30.9	-0,63	0,017	-0,002	0,015
7	31		-0,75	0,033	-0,003	0,030
All			-0,83	0,007	-0,004	0,004
ALL>12			-0,76	0,011	-0,003	0,008

1.2.3 Congestion

For many years, studies have been carried out using engineering based volume delay functions that depicts the change in speed as the number 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. 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.

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 and the research challenge is to understand new form of elasticities.

2 Differentiation and Policy

The bottom-up approach results in marginal cost estimates which are strongly site dependent. In the sections above we have presented example on environmental cost in different cities and accident costs by different weight classes. If not great care is taken to have the same background characteristics when numbers are compared the picture of marginal cost estimates that emerges will look very uncertain. The policy consequence of this variability in estimates has one negative possible outcome and two positive outcomes. The first is to say;

i) *This is too complicated* – let's guess on a regulation or an average price. Needless to say, without use of the best knowledge available both regulations and pricing will most probably be inefficient policies. A more positive outcome would be to;

ii) *design a well informed policy mix of pricing and regulation*. Some research projects, as MC-ICAM, have increased our knowledge in this area but still more can be done. It is possible that future marginal cost case studies have to come with information on the trade off between complexity and simplicity. The final response to the observation of increased variability is to introduce;

iii) *advanced pricing*. Thanks to the development in information technology more advanced pricing systems can be designed in the near future.

2.1 Intelligent economic speed adaptation

It is well known that driven distance is not the only factor, or even the most important factor, creating external accident costs. In a recent project, *Intelligent economic speed adaptation (IeSA)*, VTI has focused the attention around the need and possibility to refine the economic incentives to not only influence driven distance, but also to shape the behaviour while driving (Hultkrantz et.al. (2003)). In another project in the Swedish town Borlänge, hundreds of private cars and commercial vehicles have been equipped with a small computer, GPS-system, digital maps and mobile communication facilities. The objective of that project was to adjust drivers speed due to information. The drivers were informed about the speed limit on a display and were alerted with an acoustic signal if they drove faster than the speed limit.

In May 2002, the private car owners were invited to participate in an economic experiment for two month (September and October 2002). They would receive a monthly initial bonus (250 SEK or 500 SEK) with a reduction for each minute they drove faster than the speed limit and the experiment was designed so everyone would at least have a payment of 75 SEK each month. A majority of the car owners (95 persons) accepted to participate in the experiment, 9 drivers rejected and 10 drivers did not respond.

The participants were divided into six groups with equal previous speeding behaviour; two control groups with low respectively high bonus, two groups with low price per minute and low respectively high bonus and two with high price per minute and low respectively high bonus.

The accident risk increases progressively with the speed of the car. A rule-of-thumb for the correlation between increased speed and increased accident risk is that fatal accident risk increases with the forth power, severe injury risk in a cubic form and light injury risk with the square of the increase in actual speed. The reduction in bonus was therefore designed in a progressive way with a price for the low price groups of 0.10 SEK/minute for actual speeds 0-10% above the speed limit, 0.25 SEK/minute for speeds 11-20% above speed limits and 1.00 SEK/minute for speed offences above 20%. The high price groups had to pay the double price.

Table 7: Speed charges

	Low	*High*
0-10% above speed limit	0.10 SEK/minute	0.20 SEK/minute
11-20% above speed limit	0.25 SEK/minute	0.50 SEK/minute
21% above speed limit	1.00 SEK/minute	2.00 SEK/minute

At the end of each month, data was collected from each car through the mobile communication system. The basic record contains information about X- and Y-coordinates, time and date. The data is summarised in individual speed profiles. From this data, we examine the time and magnitude of speed violations, average speed and average legal speed as well as trip distances during the month.

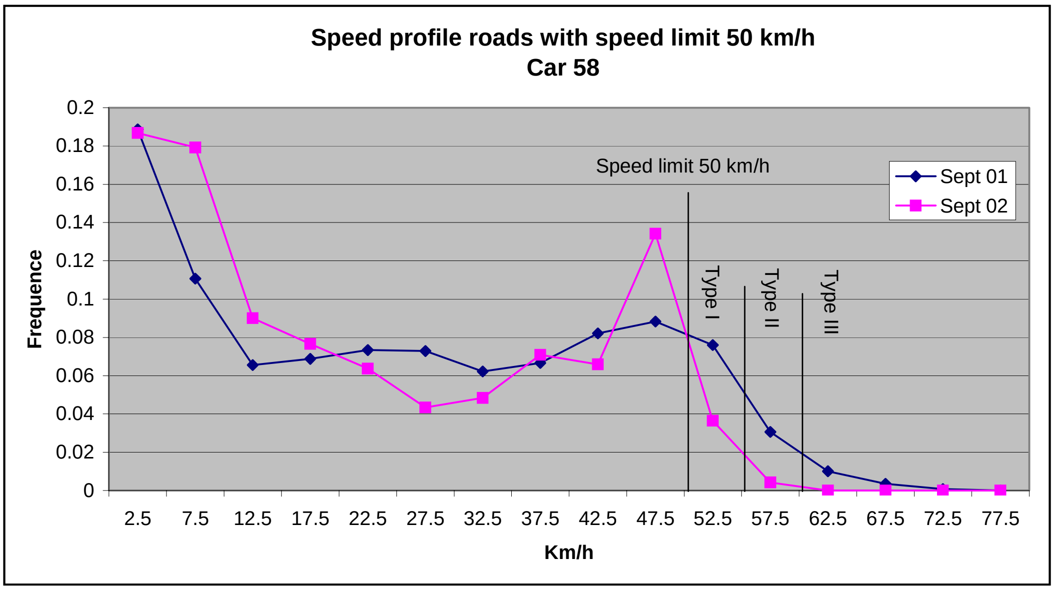

Figure 1: Speed profile of car #58 on roads with speed limit 50 km/h September 2001 and September 2002 (with charges).

Drivers that accept to participate in the economic experiment tends to be older commit less speed violations and drive slower than non-participants. During the economic experiment participants significantly reduced their speed violations compared to non-participants. The proportion speed violations was reduced from around 15% of total driving time prior to the experiment to between 8% and 5% during the experiment with the lower interval at the end of the experiment period. Non-participants had almost constant proportion violations during the experiment.

During the first experiment month the priced participants reduced the speed violations more than the zero-priced participants but the difference was not significant. However, during the second month priced participants reduced their severe violations (type II and III) significantly more than the zero-priced group; the former had a reduction of 64% while the latter only had a reduction of 15%. This effect was maintained during the third month (November) that was added to the experiment.

In conclusion, the experiment has shown that safe driving can be rewarded and that such a system will significantly reduce the speed violations committed by the participants. A system with progressive deductions will have the strongest impact on the most severe violations. The behaviour adaptation evolved as the experiment continued.

3 Transferability and Consensus

3.1 Transferability

Detailed case studies are difficult and expensive to make. Our experience in making this type of detailed studies is that the effort needed to collect the necessary data is unexpectedly large. In the road sector it is often very difficult to collect economic data on a sufficient disaggregated level. And in some situations we have found that the basic traffic volume information is not very reliable, especially if wear-and-tear cost shall be estimated as a function of the number of standard axles. The same problem is true for accidents; a good accident record contains detailed information on the type of accident, involved parties, consequences, road type, time, weather and the detailed type of the vehicle and information on the driver. However, when an accident do not happen, we usually only know the approximate number of passing axels or vehicles, not the type of car or driver. This makes risk estimates a difficult task on a detailed level. Another surprising experience is the problem to find traffic information in the rail sector; this problem tends to rise as the market becomes more liberalized.

Consequently, the need to transfer the estimates is huge. However, the general lesson is that the estimates can not simply be transferred (compare the urban costs in section 1.2.1 above for example) without taking a number of site specific characteristics into account.

From various projects (e.g. UNITE) it can be concluded that the state-of-the-art methods now are sufficient well formulated to allow them to be transferred between modes and countries. If we see these methods as containing ‘physical functions’ (accident risk, emissions etc) and values (value of statistical life etc) we can draw two conclusions; functions and some of the underlying parameters can be transferred (with care) while values should be adjusted to the country specific situation.

For emissions of a given pollutant, the exposure will vary depending on where the emissions take place due to population density, wind conditions etc. We believe that these functions - on the disaggregate level - can be transferred between countries and sites. The effects due to a specific exposure are derived from European averages and the assumption is that exposure-response functions can be generalized. However, this can be questioned and need further investigation[8]. Finally, it is obvious that the cost estimates has to be adjusted between different countries due to different cost levels. The possibility to transfer the result within the same area also needs to be discussed. For non-reactive pollutants a stable cost per tonne emitted may be derived and a transfer between vehicle types and sites (within limits) is thus possible. However, pollutants that are involved in chemical reactions are a bigger challenge. The formation of these pollutants is determined by the composition of the emissions and background concentrations. This makes it impossible to derive a cost per tonne that can be used in a transfer function.

For accidents the basic function to discuss is the accident function. The form of this function is captured in the risk and the risk elasticity. We may hope that the risk elasticity can be generalised. However, we have only seen a limited number of studies. More case studies should be carried out before we are prepared to suggest a set of transferable and reliable elasticities. The accident risk will define the level of the accident function. Estimates of accident risk are often available in each member state but the risk varies strongly between different states and local information is thus needed. The cost share that falls on a user category given an accident could possibly be generalised between states. Finally, the value of statistical life as well as other cost components should be adjusted to the country specific cost level.

3.2 Consensus

While the higher degree of variability that has followed from the change to a bottom-up-approach has made it more difficult, for the moment, to agree on a level of the external marginal cost some remarkable changes in the consensus has occurred during the last decade.

The first area where we today find (almost) consensus is the use of the willingness to pay (WTP) approach to value non-market commodities. A decade ago the use of the value of statistical life was one of the areas where the opposition towards the emerging pricing principles focused their critic on. Today it is seldom any discussion on the method to value fatalities in the transport sector. The

[8] Findings in the APHEA2 project indicate that the effects due to a certain exposure can be higher in Stockholm than in other European cities.

WTP method is in the mainstream even if internal problems exist and further developments are necessary.

The second area of (almost) consensus is the estimate of environmental costs. The knowledge around environmental cost shows the most astonishing development; from the most unknown and controversial areas of cost estimate to an area with almost consensus. The common bottom-up approach used in Europe is the impact pathway approach (IPA) and the model has created an agreement that this is the right approach. Questions may be raised around certain functions and we have seen very few marginal cost studies but few people question the approach anymore.

Around the estimates of accident cost it is possible that consensus is emerging around the approach presented in this paper although major development still has to be done. The valuation question seems, however, to be more or less consensus around. The latest proposal for a 'Eurovignette directive'[9] proposes to use unit values that are of the 'right magnitude', although the arguments around it are strange. 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. Other issues are how individuals assess the *marginal* risk related to a change in driven distance or a new trip, i.e. what is already internalised, and how this trip decision change the accident risk, i.e. the risk elasticity. In addition, 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 and the existence of externalities does also influence the behaviour of the driver. Furthermore, the type of liability system and level of fines and compensation will affect the external marginal cost.

While the principle of congestion pricing has been around for a long time, it is not straightforward to implement. Winners and losers come in a complex mix, which has proven it difficult to design a Pareto improving solution. 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; it could be possible to find consensus on speed-flow relationships and VOT. The recent developments are more about acceptability of pricing schemes and packages.

Finally, looking at the current state-of-the-art vis-à-vis short run marginal infrastructure cost some conclusions can be drawn. First, it is obviously that the number of studies is limited. The most promising research seems to be within the UNITE project. Secondly, the limited number of results is not (up till now) stable. Thirdly, to improve the estimates often the basic databases need to be improved. In addition, the common knowledge is to apply the so called forth power rule to estimate the cost for different vehicle categories with different axle loads. 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 1988) 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.

[9] COM(2003)448

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