CALCULATING TRANSPORT ACCIDENT COSTS

FINAL REPORT OF THE EXPERT ADVISORS TO THE HIGH LEVEL GROUP ON INFRASTRUCTURE CHARGING (WORKING GROUP 3)

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1. The report of the high level group on infrastructure charging stated that transport charges are not efficient unless they reflect all the costs, including the external costs, of the use of transport. It also suggested further guidance was necessary on how to estimate the various elements of marginal costs. To this end, the working group on transport accident costs was established. Chapter 2 defines the costs the working group considers relevant, the nature of accident risks, the valuation of costs and any differences that may occur between different modes. Chapter 3 considers the different mechanisms available for charging these costs to users. And Chapter 4 offers the working group's conclusions and recommendations to the high level group.

Valuation

2. Accident costs are one of the most high profile and highest costs of transport. This working group has examined the range of methods available for estimating accident costs and mechanisms for passing such costs on. Below we provide conclusions regarding the various cost categories and estimation techniques.

3. The working group has focussed on estimating the marginal external cost of road and rail accidents, as requested by the high level group, with some consideration given to the costs of other transport modes. These marginal external costs are the incremental costs of an accident borne by society at large, including victims, family and friends, imposed by those who cause the accident. The relevant factors when estimating the costs are the relationship between accident risk and traffic volume, the determining the external element and the valuation of specific cost elements. The group considered these factors in turn.

4. Traffic accident risk depends on the volume of traffic (e.g. traffic flow and degree of congestion)and on the type of vehicle (e.g. crash worthiness), road (including changes due to weather conditions) and driver (e.g. health, age, behaviour). On balance, the number of accidents rises proportionally with traffic volumes for normal **traffic levels** in **inter urban areas** and more than proportionally for higher levels of traffic and in **urban areas** (i.e. with **road type**). The external cost of the accident is also higher when involving large vehicles and HGVs rather than passenger cars - and so varies with **vehicle type** (however accident *risk* is lower). These different categories should therefore be used when considering different approaches to estimating and passing on the costs of accidents. Finally, as risk exposure clearly rises with transport activity, it is also useful to consider risk in relation to **vehicle kilometres** for the same category of infrastructure.

5. Having determined the risk of accidents, the costs themselves fall into two main categories: material and non material costs. Material costs include property damage, administrative costs, medical and hospital costs, net lost production and **congestion** caused (as measured by WG2 and if separated from total congestion costs). Such external costs are dominated however by the non material costs: the emotional and social costs of casualties resulting from transport accidents. Methods for estimating such costs may be based on "human capital" losses, however these will underestimate the value of suffering and loss. Other methods are more commonly based on a willingness to pay (WTP) to reduce the risk of such accidents. (WTP is also discussed, consistently, in WG2). This method is not perfect, and may not always accurately take account of the capacity to pay (e.g. the values reported in WTP studies may be overestimates if not constrained by

respondents' income). However they provide a useable result in terms of estimates of the value of reduced health, for injuries, and a "value of statistical life" for risks of mortal accidents. Such cost estimates follow an "ex ante" approach. For this reason, the working group favours this WTP approach to estimating the non material costs of accidents, where WTP estimates vary with scale, context, mode of transport and between Member States.

6. While the WTP component is the dominant factor in the value of statistical life (and injuries) it should be remembered that the users' own WTP component is already internalised. Under certain conditions (to some degree fulfilled in interurban car traffic with constant risk and homogenous road users), the external marginal cost boils down to only the material cost. This condition is not fulfilled in urban areas, for heavy vehicles or for rail traffic. For these the external marginal cost will include an element of the WTP resulting in a significantly higher level of external marginal costs.

7. The values calculated by this process may well differ with context, but the method remains generally applicable, across modes and across Member States. Efficient pricing - internalisation - requires that all these marginal external costs are passed on to the users concerned, using the most effective mechanism.

Mechanisms

8. Having determined the cost estimates with a method generally applicable to all modes of transport, several choices exist in terms of passing such costs on to those who bear them. General taxation, existing transport specific taxes, fines, transport user charges, the insurance system - all are possible tools. These are all pricing tools and the focus of this exercise. They should not replace existing safety standards or information programmes such as road safety campaigns, but reinforce the same safety goals.

9. A strategy to internalise the external accident costs should aim to internalise costs ex ante. While ex post coverage is possible, this requires that users anticipate the expected accident cost in their decision and signals are weak. The ex ante approach is therefore preferred.

10. Current approaches are implicitly based on general taxation or specific transport taxes such as fuel and vehicle taxes. However these are poor proxies as they are not based on the costs of accidents and provide no signals to users to alter their behaviour with regard to accidents (two requirements of an efficient economic policy tool). If such tools are used at all, they should take into account transport safety features (for instance reducing vehicle taxes when safety features are added). The greater use and variability of traffic fines, based more closely on incremental accident risks could also be a means of improving the incentives to take more care travelling.

11. The use of insurance premiums has also been considered. In a deregulated insurance industry, premiums vary considerably to reflect quite fine degrees of accident risk and cost. Insurance by its nature insulates the transport user against the risk of facing the cost of an accident and may change risk-avoiding behaviour (the "moral hazard"). However, greater variability of insurance premiums and refined bonus/malus systems *do* send a signal to transport users; can clearly be set to reflect the costs involved (including both material and non material costs); and unlike fines, are directly attributable to meeting the costs of the accident in practice. Premiums based solely on such costs would not be

excessively high (and so would avoid the risk of increasing the number of uninsured drivers) but would not necessarily cover average costs. The working group therefore believes that a sophisticated insurance structure based on detailed risk information and reflecting the different variable components of the costs of accidents is the most satisfactory available means of internalising the external costs of transport accidents. Particularly in the case of medical costs, the use of insurance switches expenditure from general taxation to users, in the manner expected in a user pays system. If the insurance system is unable to reflect these different costs continued use of the tax system may be necessary. In urban areas the importance of a mix of policy instruments are highlighted.

12. The magnitude of external costs and the effectiveness of different mechanisms depends to a great extent on the legal basis for action. For instance the allocation of health costs depends on the type of public health system and responsibility for accidents depends on the legal liability regime. When considering the allocation of costs, the working group is of the opinion that the nature of **fault** should be considered and reflected in the mechanism for passing on the cost of accidents. **In the context of transport insurance**, the liability regime defines the allocation of fault or responsibility ("strict liability"/ "no fault" etc. of the "victim", "causer" or infrastructure manager) and a mix, according to mode, may well be most appropriate. The working group is of the opinion that the choice of liability regime reflects equity considerations rather than efficiency (except where the legal costs of a fault based liability regime raise transaction costs excessively).

13. The development of all these cost estimates and mechanisms requires a range of data, detailed in the report and in the Commission publication "COST 313: Socio-economic cost of road accidents". Specific instances where data are needed include access to driver records (if insurance premiums are to distinguish between risk categories) the investigation of driver/pedestrian behaviour and regularly updated statistics on material costs of accidents and (WTP) estimates of non material costs.

1 INTRODUCTION

1.1.1 The report of the high level group on infrastructure charging proposed the pricing principles of user pays and marginal cost pricing (as adopted by the Commission in the White Paper "Fair Payment for Infrastructure Use") on the grounds that transport charges are not efficient unless they reflect all the costs, including the external costs, of the use of transport. The high level group report also concluded that further guidance was necessary on how to estimate marginal costs for the various cost elements to be recovered from users.

1.1.2 To this end, the working group on transport accident costs was established, to investigate methods of estimating the costs of transport accidents and the possible use of charges and insurance coverage to ensure the costs are borne by those who cause the accidents. Chapter 2 defines the costs the working group considers relevant, the nature of accident risks, the valuation of costs and any differences that may occur between different modes. Chapter 3 considers the different mechanisms available for charging these costs to users. And Chapter 4 offers the working group's conclusions and recommendations to the high level group.

2 MARGINAL EXTERNAL COSTS: DEFINITIONS, DIFFERENCES, and PRACTICE

2.1.1 External accident cost has for a long time been considered as a simple average cost, with more or less qualified assumptions on the allocation of the accident cost between external and internal components. While this lack of theoretical sound principles is serious, more serious is the fact that the underlying theory is not fully developed. Nevertheless, we do believe that enough information is available to move the transport policy a few steps further.

2.2 THE BASIC PRINCIPLE

2.2.1 Marginal external costs of transport accidents are the incremental costs of an accident borne by society at large, including family and friends, and can include costs borne by the victims of an accident. The aim of an accident externality charge is to increase the efficiency of the transport system. The basic conclusion from general economic theory is emphasised; the charge should *internalise the external marginal cost*. In addition, internalisation based on a ‘polluter pays principle’ (PPP) is generally seen as a ‘fair’ principle. In the context of accidents the PPP may be expressed as - *individual that imposes risks on others should be responsible for the extra cost they impose*.

2.2.2 When a vehicle enters into the traffic flow the user (i) exposes himself to the average accident risk in that transport mode. At the same time he (ii) increase or decrease the accident risk for all other users of the same mode. Finally, his entrance (iii) expose users of other transport modes with an accident risk; this risk may also increase, decrease or stay constant. When economic values are assigned to these three consequences they express the (whole) *marginal accident cost* (both internal and external).

2.2.3 The cost of an accident, *ex ante*, can be expressed as three components; (**a**) willingness-to-pay (WTP) for safety on part of those travelling in a particular mode exposed to the risk; (**b**) ditto, on the part of relatives and friends of the person; (**c**) costs on the part of the rest of the society. The user internalises in his decision the risk he exposes himself to, valued as his WTP. The remaining cost, the *external marginal cost*, consists of three components, which is named in a similar way as in Elvik (1994). (I) *System externalities* - the expected accident cost to the rest of the society (**c**) when the user exposes himself to risk (**r**) by entering into the traffic flow- mainly medical and hospital costs [**cr**]; (II) *Traffic volume externalities* - the WTP of the household (**a**), relatives and friends (**b**) and the rest of society (**c**) related to the increase or decrease in the accident risk for all other users of the same mode [$\mathbf{(a+b+c)rE_{rQ}}$]; and finally (III) *Traffic category externalities*[1] - the WTP of the household, relatives and friends and the rest of society related to the changed accident risk $\mathbf{[r'(1+E_{r'Q})]}$ in other modes of transport [$\mathbf{(a+b+c)r'(1+E_{r'Q})]}$.

2.2.4 The importance of the relationship between risk[2] and traffic flow, i.e. the elasticity[3], should be obvious. As Newbery (1988) put it "*the key element in determining the accident externality cost is thus the relationship between traffic flow and accident rates..*".

2.3 TRAFFIC VOLUME AND ACCIDENTS - RISK AND RISK-ELASTICITY

2.3.1 In the European Union every year about 50,000 individuals are killed in transport accidents, the majority in road traffic accidents. In rail transport approximately 1,300 fatalities occur every year, in commercial aviation between 20 and 80 and in waterborne transport around 180 fatalities occur annually (Table 4).

2.3.2 The vehicle owner should be aware of the marginal accident cost in his decision. The relevant accident risk is thus related to *vehicle kilometre*. The safety advantage of rail and aviation compared to road per passenger kilometre described in Table 4 becomes a disadvantage when the risk is expressed per vehicle kilometre. The (fatality) risk per million vehicle kilometre is higher in rail and aviation than in road traffic (Table 5). Consequently, we should therefore not be surprised if the accident externality charge is higher in what is generally beheld as safe modes. However, when this charge is passed on to the passengers the charge per passenger will be low.

2.3.3 The relationship between traffic volume and accidents is unfortunately a neglected area in transportation research. In road traffic a limited number of older studies exist but lately, some interesting empirical research has been presented (see Box 1).

[1] Elvik (1994) uses instead the term Physical externality (p. 720).

[2] Defined as r=Zi/Qi where Z is the expected number of accidents, Q the traffic volume and i is the charged mode or r'=Zj/Qi where j is other modes

[3] $E_{rQ}=dr/dQ_i*Q_i/r$ and $E_{r'Q}=dr'/dQ_i*Q_i/r'$

2.3.4 **Aviation** accidents are relatively infrequent which makes it difficult to suggest average numbers[4]. The accident risk per vehicle kilometre in airline passenger transport may be ten times higher than the accident risk for bus transport (Table 5). However, while a significant part of the bus accidents affect non-occupants the majority of aviation accidents affect occupants.

2.3.5 If the number of accidents increase in proportion to the number of flights the *Traffic volume externality (II)* is irrelevant. The *Traffic category externality* (III), i.e. the consequence for other persons, is also negligible in aviation. Hence, as the serious consequences almost uniquely fall on the user, only the *System externality (*I) is relevant, which result in a relatively low external accident cost.

2.3.6 The total number of fatalities in **rail traffic** in the EU in the early 1990s is estimated to about 1,300 and the number of injuries to be about 4,700 annually (ETSC 1997). Approximately 85% of the fatalities and 66% of injuries in rail accidents are non-rail users, mainly road users at crossings (Table 6). Rail accidents differ between rail track types, on high quality tracks the fatality risk is 30% lower than on the average track. A fatality and injury risk below average is thus appropriate to use on new constructed rail corridors.

2.3.7 The risks for railway users are limited and consequently S*ystem (I) and Traffic volume externalities (II)* are negligible. Nevertheless, accident externality charges are relevant because the *Traffic category externality* (III) is significant. Even if the number of car/train accidents increases in proportion to the train traffic volume the externality may be substantial. Given the relatively large number of non-user fatalities we expect a relatively high external accident cost on railways.

2.3.8 Based on currently available data, it is estimated that, on average around 140 people losing their lives annually at **sea** in freight and passenger transport accidents in European Waters. The average number of fatalities on **inland waterways** is estimated to around 40 annually. Table 5 relates the accidents to passenger kilometres and suggests a surprisingly high number. The main cost element in waterborne transport is related to property and environmental damage and not the cost of human casualties (ETSC 1997). As in aviation only the *System externality (I)* is relevant resulting in a relatively low external accident cost. Accidents with leisure boats are not included in these figures.

2.3.9 Clearly, the above analysis suggests that the framework for analysing transport accident costs and risks is applicable to all modes of transport.

2.3.A. ROAD TRANSPORT

2.3.10 Each year in the Europe Union approximately 45.000 people are killed in road traffic accidents and almost 1.6 million are reported injured (Table 4). While a comparison of

[4] ESCT (1997) suggest that in airline passenger transport around 80 fatalities occur annually while the Green Paper 'Towards Fair and Efficient Pricing in Transport' suggests 18 fatalities

road accident fatalities and related risk measures is indeed difficult[5], a similar comparison of injuries is almost impossible due to *underreporting*. Evidence suggests that, generally, in Europe serious injuries are underreported by about 30% and slight injuries by about 60% (OECD-IRTAD, 1994). However, the rate may vary widely between different Member States· To find a common European wide risk to apply is obviously impossible.

2.3.11 The accident risk differs between different vehicle categories and even more important, the proportion of person injured within the vehicle to persons injured outside the vehicle will be dependent on vehicle type. The lighter vehicle types, as motorcycles, generates the highest risk to the occupants themselves (**r**) while the heavy vehicle types, as buses, generates the main risk for non-occupants (**r'**). This will strongly affect the external accident cost, i.e. *Traffic category externality (III).* Although the difference in accident risk is huge between different Member States the similarities in the pattern of occupants risk and non-occupants risk are striking as is shown in Table 7.

2.3.12 The discussion above points at the importance of differentiation. Partly an explanation of the difference between vehicle types is the difference in accident risks between road type or traffic environment (Table 8). It is important to note that as the accident *risk* is reduced it may well be that the consequences per accident become more serious.

2.3.13 After survey the literature (Annex 1) a number of consistent but involved conclusions may be drawn in relation to the road traffic accident elasticity. Single-vehicle accidents probably have negative risk elasticity while multi-vehicle accidents show, on average, a limited positive risk elasticity. More severe accidents may have a lower elasticity than light accidents but the evidences are sparse. On balance, taking the relative costs of different accident types into account, it seems reasonable to assume that the total accident cost is proportional to the traffic volume on interurban road links at low to moderate flow levels, i.e. the risk elasticity is zero. This conclusion is supported by the practice among Road authorities, which usually employ a zero risk elasticity on road-links (UK COBA, Swedish EVA). At high and even congested traffic flows the risk elasticity may be positive.

2.3.14 Consequently, on interurban roads only the *System externality (I)* is relevant, as the elasticity is negligible for car-car accidents and the number of accidents with other road user categories are limited. Ignoring the cost of accidents with only material damages we present in Table 12 the marginal accident cost for interurban car traffic on an average Swedish road by cost components. On heavy goods vehicles we expect a higher externality charge because, even on interurban roads, we have a significant number of accidents involving other user groups.

2.3.15 The risk elasticity appears to be higher in urban areas than in non-urban areas. This is consistent with the practice among Road authorities to have flow dependent risk

[5] The fatality and injury risk varies widely between different Member States. The highest *fatality risk* per 100,000 population is 29 and the lowest 6.5; the highest risk per million registered passenger cars is 1043 and the lowest 164 while the highest *accident risk* per million vehicle kilometre is 0.67 and the lowest 0.15.

functions at intersections; as the number of intersection increases the risk elasticity will increase.

2.3.16 In urban areas we find two different kinds of relationships between accidents and traffic volume. Accidents involving only motor vehicles seem to increase progressively with traffic volume, while accidents between motor vehicles and unprotected road users increase digressively. Consequently, all three types of externalities are represented in urban areas; in addition to the *System externality* (I) the elasticity for car-car accidents may be positive generating *Traffic volume externality (II)* and the number of accidents with unprotect road users are significant resulting in a relevant (but decreasing) *Traffic category externality (III).* On balance, the total external marginal cost is probably *u-shaped* with decreasing costs at low traffic volumes and slowly increasing costs at higher traffic volumes (Table 13*)*. The total accident externality charge is likely to be over *ten times* higher in a central city area than on interurban roads. This fact highlights the need for different policy responses on urban and interurban road networks.

2.3.17 For the vulnerable road users themselves their risk will be falling when the number of pedestrians and cyclists increases as follows from the models by Maycock and Hall (1984), Brüde, Larsson (1993) as well as Ekman (1996). The marginal cost will thus be falling and unprotected road users internalise most of the accident cost. Consequently, the remaining external component is negative, i.e. they should be subsidised because more pedestrians and cyclist reduce the risk for existing vulnerable road users.

RISK AVOIDING BEHAVIOUR, CONGESTION AND THE HIDDEN COST OF ACCIDENTS

2.3.18 The user reacts in a number of different ways when he perceives that the risk level has changed. Peltzman (1975) developed the hypothesis of *risk compensation* and presented evidence showing that a safer environment due to stricter vehicle safety regulations in US was compensated by the user with increased exposure to risk - *driving more intensely* as Peltzman put it. In the same way a more unsafe environment may be compensate by the user with reduced exposure to risk. These reactions generate a cost to the user and reduce the observed change in risk. The cost of this *risk-avoiding (RA) behaviour* has to be included in the external marginal cost.

2.3.19 The marginal cost may be estimated based on the observed elasticity including the cost of RA behaviour or it may be estimated on pure risk elasticity *(*i.e. the risk change without any RA-behaviour*)* without any additional cost. Peirson et al (1994) introduces a form of RA behaviour where the user, when he selfish adapt his risk behaviour, reduces the risk for all other users. The RA behaviour includes an element of *positive externality*. Johansson (1996) shows how this can be internalised through the accident externality charge in a second-best situation where the RA behaviour is not subsided *per se*.

2.3.20 When the traffic flow increases the number of possibly conflicts increase but the speed goes down; the outcome may be more but less severe accidents. Shefer et.al. (1997) suggests that the reduction in severity is so strong that the total accident cost is reduced due to increased congestion. Consequently, congestion may have a positive effect and will reduce the accident externality charge. On the other hand we know that accidents cause traffic disturbances that may be measured as congestion. On top of the accident cost estimated as in this paper the extra cost of traffic disturbance should be levied. However, to separately estimate congestion as a pure traffic flow problem and as an incidence/accident problem is difficult. This distinction is not so important when designing the charge, the label of the components will differ but the sum of charges will be the same. But when design policy and investment measures the information may be more important as pure traffic flow congestion requires one solution and incidents/accidents another.

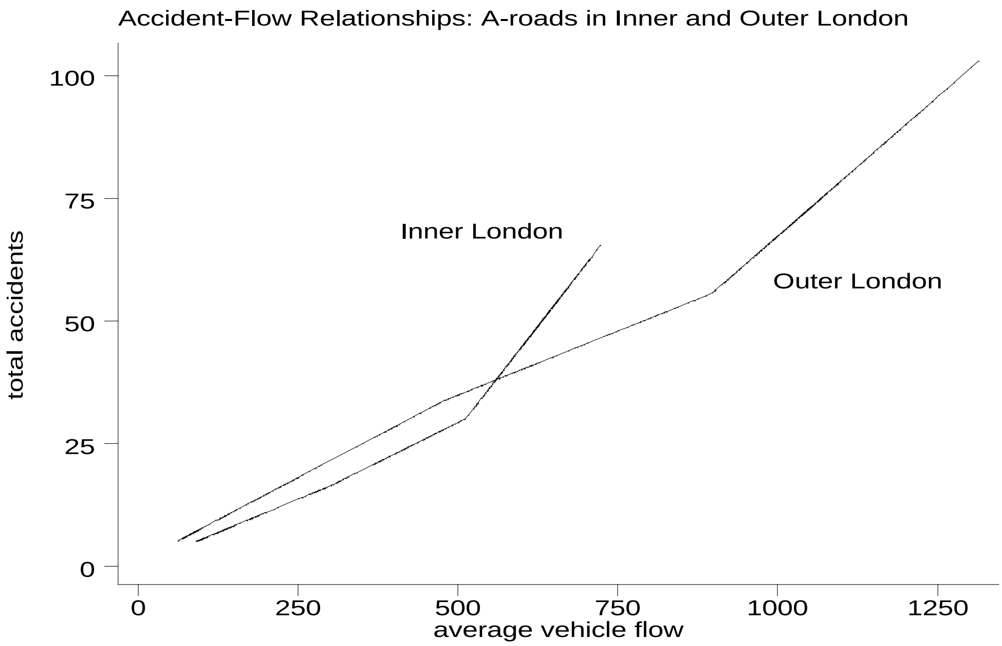
2.3.21 It is reasonable to assume that the cost of RA behaviour for unprotected road users is substantial. Reduced walking, parents driving their children to school etc. are examples of RA behaviour (Maddison 1995). In addition, if users perceive risks to increase with higher traffic volume they will reduce the speed; the accident externality is transferred to a congestion externality. An extreme example is the situation where an accident actual has happened creating congestion. While these costs are relevant and hidden costs of accidents we favour the first method mentioned above, i.e. these additional elements should be estimated separately and added to the external marginal cost. If the congestion consequence is estimated as congestion cost or as an accident cost is irrelevant for the total outcome.

BOX 1. THE RELATION BETWEEN ACCIDENTS AND TRAFFIC FLOWS IN LONDON

By Andrew Dickerson, John Peirson and Roger Vickerman

If accidents are a random event and drivers take no adjusting behaviour, then one would expect the number of road accidents to increase as the square of the traffic flow, see Newbery (1987). However, drivers drive more carefully and at lower speeds at higher traffic flows which results in the accident-flow relationship being less than a square law. A number of studies have attempted to investigated this relationship and the evidence suggests that it is near to being a proportional relation. Dickerson, Pearson and Vickerman (1998) have suggested that many of these studies suffer from the defect of aggregating different relationships for different types of roads which results in the erroneous conclusion of a near proportional relationship.

If the accident-flow relationships are investigated for different types of roads and, in each case, the road network is fixed and observations are made across time, then near proportional relationships are found at low and moderate flows, but the accident elasticity is higher at higher traffic flows. This implies that the accident marginal externality is negligible at low to moderate flows, but may be important at higher flows. The diagram below shows regression piece-wise linear splines for accident and traffic flow data collected for A-roads in Inner and Outer London for data over the period 1993-95 (A-roads are non-motorway major roads). Other regressions show similar relationships for different types of roads and areas. The slope of the relationships vary dramatically between different types of roads.



There are at least three further important issues in the relation between accidents and traffic flow. Firstly, the nature and severity of accidents may vary with traffic flow. At high flows drivers may concentrate more and drive at lower speeds. This is likely to change the mix of types of accidents and is likely to result in fewer severe accidents. Recent work-in-progress by Dickerson and Peirson on the same London data indicates this to be the case. Such effects greatly complicate the relationship between traffic flows and external effects. Secondly, the mix of traffic may affect the number and types of accidents. This implies that the external effects vary between different road users. Indirect empirical evidence is given on the suggestion in Peirson, Skinner and Vickerman (1998) and work-in-progress by Dickerson and Peirson provides more direct evidence. The latter work suggests that as the number of large vehicles, e.g. buses and trucks, in traffic increases, there are more accidents involving just other road users, e.g. cars hitting cyclists. Thirdly, the risk of accidents at higher traffic flows appears to generate the externality of congestion. It is desirable to examine how the accident and congestion externalities are related. In general, as traffic flows increase, the number of accidents do not increase as a square law. The accident externality is transformed into a congestion externality. This relationship is only just beginning to be investigated, see Shefer and Rietveld (1997).

2.4 ACCIDENT-PRONE PERSONS, FAULT AND NEGLIGENCE

2.4.1 In the discussion above we have distinguished between different modes, vehicle categories and traffic environment. Implicitly we have assumed that within these definitions the risk is homogenous. However, accident is a random event with a large variability in the probability. The accident risk depends on the traffic flow as discussed at length above, the road environment including weather condition, the vehicle type and the behaviour of the drivers.

2.4.2 A slippery road surface increases the risk of personal injury accidents three to six times. In the dark period the risk may increase five to ten times compared to the dry daylight situation (Engström et.al.). The difference between road types is less extreme, an old road construction may have a risk of three times a modern motorway (COBA).

2.4.3 The drivers behaviour and personality affects the risk. However, personality as control, aggressivity, lifestyle etc can not explain more than 10-20% of the accident variation (Engström et.al. p313). Speed is clearly correlated to risk. If the speed is increased with 10% the risk increases with 40% (Carlsson 1989). Alcohol consumption also increases the risk, with a consumption of 0.5 promille the risk increase four times, with a consumption of 1.5 promille the risk increase forty times. Health factors also affect the risk but the quality of the empirical data is weak. Age have a significant effect on the risk of causing an accident. Young drivers up to the age of 25 have an accident risk between two and six times higher than middle age drivers. At the age of 60 the risk starts to increase again suggesting that drivers aged 75 to 80 have an accident risk six to nine times higher than the middle age group.

2.4.4 There are substantial differences in the crashworthiness of different car models. The mass and the size of the car are essential factors in explaining these differences. Big car models have a lower occupancy risk while they are more ‘aggressive’ i.e. generates more casualties for non-occupants than smaller cars. The driver’s risk of injury is in the worst car models three times the risk in the best car and 1.6 times the risk in the average car. The aggressively of the worst car model is two to three times the best and 1.4 times the average. (See Huttula, Pirtala and Ernvall 1997).

2.4.5 The external marginal cost will be higher, due to higher risk, in bad weather and on small roads. To differentiate a charge according to weather seems rather meaningless while the difference between road type is more important to take into account. If this is not done a charging system may create adverse route choice decisions. Personality, behaviour and age affect the risk and consequently the external marginal cost. This is already known among insurance companies. The vehicle type affects both the risk and the occupancy/non-occupancy risk. Heavy vehicles, although with a higher general safety, may generate a large risk for other road users and should be levied a high external marginal cost. The aggressivity of different vehicle types will thus strongly affect the relevant charge.

2.4.6 Assume that two equal drivers have an accident where one of them did one single mistake. The mistake is impossible to monitor and can not be included in any regulation or charging system ex ante. Ex post, one of them will be guilty. In such a situation the observable marginal external cost will be equal between the two drivers. We suggest that it is efficient to have the same charge for the two drivers in this case. However, if one of them belongs to an accident-prone group and the other a safe group of users their risks are possible to estimate ex ante and it is efficient to have different charges. The concept of fault and negligence do not pose any problems to the pricing principle as long as this group is identified ex ante. Nevertheless, these complex matters are not well understood.

2.4.7 Finally, in accidents between different categories of users the behaviour of the opposite category will affect the risk. A careless pedestrian will increase the risk that a car will hit the pedestrian, a careless driver will increase the risk that a train will hit the car at level crossings etc. The increased risk due to this behaviour will increase the external marginal cost of both modes. If this is reasonable or not is a complicated legal/ethical question. On one hand it can be argued that the system should be designed so it can accept a faulty behaviour without terrible consequences. In this case a strict responsibly could be imposed on the heavy mode and consequently a higher external marginal cost. On the other hand it can be argued that people are responsible for their own behaviour and are aware of the risk within the system. With this view a responsibility based on negligence is appropriate and the external marginal cost will not be increased on the heavier mode. We can not give one right recommendation; the practice is coded within the legal system.

2.5 THE VALUATION OF ACCIDENTS

2.5.1 The valuation of accidents is a controversial matter – and should probably so be. While it is evident that life is too important to value in monetary terms we know that changes in risks are a different matter. While no one would trade their life for a sum of money most people will be prepared to choose between safety equipment's with different prices and safety performance or between different ways of crossing a street compared to the saving of time. In Box 2 we briefly discuss different valuation methods. For a deeper discussion on methods we recommend the European Union COST 313 project.

2.5.2 Road planning has probably been the field where the value of statistical life and injuries has been most widely used. The cost of an accident consists of both '*cold-blooded*' material cost and a '*warm-blooded'* component. The material cost includes property damage, administrative cost, medical and hospital cost and net lost production. Together these elements are only 9% of the whole accident value for fatalities, 20% for severe injuries and 40% for light injuries (see Table 10 for Swedish figures). The '*warm-blooded'* willingness-to-pay (WTP) component is the dominant component and overshadows all other costs.

2.5.3 An initial example may explain the problem we have to face and also the recommendation we give. *Ask parents what they are willing to sacrifice for their children's safety – the answer will be a considerable amount of money that they will spend to reduce the risk. After a serious accident has occurred the question on risk-reduction has no meaning anymore – life can't be valued in money. However, the monetary loss for the parents can be measured but will only be a small amount*. The use of only the material accident costs will thus seriously underestimate the true value people will invest in safety. It may then be tempting to add a component for 'life' but a value ex-post underestimates the true value. Instead an ex ante WTP approach should be favoured.

2.5.4 However, the problems to estimate willingness-to-pay values for risk reduction should not be underestimated. See Schwab and Soguel (1995) for a discussion on a number of methodological problems in connection to WTP studies of risk reductions.

2.5.5 It is often observed that the aversion against one accident with ten casualties is larger than for ten accidents with one causality each. The former type of accidents are a characteristic of aviation, maritime and often rail and public transport accidents. The question then arises - can we use the same WTP for all modes of transport? The disaster aversion may be divided into "scale effects" and "context effects". The argument that the "scale effect" - number of casualties - should influence the WTP has only limited empirical support. However, the "context effect" seems to influence the perceived seriousness of an accident. The context could be related to the control of the risk, if the risk is voluntary or not, and the level of own responsibility. Type of transport mode, air borne, under water etc., may also affect the "context". The WTP to avoid a lost statistical life in the metro has been estimated to approximately 50% higher than the WTP in road traffic (Jones-Lee (1995)). While the context effect weakly support an introduction of different values in different modes it does question the use of the same valuation method in all modes of transport.

2.5.6 One consequence of the WTP approach is that values expressed *ex ante* is not equal to values expressed *ex post*. After an accident has occurred the term 'risk' has another meaning and the WTP will be expressed in relation to one certain accident. Naturally, in the case of fatal accidents the WTP of the victim is zero even if relatives and friends may express a high WTP. This is in principle not a problem and we should not expect to find that *ex post* and *ex ante* values are identical. As Vickrey (1968) put it *"it may be convenient but it is not logically necessary that the aggregate of charges assessed should just cover the payments to the injured…"*.

2.5.7 We would like to highlight the fact that the WTP approach does not value a person's life *per se*. In fact such an exercise is generally believed to be impossible and are in fact irrelevant. Infrastructure investments, regulation and pricing is about *reducing the risk* for many persons and not about saving *one specific life*. The WTP method thus takes its starting point at the value people put on a certain risk reduction. It is often convenient to transfer this individual-based value on risk reduction to a value on statistical life (VOSL) (see Box 2).

2.5.8 The relevant question to ask in the pricing discussion is *'what are the compensation required by all other users to accept one more vehicle on the infrastructure?'* The traditional approach has been to apply the values developed for investment planning in estimates of the external marginal cost. If the willingness-to-pay is an increasing, concave function of risk reduction[6] the WTP estimated for investment planning will <u>not</u> be an overestimation of the value relevant for pricing.

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[6] See e.g. Jones-Lee (1989).

2.5.9 The cost of an accident, *ex ante*, has in section 2.2 been expressed as three components; (**a**) willingness-to-pay for safety on part of those travelling in a particular mode exposed to the risk; (**b**) ditto, on the part of relatives and friends of the person; (**c**) ditto (or costs), on the part of the rest of the society.

2.5.10 The borderline between the material losses and the WTP for safety is uncertain. A common assumption is that the individual when making his decision on the ”risk market” assess a value on the risk that includes *value of own lost consumption*. No additional component covering this item is therefore necessary. The whole *net lost production* can be assumed to be a loss for the rest of the society and majorities of the cost for *hospital care, administration and property damage.* A large part of this net lost production is in fact tax income on the person’s gross income. To summarise, as the user is paying a part of the material losses approximately 80% of the material losses in fatal and severe accidents and 40% in slight accidents has to be covered by *the rest of the society* and constitutes a part of the c-component. In Table 11 we summarise relevant values to use in the estimate of the external marginal accident cost in Sweden.

2.5.11 While it is evident that most persons have positive WTP for increased safety for relatives and friends, it is less clear how this fact should be treated in the context of accident externality charges. When it comes to accident externality charges we believe the conclusion will be different. *First*, the b-component of relatives and friends to users of *other* transport systems (*Traffic category externality*) will always be relevant irrespectively of their preferences over the travellers well-being in general of the simple reason that the consumption of these groups will not be affected. The same reasoning will hold true also for the cost term related to traffic volume externality.

BOX 2. METHODS FOR VALUATION OF ACCIDENTS

To value accidents we may distinguish between output-based (or human capital) definitions and social welfare (or willingness-to-pay) definitions. The output based approach that has been most widely used is the "gross output" or "human capital" definition. The major component in these approaches is the *discounted presented value of the victim's future output (income) that is foregone due to his premature death*. Allowance is often made for non-market output and for various "direct" economic costs such as medical cost, cost of administration and property damage.

An alternative output based concept is the "net output" definition. This concept takes into account the fact that a person consumes a considerable amount of what he produces during his lifetime. The discounted present value of the victim's future consumption is subtracted from the "gross output". This approach provides a pure narrow economic impact for the rest of the society due to a person's premature death. The net production is approximately only 20% of the gross production for fatal accidents while the two measures are equal for light injuries.

The objection to the last approach is obvious - when a person has retired the net present value will be negative! The net output approach is thus seldom used. But also the gross output approach has a number of fairly obvious shortcomings; it focuses exclusively upon output effects and takes no account of the fact that we value our life of more sophisticated reasons than our estimated production capacity. To meet this criticism an additional element to the gross output has been advocated; often called 'pain, grief and suffering'.

Accepting the fact that the value of reduced risk of death and injuries includes a number of different consideration by the individuals it is more appropriate to leave the *ad-hoc* "pain, grief and suffering" component and concentrate on individual preferences. The trade-off people make between risk and money - individual marginal rate of substitution of wealth for probability of death and injury - is their "willingness-to-pay" (WTP) for risk changes. Jones-Lee (1989), Johansson (1995) and Viscusi (1993) give comprehensive discussions on the theoretical issues related to valuation of safety.

An early CVM study related to risk reductions in traffic is Blomquist (1979). Jones-Lee et al (1985) was probably the first study with strong policy influences. The reaction on this study convinced the Swedish National Road Administration to initiate a study, Persson and Cedervall (1991), which has strongly influenced the used values in the road planning. Kidholm (1995) made a similar study in Denmark while Elvik (1993) summarised existing studies and suggested changes in the Norwegian practice. The European Commission (1994) summarised the current practices in the COST 313 project (see Table 9).

The marginal rate of substitution of wealth for probability of death (WTP) is often transferred to the Value of Statistical Life (VOSL). Assume that the WTP is expressed for a small change in the probability (**dz**) for one individual. Sum these small changes over **n** individuals such that **n*dz=1**; i.e. in a group of size **n** one statistical death will be avoided. The VOSL may then be expressed as the sum of the WTP over all **n** individuals[7]. The size of the WTP component depends on the initial risk level and the magnitude of the risk change in question. Official VOSL are (hopefully) estimated with the relevant values for the area in which they are intended to be used.

[see also P. Hammond Economica, 1981, Vol. 48. pp. 235-250]

2.6 CONCLUSION AND DISCUSSION

2.6.1 The basic principle of the external marginal accident cost is straightforward. The magnitude of the cost depends on risk elasticity, the external element of the cost and the valuation of accidents. However, the empirical data needed to estimate the cost are not well developed in all areas. Consequently, figures on the magnitude of the external accident cost are prone to relatively large uncertainty. Having said this, we do believe

[7] . VOSL=WTP*n = WTP/dz

enough information exists to estimate external accident cost, which will give the proper structure and relation of costs.

2.6.2 The external marginal cost consists of three components;
(I) *System externalities* - the expected accident cost to the rest of the society when the user exposes himself to risk - mainly medical and hospital costs;
(II) *Traffic volume externalities* - the willingness- to-pay of the household, relatives and friends and the rest of society related to the increase or decrease in the accident risk for all other users of the same mode;
(III) *Traffic category externalities* - the willingness- to-pay of the household, relatives and friends and the rest of society related to the changed accident risk in other modes of transport.

2.6.3 All modes generate *System externalities* (I). In interurban road traffic the evidence suggests that the number of accidents increase in proportion to the traffic volume, i.e. the *Traffic volume externality (II)* is negligible. Although the evidences for this relationship on other modes of transport is limited we may assume that this holds true also for Rail, Aviation and Waterborne transport. In urban areas the number of accidents increase faster than the traffic volume, which results in a relevant *Traffic volume externality (II)*. Even if the number of accidents between different modes do not increase proportional with traffic volume the conflict between categories generate a relevant *Traffic category externality (III)*. This externality is relevant in urban road traffic (cars versus vulnerable road users), for heavy (Goods) Vehicles and for rail (cars versus train). In Waterborne transport and Aviation the majority of the casualties are users within that mode.

2.6.4 The cost of an accident consists of both '*cold-blooded*' material cost and a '*warm-blooded'* component. The '*warm-blooded*' willingness-to-pay (WTP) component is the dominant component and overshadows all other costs. The use of only the material accident costs will seriously underestimate the true value people will invest in safety. An ex ante WTP approach should be favoured.

2.6.5 We highlight the fact that the WTP approach does not value a person's life *per se*. Infrastructure investments, regulation and pricing is about *reducing the risk* for many persons and not about saving *one specific life*. The WTP method takes its starting point at the value people put on a certain risk reduction. Yet it is often convenient to transfer this individual-based value on risk reduction to a value on statistical life (VOSL). This highlights the difference between cost accounting *ex post* as a base for cost recovery and insurance and marginal external cost *ex ante* as a base for efficient incentives.

2.6.6 While the high WTP component may be controversial it should be remembered that the zero risk elasticity on interurban roads and in Aviation and Maritime transport implies that only the system external cost has to be internalised. However, the WTP component will affect urban road transport, HGV and Rail.

2.6.7 An additional complexity emerges when we introduce the problem of risk avoiding behaviour. The cost of this behaviour exists and should be internalised but it is difficult to observe its magnitude.

Table 1 Summary of the External Marginal Accident Cost by Mode

Mode	System externality	Traffic Volume Externality	Traffic Category Externality
Definition	Expected accident cost to the rest of the society (c) when the user exposes himself to risk (r) by entering into the traffic flow- mainly medical and hospital costs cr	The WTP of the household (a), relatives and friends (b) and the rest of society (c) related to the increase or decrease in the accident risk for all other users of the same mode $(a+b+c)rE_{rQ}$	The WTP of the household (a), relatives and friends (b) and the rest of society (c) related to the changed accident risk in other modes of transport $(a+b+c)r'(1+E_{r'Q})$
Aviation	**Relevant.** Material, hospital and medical costs in relation to passengers casualties.	**Irrelevant** We do not assume that the risk changes with number of flights.	**Irrelevant.** The number of non-occupants casualties is negligible.
Rail	**Relevant /small.** Material, hospital and medical costs in relation to the small number of passenger casualties.	**Irrelevant** Even if the risk may change with number of trains the number of train/train accidents is small.	**Relevant/Large.** The number of non-occupants casualties is the main part of rail accidents.
Waterborne	**Relevant.** Material, hospital and medical costs in relation to accidents. May be high due to property and environmental damages	**Irrelevant** See Aviation.	**Irrelevant**. See Aviation.
Road (Car) - interurban	**Relevant.** Material, hospital and medical costs in relation to car user casualties.	**Irrelevant/Small** The risk is unaffected by the traffic volume.	**Irrelevant/Small** A limited number of accidents with unprotected road users.
Road (Car) - urban	**Relevant.** Material, hospital and medical costs in relation to car user casualties.	**Relevant/Large** The risk increases with traffic volume in urban areas.	**Relevant/Large** A significant number of accidents with unprotected road users.
HGV	**Relevant/Small.** Material, hospital and medical costs in relation to user casualties.	**Relevant** The risk increases with traffic volume in urban areas.	**Relevant/Large** The majority of accidents are with relatively less protected users (cars).

GUIDELINE TO ESTIMATE THE EXTERNAL MARGINAL ACCIDENT COST

2.6.8 To estimate the external marginal accident cost we need three types of information, i) accident or casualty risk, ii) risk elasticity and iii) economic valuation. All these categories have been discussed in the previous sections and a short guideline is presented in this section.

2.6.9 We recommend to base the estimates on *casualty risk. A*s the number of casualties per accident differ between different modes and accident types the economic valuation per accident may not be constant. We define three types of casualty, i) fatality, ii) severe injuries, iii) slight injury. In addition some costs that occur also in non-personal injury accidents has to be taken into account; consequently we need to define a forth category; iv) damage only accidents. The exact definition of these casualty types differs between Member States. However, as we recommend to use the economic values defined in each Member State no inconsistency should occur due to different definitions. For estimates of the external accident cost the data on accidents and the Member States should supply valuation.

2.6.10 In addition we need to know the mode and vehicle type of the victim as well as the other vehicle element in the accident. Finally we need to know the exposure by mode and vehicle type. We use driven kilometre as the relevant measure of exposure for each mode/vehicle type. Table 5 summarises such risk estimates for some Member States. Annex 2 presents Swedish casualty risks used in the following example.

2.6.11 For each casualty a number of cost elements are relevant. See table 7 for a summary of values presented in the COST 313 project. The values used in the Swedish infrastructure planning is presented in table 8 and how this is transferred to values used in estimates of the external marginal cost is presented in Table 9. Annex 2 gives a guideline how to transfer values used in Road Investment planning to the purpose of estimating the external marginal cost.

2.6.12 The risk elasticity should be defined by casualty type and mode/vehicle type. However, this detailed information is not available and in the previous sections we have discussed possible magnitudes of the elasticity between the same type of vehicles and between different categories.

2.6.13 Based on this type of information we may estimate in Annex 2 the marginal accident cost and the external marginal accident cost. Table 10 presents the marginal accident cost on Swedish interurban roads which is stated to be around 7.09 ECU/100vkm. Of these costs 65% is internal WTP to the driver, 7% internal (direct and indirect) material cost for the household and 24% cost based on WTP for relatives and friends. While the last component may be debated we assume that it is internal as long as it is relatives and friends of the driver (as a non-market transaction between relatives and friends). The external marginal cost is the remaining 11% or around 0.78 ECU/100 vkm. The example suggests that the cost for HGV could be around 5 ECU/100vkm, which is 60% of the marginal cost. For busses approximately 70% of the marginal cost is external and for MC only 11% is external. Railway transport is a safe transport mode and the risks for the groups of railway users are limited. However, the risk for road users may be significant as the serious consequences almost always falls on the persons outside the train, mostly car users. If we assume the elasticity to be 0.5 we end with an external cost of 30 ECU/100vkm which is 70% of the marginal cost. It should be remembered that the accident statistics is based on data from the end of the 80's. Finally, we have discussed the relevant accident rate per flight kilometre and assumed that an accident only affects the occupants themselves. If we use the same values as in the other examples we may suggest a price relevant cost of approximately 0.7 ecu/100vkm or only 6% of the marginal cost.

***Table 2* Examples of marginal external accident cost and marginal accident cost (ECU/100vkm)**

	System externality	Traffic volume externality	Traffic category externality	External accident cost	Marginal accident cost
Car – interurban	0.78	0	-	0.78	7.09
Car - urban	0.90	2.10	3.70	5.58	n.a.
HGV	0.40	-	4.58	4.98	8.22
Bus	0.47	-	6.68	7.14	10.76
MC	6.27	-	0	6.27	56.21
Rail	1.28	-	28.88	30.17	43.13
Air	0.67	-	0	0.67	10.53

2.6.14 In Urban areas the external accident cost is more complicated to estimate. As we have seen both the traffic volume and the traffic category externality will be significant. Furthermore, the elasticity may not be constant over the traffic flow, which means that the external marginal cost is not a constant. An example for passenger cars is presented in Table 11.

2.6.15 These examples may easily be extended to more Member States and updated when required. The main complication seems to be the risk measure and the elasticity. Accident data are usually not compiled in the necessary format - casualty, victim, other involved element. If these types of data are asked for in an early stage, when the figures are compiled, it should be possible to collect a comprehensive database. Yet, the biggest uncertainty is due to the magnitude of the important elasticity. This is an area where only more genuine research can give a better answer. In addition, none of the figures presented in this paper/report includes the hidden costs of adjusted behaviour due to the accident risk. The magnitude of this hidden cost may be substantial but more research is need before we may include this kind of costs in our estimates.

3 INTERNALISATION: MECHANISM FOR CHARGING COSTS TO USER

3.1.1 The discussion on internalisation of external costs has until now almost exclusively focused on the use of the *Fuel excise duty*. Only Vickrey (1968) seems to have included insurance system as a policy instrument; lately this possibility has been highlighted in the EU-Commissions Green Paper ”Towards Fair and Efficient Pricing in Transport” (1995). We discuss internalisation around the concept of *ex post* and *ex ante* systems where both pricing, regulation and liability or fines may be included. Already today we have a mix of systems - insurance, tax and regulations – and a new strategy would most probably include many different systems but in a co-ordinated way. We deal with both the efficiency aspects of prices - the extent to which marginal costs can be internalised by differing instruments; and fairness aspects, which focus on cost recovery, ex post costs.

3.1.2 The purpose is to estimate the level of the cost that should be internalised. From the outset it should be clear that internalisation of the accident cost is only one part of a traffic safety policy. In addition a number of other cost-effective policies should be discussed, such as infrastructure investments, influences of driver behaviour and vehicle standard. However, as long as the external costs are not internalised the efficiency of all the additional policies will be reduced. Internalisation of the external accident cost is a necessary condition for a socio-economic efficient traffic safety policy, but it is not a sufficient condition.

3.1.3 We distinguish between *ex post* or *ex ante* respectively *privately initiated* or *state initiated* methods to control risk. The privately initiated method is (i) *liability* ex post or (ii) *injunction* ex ante. The state may initiate (iii) *regulation or taxes* ex ante and (iv) *fines* ex post (Shavell 1987).

Table 3 . Summary of mechanisms for charging costs to users

	EX ANTE	EX POST
PRIVATE INITIATED	Injunction *(Insurance Premium **)*	Liability/insurance
STATE INITIATED	Fuel excise duty (*) Annual vehicle tax Welfare/health charges General taxation	Fines

*) Variable charge that can be seen as a private marginal cost for the user. **) Partly variable.

3.1.4 The possibility that injures will be unable to pay fully for harm done or will escape responsibility favour *ex ante* approaches. Administrative costs and information uncertainty on risks favour *ex post* methods. The location of the best risk information is a factor bearing on the choice between *state* and *privately initiated* approaches. The dispersion of harm reduces the effectiveness of privately initiated approached to control risks.

3.1.5 Pricing is not always the best ex ante state initiated system. The decreasing charge related to accidents with unprotected road users in urban areas suggests that a ‘corner solution’ may be the most efficient solution, i.e. no car traffic at all, which is easiest to achieve through regulation. The pros and cons of pricing versus regulation follow in this area the mainstream in the literature.

3.1.6 Under the assumption that the state has the best risk information or that injures will be unable to pay fully for harm done an ex ante state initiated control of the risk is recommended, i.e. taxation or regulations. The advantage of the ‘traditional’ internalisation method, the Fuel excise duty, is low transaction costs (as the tax already exists) and a reasonable good correlation with distance. However, the charge is uncorrelated to vehicle type, environment or driver skill. Furthermore, the excise duty gives incentives to fuel efficiency, which may not be correlated with safety improvements, possibly, the opposite. The use of the Annual vehicle tax makes it possible to link the charge to vehicle type and partly driver skill but the charge becomes totally independent on driven distance and the environment.

3.1.7 It is evident that an internalisation through the Fuel excise duty never will be able to charge high-risk drivers different from low-risk drivers or adjust the charge according to the specific risk, e.g. by road type. Internalisation through an insurance system will in principle be able to handle the first problem in a more differentiated way. The second problem has to be handled with more advanced charging mechanism.

3.1.8 The insurance policy transfers an ex post liability to an ex ante premium. From the outset it should be clear that insurance is a method of managing risk by distributing it among large numbers of individuals. The main aim is not to internalise accident costs or affect behaviour.

3.1.9 A kilometre charge, an advanced form of the current vignette (or user charge) on HGV, is another possible mechanism for passing on accident costs. The charge can in principle be vehicle (or driver) and environment specific as well as distance related. In urban areas the same conclusion holds true for modern Road Pricing systems. The degree of sophistication of the system will constrain the degree to which charges can vary with risk or transport user.

3.1.10 Were sufficiently advanced technologies available, insurance companies could use this precise information to greatly refine their premium charges.

3.1.11 It is obvious that a number of market failures exist regarding to traffic safety. External cost is only one of these failures. Customers can make well-balanced choices between safety and other aspects only if they accurately can assess the safety level offered by different alternatives. As this information is not easily available an imperfection occur. A second information problem is sometimes called Myopia. Because customers are not well informed about the risk of different operators they can cheat on their safety performance. The prevention cost they save are borne today while the accident cost, if they are lucky, may be postponed many years. Consequently, in addition to the discussed internalisation of external accident cost provision of better information seems to be an additional important policy.

3.2 THE POTENTIAL OF THE INSURANCE SYSTEM TO INTERNALISE ACCIDENT COST

3.2.1 The main aim of the liability insurance system is to spread the economic burden of accidents over the group that faces an accident risk and the system is thus not geared towards accident prevention or internalisation of the external costs.

3.2.2 By paying a relatively small sum – the premium – the insured policyholder receives a promise from an insurance company to pay the insured if he suffers a loss. The insured avoids the risk of suffering a large loss by substituting it for the certainty of suffering a small premium cost. The theory of insurance predicts that a policyholder will purchase insurance so that he is covered for all his losses given that the insurance market is competitive.

3.2.3 Insurers try to set the price of coverage in accordance with the expected loss – the probability of a loss (risk) multiplies by the magnitude of the loss if it occurs. Such pricing is based on average insurance costs rather than marginal costs, but when accurate (capable of discriminating between different risk characteristics) it is capable of sending quite precise price signals to the insured (by passing some of the risk on) and so offering partial internalisation.

3.2.4 Lost earnings and medical expenses rather than non-material costs usually bound the magnitude of the loss, the coverage. The marginal external cost is dependent on the risk elasticity, the risk and the ex ante valuation of accidents. Consequently, a difference between insurance premiums and pure marginal cost can be found around the use of ex post or ex ante values and the use of average cost or marginal cost, the latter is affected by the elasticity.

3.2.5 The existence of the uncertainty surrounding the *non-pecuniary* losses causes divergence between ex post and ex ante cost estimates and thus a divergence between coverage optimal for compensation and coverage optimal for deterrence. This problem is most obvious in the case of fatal accidents. The coverage of costs compared to the ex ante valuation is one indicator on the possible degree of internalisation through insurance systems. However, under certain conditions the material cost is the dominant part of the external marginal cost reducing this difference.

3.2.6 If insurance spread the burden of risks so effectively that policyholders can engage in higher risk activities the safety effect of an insurance system may be negative. This is the *moral hazard* problem, which, in principle, can be partially countered by means of differentiated insurance premiums. A major problem for any scheme (including Fuel Excise Duty) to internalise external costs, is the difficulty to observe individual behaviour; i.e. we have asymmetric information. This problem has generated a complex premium structure, which includes ex post charges as Bonus/Malus to compensate for the lack of information ex ante. Nevertheless, considerable risk sharing and possible moral hazard still occurs (see Boyer, Dionne (1986) and Pauly (1974)).

3.2.7 Internalisation of the external accident cost is about affecting behaviour. Any charge/premium has to be linked to the activity/decision that generates accidents. The insurer will always use a market classification with high correlation to the cost and the risk (Harrington, Doerpinghaus 1993). The use of information that has no predictive power will not be rewarded over time and the market will classify as long as premiums can be reduced for low-risk groups. Competitive adjustments in the supply of coverage would ensure different premiums linked to the activity/decision. While profit maximisation and competition provide insurers with incentives for accurate classification, the cost of obtaining relevant and accurate information will frequently be prohibitive.

3.2.8 To achieve internalisation through insurance systems we should ensure a competitive insurance market with coverage in line with *ex ante* values of statistical life. However, the existence of elasticity in the expression of external marginal cost suggests that ex ante values could be reduced when determining the coverage. In addition, the elasticity gives rise to more complex charging structures in urban areas and may not be properly handled by the insurance system. The actual consequences for the cost recovery of the insurance industry require further investigation. Finally, the use of government information and charging systems should be offered insurance companies to improve the premium structure.

3.2.9 Although, the insurance system is not aimed at internalisation the premium may be seen as an instrument for partial internalisation of external accident cost. A competitive market will ensure that the premium approximates the expected claim cost, which includes the risk level and the ex post cost of an accident. Such a premium goes many steps towards internalisation. However, the existence of uncertainty regarding non-material losses causes a divergence between ex post and ex ante costs and thus coverage optimal for compensation and coverage optimal for deterrence. Finally, the cost of information and charging may be too high to make it feasible for insurance companies to align their premiums with detailed risk classification and activities.

3.3 CURRENT PRACTICE

3.3.1 We can not find any current practice with the aim to internalise the marginal external accident cost in any Member State. However, in some Member State the level of the *Fuel excise duty* is discussed as a way to internalise external costs. *Annual vehicle taxes* appear not to be safety related anywhere. The *Purchase tax* is often dependent on the price of the vehicle. Introduction of expensive safety equipment will thus increase the taxation, which is a perverse safety policy. Neither the current *Eurovignette* system nor existing *Road Pricing*/*Tolls* are safety related

3.3.2 While government initiated pricing is rare as a safety policy the use of regulation is widespread. Vehicle standard, driver education and behaviour (e.g. speed) are regulated in Member States.

3.3.3 In some Member State governments’ welfare and health charges is directly charged road users. In other the main part of the costs due to an accidents is born by the government and thus the general taxation system.

3.3.4 Summaries of the current European insurance systems are presented in section 3.2.a below. The coverage of costs compared to the ex ante valuation is one indicator on the possible degree of internalisation through insurance systems. This is discussed in sub-section 3.2.b below. The insurance premium is the ex ante outcome of the insurance policy. Both the level and the structure of the premium will influence the level of internalisation and the potential for behaviour influences (section 3.2.c).

3.2.A. EUROPEAN INSURANCE SYSTEMS

3.3.5 In all EU-countries, there is a legislative requirement that makes it obligatory for motor vehicle to have insurance in respect of liability for personal injury and property damage of third parties.

3.3.6 The motor insurance industry has been deregulated in the European Union. However, the process to adapt to a deregulated environment has not yet stabilised. Different Member States have advanced to a different degree where UK seems to have made the fastest progress. This is important to remember when the function of the insurance market is studied.

3.3.7 While internalisation through insurance system is of interest for all modes of transport we concentrate this discussion on the Road system.

3.3.8 Most liability systems are based on the system of fault where the onus falls upon the victim to establish that another person was guilty of causing the injury or damage in order to obtain compensation. If this cannot be proven compensation may not be paid. In some European countries the principle of liability based on fault applies unconditionally to road traffic accidents. This is true of Belgium, the Netherlands, Luxembourg, Italy, UK and Ireland. In UK, Ireland and Belgium the injured party is required to provide unqualified proof of fault. In Italy, the Netherlands and Luxembourg fault of the damaging part is assumed until he provides proof of the contrary. However, in the Netherlands the presumption of fault applies only in favour of non-motorised victims.

3.3.9 Other European countries have introduced a system of strict liability; Denmark, Spain (within limits), Greece, Germany (within limits) and France, i.e. irrespective of fault. In France the driver and owner are liable without restrictions for bodily injury or death of non-motorised victims if the person injured or killed is younger than 16 or older than 70 years, or has at least 80% disability (loi Badinter 1985). In this case, neither the existence of an inevitable event nor negligence on the injured party can lead to an exemption of the principle of fault liability. Spain, and to some extent Denmark, have the principle of liability for material damage but strict liability in the case of bodily injuries.

3.3.10 Sweden, Finland and Norway operate systems which combine features of the fault and strict liability systems, coupled with "no fault" arrangements resembling systems in some states in USA where policyholders receive compensation from their own insurers. The policy is based on "strict responsibility", i.e. irrespective of whether the vehicle has been used irresponsibly or not, the cover has to be paid. The obligatory part of the insurance in the Nordic countries covers the cost for the driver, passengers and other persons irrespectively of who is at fault and are covered by the own vehicle insurer.

3.3.11 Three different approaches are thus taken towards motor liability insurance within EU. Comprehensive analyses of the pros and cons of the different systems is not within the scope of the present paper. Possibly consequences on the internalisation of different insurance systems can be; if accidents are seen as a stochastic event with equal cost burden independent of behaviour a no-fault system will be appropriate; if driver behaviour is seen as important a fault system may be favoured or a no-fault system with bonus/malus. Finally, if the cost burden always fall on the other party (for example vulnerable road users) a strict liability system may be favoured.

3.3.12 While we are not in the position to recommend any system it appears that a mix of systems may be appropriate to internalise accident costs. The strict liability in relation to *relatively* vulnerable road users (cars in HGV/car accidents, pedestrians in motor vehicle/pedestrian accidents, cars in rail/car accidents) is essential to internalise the *traffic category externality (III*).

3.3.13 In many Member States, the social security authorities have the right of full recourse on motor liability insurers for costs incurred by traffic accident victims. In practise the consequence of the arrangement is internalisation of these costs in the premium paid by the insurance consumer. In Finland, this is organised in the reverse: motor insurers in their capacity as primary payers settle all claims for victims.

3.3.14 Motorists are taxpayers in conjunction with their Motor Liability Insurance Premium in most of the Member States. Value Added Tax, VAT, is the most common form, in some countries under the name of Insurance Premium Tax. In Denmark, there is no VAT on the premium, but a 50% tax is added to the premium with the very motivation of internalising motor accident hospital costs. In Finland, in addition to the 22 % premium tax, a special levy for the same purposes as is in Denmark is collected. Furthermore, for the financing of national Road Safety organisations, one per cent levies are collected in France and Finland.

3.2.B. THE COVERAGE OF COSTS IN INSURANCE POLICY – LIMITS AND PRACTICES.

3.3.15 The limits of cover vary between countries as seen in Table 15. When the insurance limit is compared with the value of statistical life for fatalities we find that the limit is restrictive in four of the Member States of which we have information. For three of these cases the limit is sever and reduces the amount with 50% or more.

3.3.16 The European Union tries with directive to align the minimum amounts of insurance cover of the Member States. The minimum cover required by the Second Council Motor Liability Insurance Directive (84/5/EEC) is 350.000 ECU per victim in the case of personal injury and 100.000 ECU per claim in the case of damage to property. The Council has recently directed a questionnaire to the Member States i.e. on the need to review these minimum covers.

3.3.17 An important difference between Member States concerns damages for surviving dependants. Today, this is awarded in all EU countries with the exception of Denmark, the Netherlands and Germany. The group of those surviving dependants entitled to claim is sometimes confined solely to the closest relations (spouse or small children)(UK). In other countries siblings and grand parents are entitled to claim (Belgium, Greece).

3.3.18 In each Member State, the amount of compensation which victims may claim is the result of the legal system of liability. This is not to be confused with the minimum guarantee of the statutory insurance schemes. We have compared the ”most generous” award with the Value of statistical life (VOSL). However, *”in the real world every case is unique and there is no correct figure in any compensation case..... In some Member States the process has been described as a lottery”* (McIntosh and Holmes (1990).

3.3.19 Although the McIntosh and Holmes study is very fragmentary and incomplete, making it conclusions difficult to draw, we compare the compensation for invalidity and fatality for two different persons, a 40-year-old man, doctor, with two children and 20-year-old single woman who studies. In the case of instant death the variation between the two cases and the deviation from the VOSL seems to be rather extreme (Table16). The relatives of the single woman will in some member states hardly receive any monetary compensation at all. If she were killed in Italy her relatives would receive 300,000 ECU but in UK less than 1000 ECU. For serious injuries the variation is much smaller (Table17). Here the different approaches related to relatives are not so obvious.

3.3.20 In Belgium, France and Germany, UK social bodies may claim against the insurance company of the driver who caused the accident. The system usually operates so that the social security schemes compensate the hospitals in the first instance and the State later requires the recovery of the costs from the insurers. In Finland, all claims are directed to the insurance company. In Sweden and Denmark the social security scheme covers all road accidents in the framework of the general health insurance and no claim is possible against the insurance company. However, the company bears the material damage cost and may bear the non-material costs as mental distress etc.

3.3.21 With the reservations mentioned, some observations may be drawn from this summary. In the case of fatalities the difference between the victims' willingness-to-pay and the possible award is very large. The underlying reason is the discussed uncertainty causing the difference between *ex post* and *ex ante* values in the case of non material losses. An insurance system basing premiums on ex post values will therefore be far from reflecting the proper external accident costs in the case of fatal accidents. To avoid this underestimation, and the "lottery" of ex post compensation, consideration should be given to the use by insurers of ex ante values of non material costs. Setting value or "cover" limits, as done in some Member States inhibits the efficient internalisation of costs. Other Member States have practices which reduce the award. Finally, in some Member States, notably Sweden, the social security system covers the medical costs and some other losses. In Sweden evidence suggests that the insurance system only covers 25% of the losses.

3.2.C. PREMIUM STRUCTURE

3.3.22 The general cost of an insurance policy consists of a number of elements; the ‘pure’ Premium, Reduction in premium when safety devices etc are installed, Reduction in premium for extra driver education, Bonus/Malus, Deductibles and reduction after serious negligence (Vaaje 1995). All these components affect the actual cost perceived by the policyholder and have thus bearing on the potential behaviour influence.

3.3.23 The common basic criteria used for calculating and applying motor insurance premiums by insurers are related to the drivers, the type of vehicle and place where the vehicle is kept and used. These criteria is often refined to such details as age, sex, claims and driving experience. As to vehicle itself, engine capacity, power to weight ratio, performance, cost of parts, etc. may be taken into account.

3.3.24 The use of distance driven as a rating variable or variable is not common place across the European Union. The reasons may be; i) state of development of rating structures after the de-regulation, ii) a feeling that policyholders will not or cannot accurately disclose their anticipated annual mileage (so creating the possibility of fraud). However, it should be noted that in the long de-regulated United Kingdom market, use of distance driven as a rating variable is both common place (without any suspicion of fraud) and both lowers and raises premiums away from the ”average”.

3.3.25 The policyholders are divided into as homogenous risk categories as possible. For each of these categories the mean cost of the risk per vehicle is estimated. Together with transaction costs this indicate the so-called ”*a priori*” price to be paid by the policyholder. However, as this information is difficult to acquire a detailed ”a priori” system may be adjusted with a ”*a posteriori*” system. In these systems the initial premium is modified in the light of the policyholder’s involvement in accidents. The most common such system in use is the Bonus/Malus system where the premium will be affected by actual safety performance.

3.4 BEHAVIOURAL INCENTIVES

3.4.1 The internalisation method should give behavioural incentives to the user. It is thus important the any charge or premium is linked to the activity/decisions that generates the accidents, such as; i) driven distance, ii) modal choice, iii) driver skill and behaviour, iv) choice of vehicle and safety equipment.

3.4.2 A mileage-dependent charge differentiated by vehicle standard, driver skill and road type is the *first best* solution, which will, in a perfect world, affect all of the decisions above. However, this may not be feasible due to the costs of the system. In addition the user may not perceive the mileage costs when, for example, he purchases a new vehicle. A *Second-best* solution includes a simpler mileage-dependent system together with an annual vehicle and driver related charge.

3.4.3 Recent evidence on elasticities in transport suggests a much higher sensitivity towards price changes than what was previously thought. "In reality, competition between modes, routes or firms gives rise to a wide range of price elasticities, generally much more elastic than conventional wisdom would suggest."(Oum 1992).

3.4.4 The basic price elasticities of interest for a discussion on behavioural change as a result of a price-based policy are own price elasticities on transport demand and substitution elasticities between different type of vehicles. Finally, substitution elasticities with respect to other modes are also of relevance. The substitution elasticity between similar products can be almost infinite. A minor price difference can generate major changes in consumption patterns.

3.4.5 For car use, long run fuel price elasticities can be quite high, and a comprehensive summary of fuel price elasticities (Goodwin 1992) suggests that *traffic volume elasticities* with respect to fuel prices are -0.16 in the short run and -0.33 in the long run. While this is good news for a policy aiming at reducing CO_2 emissions through fuel prices, determining price elasticities for the internalisation of accident costs would be almost impossible.

3.4.6 Even if such elasticities could be determined, current premiums are seldom levied as variable charges. Instead they are basically fixed on an annual basis. In a few countries high-risk vehicles are subject to increased premiums but the additional premium is still not in proportion to the actual risk presented by these vehicles (Vaaje (1995)). The pricing of insurance may therefore have little influence when purchasing a new vehicle. Encouragement of new safety equipment may be achieved through insurance premium (extra braking lights, air bag, etc) but there is little empirical evidence for this. The same is true for differentiated premiums according to driver education, which exist in France and Norway.

3.4.7 Traffic and accident fines are an alternative means of passing on costs and clear incentives, however Petterson finds that incentives for accident-free driving (insurance) is more effective than schemes with punishment after an accident (fines) (Petterson, Englund (1997)).

3.4.8 The general believe in modern insurance thinking of the Bonus/Malus system is that a car driver, the very seconds before an accident situation does not react in accordance with the Bonus/Malus factor in the Insurance terms, but follows the internal models of attitude he represents. Hurst (1980) focus on this weak area in the B/M system – *'Insurance rebates like no-claim bonuses are appropriate rewards for good behaviour, but they are so hopelessly delayed that it is hard to see how they could reinforce specific safe driving behaviour'*. This theory is supported by research results in Finland – '*The result do not indicate effects of the means of insurance policy in the direction of traffic behaviour'* (Backman et.al. 1984) - and Sweden (Englund 1995). However, the latter concludes that *'….we ought to use B/M systems. If we want to attain an effect on road safety, however, we should design the system carefully…*'. Many authors (Negrin, Italy 1995) including the OECD (1990) share this positive faith in the B/M system, irrespectively of the weak empirical evidence of its effect.

3.4.9 "Deductibles" seem to have their strongest effect on the number of reported accidents but the empirical evidence around this effect is also limited (Backman, Haapanen, Mikkonen (1981)). It may simply deter small claims (reducing insurers' administrative costs) rather than indicate a reduction in accidents.

3.4.10 The choice of vehicle may also be affected by information in addition to charges. The importance of vehicle choice should certainly not be ignored, since the studies in this field strongly promote the product development of the automotive industry (Huttula&Ernvall,1992,1994).

3.4.11 The empirical evidence of the relationship between the current premium structure and different activities/choices are limited and weak. As the current premium structure has a very weak correlation with distance we may not expect any effect on distance and number of trips. Neither Beckman et.al. (1984) nor Eriksson (1986) found any relationship between premium and modal split. The problem to create incentives for safer behaviour is the absence of an appropriate monitoring system *ex ante* (Bower (1991)). Incentive can thus only be created *ex post* with a B/M system, which only give a limited effect as the incentives are delayed. Some authors suggest that the insurance should be linked to the driver (license) instead of the vehicle (Backman et.al. 1984) In 'principle' many authors believe that insurance premium has an effect on vehicle choice (Petterson (1982), Eriksson (1986), Fröyland(1983) but the empirical evidence is, once again, limited.

3.4.12 It is evident that a 'mileage-charge', as the fuel price, affects both driven distance (including both numbers of journeys, choice of origin-destination and modal split) and vehicle technology. As fuel costs are linked to energy consumption this creates an incentive for energy efficiency. It obviously exists a *potential* for a mileage-dependent safety related charge to influence behaviour in a number of different dimensions; distance, modal split, vehicle choice and technology. However, the current premium structure is most often charged on an annual basis, which basically only may affect vehicle choice and technology.

3.5 Is it possible to improve the European Insurance system for fairer and more efficient charges

3.5.1 Even if the liability insurance system is not geared towards accident prevention or internalisation of the external costs an internalisation has already taken place to some degree and a potential exists for further improvements. Below we discuss a number of possibilities to influence the insurance market so that internalisation of accident costs can be achieved.

3.4.a Claim always Medical costs against insurance companies

3.5.2 In many countries (Belgium, France and Germany, UK) social bodies may claim against the insurance company of the driver who caused the accident. A new Road Traffic (NHS Charges) Bill with the purpose to ensure that charges reflect the real cost of treatment was presented in UK in 1998 (see Box 4). In Finland, all claims are directed to the insurance company. However, in Sweden, all medical and hospital costs are met by the social security systems within the general health insurance; no claim is possible against the insurance company.

3.5.3 When the medical cost (**c**) is shifted to the user he will purchase an insurance policy for a premium equal to the *system externality* (I) (**p_{ins} = cr)**. The remaining external cost consists of *traffic volume* (II) and *traffic category externality* (III).

3.5.4 At first glance these two remaining components seems to be a considerable part of the external marginal cost. But recall the empirical evidences of interurban road traffic accidents and traffic volume presented above; if the risk is constant and the number of intersystem accidents negligible only the *system externality* (I) is relevant. For passenger cars no accident charge is necessary on interurban roads if the social security system always claims against the insurance company. In actual fact, the cost responsibility is shifted from general health insurance to the insurance system (the social security system should no longer be allowed to subsidise traffic).

3.5.5 In Maritime and Air-transport, where the main victims are users of each mode, the *system externality (I)* dominates and consequently a cost responsibility for all material costs will go a long way towards internalisation.

3.5.6 However, in rail transport as well as for HGV the *traffic category externality* (III) is the main cost component. Therefore, an accident charge or additional policy measure has to be taken to internalise railway and HGV accident cost. However, as discussed in the previous section, we face a problem of negligence by the injured party, which complicates the policy recommendation.

3.5.7 If the social security system always claim against the insurance company and if the premium is variable (see below) the insurance system internalises the majority of the external accident costs in many cases. The notable exceptions are urban road transport, heavy (goods) vehicles and rail transport. We suggest therefore that additional policy measures should be studied in these cases.

<u>BOX 3</u> - A new Road Traffic (NHS Charges) Bill in UK

The NHS currently has the power, under the *Road Traffic Act 1988*, to recoup the costs of treating the casualties of road traffic accidents. Hospitals may levy an "emergency treatment fee" directly on the patients, and NHS trusts may then levy rather larger fees in respect of out-patient and in-patient treatment on the insurance company which has made a compensation payment in respect of the accident. However, the system is seen as bureaucratic and much of the possible revenue which could be recovered from insurance companies is left unclaimed.

The new *Road Traffic (NHS Charges) Bill* (Bill 3 1998-99) transfer the responsibility of ensuring payments in respect of road traffic accidents to the insurers, and create an administrative system under which these payments will be handled.

The main thrust of the Bill provide that where a person is injured or killed as a result of a traffic accident involving a motor vehicle, and a compensation payment is made (e.g. by an insurance company) in respect of that injury, then the person making the compensation payment is liable to pay the Secretary of State the "appropriate charges" to cover their NHS treatment. The "compensation payment" is defined as covering both payments made by authorised motor insurers and payments made by the Motor Insurers' Bureau where drivers are uninsured or untraceable.

The Government's aim is to set a simple tariff, with a set fee for patients treated in accident and emergency departments, and a daily rate for those admitted for in-patient treatment. These rates will be set at such a level that they should deliver, overall, the actual cost to the NHS of the treatment of road accident casualties. To reflect these costs, there would be a new flat-rate fee of #354 for patients treated in accident and emergency departments or outpatient clinics, and a daily rate of #435 for patients admitted to hospital as in-patients (figures from press-release).

The Bills suggests a new administrative mechanism, whereby insurance companies who are making a payment in connection with a road traffic accident will be obliged to apply to the Secretary of State for a "certificate of NHS charges". The charge on the certificate must then be paid within 14 days of the date on which the compensation payment to the injured party has been made. This will thus transfer the responsibility of initiating the payment from NHS trusts to the insurance industry, and will centralise the NHS administration in one place.

There appears to be some disagreement as to the actual effect which the Bill will have on premiums. While the Department of Health is estimating £6-£9 and the AA £10, the Association of British Insurers were quoted in the *British Medical Journal* as saying that "most companies already take their liability under the existing law into account when assessing premiums". Other estimates suggest that premiums might increase by as much as £20.

Source: House of Commons, Research Paper 98/108.

3.4.B. ENCOURAGE THE USE OF VARIABLE PREMIUMS

3.5.8 It is (for the theory) a disturbing fact that few insurance companies offers distance related insurance policies while a distance related charge is the universal method to internalise the external accident cost. Three reasons can be found for this; i) the risk is not better correlated to driven distance, ii) the cost to classify driven distance is too high iii) the obvious possibility of fraud. Previous regulations may also still influence the use of distance related charges.

3.5.9 We expect the insurance market to charge insurance premiums that are aligned to the expected claims cost for small sub samples of road users. In a competitive environment an insurer will always want to opt for the system that minimises the degree of cross subsidisation between risk groups. With the development of new charging mechanisms a radical move towards variable premiums is possible.

3.5.10 The role of the State could be limited to ensure a low cost possibility to classify driven distance with new technology, as Electronic Road Pricing or Advanced Kilometre Tax Systems.

3.4.C. APPROACH TOWARDS AN INTERNALISATION OF THE TRAFFIC VOLUME AND CATEGORY EXTERNALITY WITHIN THE INSURANCE SYSTEM

3.5.11 Already with these steps a large part of the externality is internalised in interurban road traffic, air and maritime traffic. However, the remaining tricky question is about the *traffic volume externality (II)* and the *traffic category externality (III)*. We do not, for the moment, see any simple way of recovering these externalities within an insurance solution but present some ideas below.

3.5.12 Let us develop an approach where the full accident cost **(a+b+c)** is transferred to the individual road users for accident cost inflicted on others. Road users would obviously have to take out an insurance against the possibility of meeting with a serious accident. A competitive insurance market would offer an insurance premium such as $\mathbf{p_{ins} = (a+b+c)\, r}$, i.e. the average accident cost. With risk elasticities around 0.2 to 0.4 this premium will be above the external marginal cost.

3.5.13 Recall that the immaterial components, which are the all-dominant part of **a** and **b**, are *ex-ante* values. To ask for an *ex-post* compensation of the whole *ex-ante* value is not necessary of efficiency reason. If the risk elasticity is constant the cost responsibility may be adjusted to $[(\mathbf{a}+\mathbf{b}+\mathbf{c})\mathbf{E_{rQ}}]$ for intra-system accidents. Such a step would make all accident externality charges unnecessary given that the insurance premium is charged as a variable charge. Make the coverage (possible through an extra tax) in urban areas equal to between 20% and 40% of the ex ante VOSL.

3.5.14 The *traffic category* externality is simpler to internalise through the insurance premium if we have a zero elasticity. The traffic category externality will be covered in a system of the French type (Loi Badinter 1985) where a strict liability is extended to ”other traffic categories”. This will mean that the users of motor vehicles, especially heavy vehicles, will face increased expected cost in traffic with vulnerable road users. The competitive premium would thus be equal to the risk times the expected loss.

3.5.15 However, we have seen that the risk elasticity may be around -0.5. An adjusted cost responsibility of approximately half the accident cost in accidents between passenger cars and unprotected road users would internalise this external cost. Although, a traffic volume variable premium may only be possible in areas with advanced Road Pricing the proposed cost responsibility is still an improvement over the current mineral oil tax internalisation.

3.5.16 HGV accidents have in general a low level of intra-system risk but a high level of intersystem risk if we consider HGV traffic as a separate ”system”. A proper internalisation could be achieved if HGV also have an adjusted cost responsibility for accidents with other road users. Some limited evidences (Jovanis and Chang (1986)) suggests that the relevant elasticity could be of the same order as in car/unprotected road users accidents above, i.e. a cost responsibility of approximately half the accident cost would internalise this external cost.

3.5.17 Also rail transport could be responsible to coverage of approximately half the VOSL in accidents with car traffic.

3.6 Conclusion and Discussion

3.6.1 The liability insurance system is not geared towards accident prevention or internalisation of the external costs. However, the system has a safety effect, which should be taken into account.

3.6.2 Three different approaches are taken towards motor liability insurance within the European Union. If accidents are seen as a stochastic event with equal cost burden independent of behaviour a no-fault system will be appropriate; if driver behaviour is seen as important a fault system may be favoured or a no-fault system with bonus/malus. Finally, if the cost burden always fall on the other party (for example vulnerable road users) a strict liability system may be favoured. While we are not in the position to recommend any system it appears that a mix of systems may be appropriate to internalise accident costs. The strict liability in relation to relatively vulnerable road users (cars in HGV/car accidents, pedestrians in motor vehicle/pedestrian accidents, cars in rail/car accidents) is essential to internalise the *traffic category externality (III*).

3.6.3 Based on current practice we conclude that in the case of fatalities the difference between the victims willingness-to-pay and the possible award is alarmingly huge. The insurance system will be far from an internalisation of the accident cost in the case of fatal accidents. However, the insurance system may surprisingly well cover the accident costs for injuries. But some Member States have introduced limits to the amount of insurance cover, which is in opposition to an efficient internalisation. Other Member States seems to have practices, which reduced the award. Finally, in some Member States, notably Sweden, the social security system covers the medical costs and some other losses.

3.6.4 Consequently, the coverage in the case of fatal accidents could be increased, possible through taxation. The social security system should always claim against the insurance company. This change will also reduce the burden on general taxation, which opens a possibility for tax reduction. If the premium is variable the insurance system internalises the majority of the external accident costs in most cases. The notable exceptions are urban road transport, heavy (goods) vehicles and rail transport. We suggest therefore that additional policy measures should be studied in these cases.

3.6.5 The internalisation method should give behavioural incentives to the user. It is thus important the any charge or premium is linked to the activity/decisions that generates the accidents, such as; i) driven distance, ii) modal choice, iii) driver skill and behaviour, iv) choice of vehicle and safety equipment.

3.6.6 The empirical evidence of the relationship between the current premium structure and different activities/choices are limited and weak. It is evident that a ‘mileage-charge’, as the fuel price, affects both driven distance (including both numbers of journeys, choice of origin-destination and modal split) and vehicle technology. As fuel costs are linked to energy consumption we create an incentive for energy efficiency. It obviously exists a *potential* for a mileage-dependent safety related charge to influence behaviour in a number of different dimensions; distance, modal split, vehicle choice and technology. However, the current premium structure is most often charged on an annual basis, which basically only may affect vehicle choice and technology.

3.6.7 With the development of new charging mechanisms a radical move towards variable premium is possible. The role of the State could be limited to ensure a low cost possibility to classify driven distance with new technology, as Electronic Road Pricing or Advanced Kilometre Tax Systems. We expect the insurance market to charge insurance premiums that are aligned to the expected claims cost for small sub samples of road users, i.e. if the distance-based systems are useful the market will use them to charge insurance premiums.

3.6.8 Already with these steps a large part of the externality is internalised in interurban road traffic, air and maritime traffic. However, the remaining tricky question is about the *traffic volume externality (II)* and the *traffic category externality (III)*. We do not, for the moment, see any simple way of recovering this externality within an insurance solution.

3.6.9 The Commission can study and develop models aiming at the reallocation of the accident costs by way of legislation in the Member States. Different forms of liability insurance should be discussed to internalise the traffic volume and traffic category externality. However, these arrangements would largely penetrate the fields of national taxation and social security.

4 CONCLUDING OPINIONS OF THE WORKING GROUP

14. The report of the high level group on infrastructure charging stated that transport charges are not efficient unless they reflect all the costs, including the external costs, of the use of transport. It also suggested further guidance was necessary on how to estimate the various elements of marginal costs. To this end, the working group on transport accident costs was established. Chapter 2 defines the costs the working group considers relevant, the nature of accident risks, the valuation of costs and any differences that may occur between different modes. Chapter 3 considers the different mechanisms available for charging these costs to users. And Chapter 4 offers the working group's conclusions and recommendations to the high level group.

Valuation

15. Accident costs are one of the most high profile and highest costs of transport. This working group has examined the range of methods available for estimating accident costs and mechanisms for passing such costs on. Below we provide conclusions regarding the various cost categories and estimation techniques.

16. The working group has focussed on estimating the marginal external cost of road and rail accidents, as requested by the high level group, with some consideration given to the costs of other transport modes. These marginal external costs are the incremental costs of an accident borne by society at large, including victims, family and friends, imposed by those who cause the accident. The relevant factors when estimating the costs are the relationship between accident risk and traffic volume, the determining the external element and the valuation of specific cost elements. The group considered these factors in turn.

17. Traffic accident risk depends on the volume of traffic (e.g. traffic flow and degree of congestion)and on the type of vehicle (e.g. crash worthiness), road (including changes due to weather conditions) and driver (e.g. health, age, behaviour). On balance, the number of accidents rises proportionally with traffic volumes for normal **traffic levels** in **inter urban areas** and more than proportionally for higher levels of traffic and in **urban areas** (i.e. with **road type**). The external cost of the accident is also higher when involving large vehicles and HGVs rather than passenger cars - and so varies with **vehicle type** (however accident *risk* is lower). These different categories should therefore be used when considering different approaches to estimating and passing on the costs of accidents. Finally, as risk exposure clearly rises with transport activity, it is also useful to consider risk in relation to **vehicle kilometres** for the same category of infrastructure.

18. Having determined the risk of accidents, the costs themselves fall into two main categories: material and non material costs. Material costs include property damage, administrative costs, medical and hospital costs, net lost production and **congestion** caused (as measured by WG2 and if separated from total congestion costs). Such external costs are dominated however by the non material costs: the emotional and social costs of casualties resulting from transport accidents. Methods for estimating such costs may be based on "human capital" losses, however these will underestimate the value of suffering and loss. Other methods are more commonly based on a willingness to pay (WTP) to

reduce the risk of such accidents. (WTP is also discussed, consistently, in WG2). This method is not perfect, and may not always accurately take account of the capacity to pay (e.g. the values reported in WTP studies may be overestimates if not constrained by respondents' income). However they provide a useable result in terms of estimates of the value of reduced health, for injuries, and a "value of statistical life" for risks of mortal accidents. Such cost estimates follow an "ex ante" approach. For this reason, the working group favours this WTP approach to estimating the non material costs of accidents, where WTP estimates vary with scale, context, mode of transport and between Member States.

19. While the WTP component is the dominant factor in the value of statistical life (and injuries) it should be remembered that the users' own WTP component is already internalised. Under certain conditions (to some degree fulfilled in interurban car traffic with constant risk and homogenous road users), the external marginal cost boils down to only the material cost. This condition is not fulfilled in urban areas, for heavy vehicles or for rail traffic. For these the external marginal cost will include an element of the WTP resulting in a significantly higher level of external marginal costs.

20. The values calculated by this process may well differ with context, but the method remains generally applicable, across modes and across Member States. Efficient pricing - internalisation - requires that all these marginal external costs are passed on to the users concerned, using the most effective mechanism.

Mechanisms

21. Having determined the cost estimates with a method generally applicable to all modes of transport, several choices exist in terms of passing such costs on to those who bear them. General taxation, existing transport specific taxes, fines, transport user charges, the insurance system - all are possible tools. These are all pricing tools and the focus of this exercise. They should not replace existing safety standards or information programmes such as road safety campaigns, but reinforce the same safety goals.

22. A strategy to internalise the external accident costs should aim to internalise costs ex ante. While ex post coverage is possible, this requires that users anticipate the expected accident cost in their decision and signals are weak. The ex ante approach is therefore preferred.

23. Current approaches are implicitly based on general taxation or specific transport taxes such as fuel and vehicle taxes. However these are poor proxies as they are not based on the costs of accidents and provide no signals to users to alter their behaviour with regard to accidents (two requirements of an efficient economic policy tool). If such tools are used at all, they should take into account transport safety features (for instance reducing vehicle taxes when safety features are added). The greater use and variability of traffic fines, based more closely on incremental accident risks could also be a means of improving the incentives to take more care travelling.

24. The use of insurance premiums has also been considered. In a deregulated insurance industry, premiums vary considerably to reflect quite fine degrees of accident risk and cost. Insurance by its nature insulates the transport user against the risk of facing the cost of an accident and may change risk-avoiding behaviour (the "moral hazard"). However, greater variability of insurance premiums and refined bonus/malus systems *do* send a

signal to transport users; can clearly be set to reflect the costs involved (including both material and non material costs); and unlike fines, are directly attributable to meeting the costs of the accident in practice. Premiums based solely on such costs would not be excessively high (and so would avoid the risk of increasing the number of uninsured drivers) but would not necessarily cover average costs. The working group therefore believes that a sophisticated insurance structure based on detailed risk information and reflecting the different variable components of the costs of accidents is the most satisfactory available means of internalising the external costs of transport accidents. Particularly in the case of medical costs, the use of insurance switches expenditure from general taxation to users, in the manner expected in a user pays system. If the insurance system is unable to reflect these different costs continued use of the tax system may be necessary. In urban areas the importance of a mix of policy instruments are highlighted.

25. The magnitude of external costs and the effectiveness of different mechanisms depends to a great extent on the legal basis for action. For instance the allocation of health costs depends on the type of public health system and responsibility for accidents depends on the legal liability regime. When considering the allocation of costs, the working group is of the opinion that the nature of **fault** should be considered and reflected in the mechanism for passing on the cost of accidents. **In the context of transport insurance**, the liability regime defines the allocation of fault or responsibility ("strict liability"/ "no fault" etc. of the "victim", "causer" or infrastructure manager) and a mix, according to mode, may well be most appropriate. The working group is of the opinion that the choice of liability regime reflects equity considerations rather than efficiency (except where the legal costs of a fault based liability regime raise transaction costs excessively).

26. The development of all these cost estimates and mechanisms requires a range of data, detailed in the report and in the Commission publication "COST 313: Socio-economic cost of road accidents". Specific instances where data are needed include access to driver records (if insurance premiums are to distinguish between risk categories) the investigation of driver/pedestrian behaviour and regularly updated statistics on material costs of accidents and (WTP) estimates of non material costs.

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Table 4 Transport Fatalities, Casualties and Accident Risk in the European Union by mode

.	Fatalities	Casualties	Fatalities per billion passenger kilometres		
			EU average	MS with lowest risk	MS with highest risk
Road (1995)*)	45,000	3,450,000[a]	13	6	118
Rail (average 88-92)	600[b] (1,300)*)	1300[b] (4,700)*)	2	1	10
Aviation (1994)	18 (86)*)	6 (183)*)	0.5	-	-
Inland waterway & maritime *)	180	234	0.5[d]	-	-

Source : Towards Fair and Efficient Pricing in Transport, *) Transport Accident Costs and the Value of Safety, ETSC, 1997; a) adjusted for under reporting – 1,530 reported; b) no railway personnel, only 50% of accidents at level crossings are included; c) only commercial aviation; d) based on UK statistics..

Table 5 Passenger fatality risks per million vehicle and passenger kilometre, UK.

Mode	Fatality risk per 10^6 vehicle km.	Fatality risk per 10^6 passenger km.
Car	0.006	0.004
Bus	0.004	0.0004
Rail	0.10	0.001
Water	n.a.	0.006
Air	0.04	0.0003

Source: Collings (Dept. Of Transport UK).

Table 6 Fatality and injuries in EU 1989a) and ditto risk per million train kilometres in Sweden 1982 – 1988c).

	Fatalities in EU	Injuries in EU	Fatality	Severe injury	Slight Injury
Level crossings accidents (road casualties)	969[b)]	174[b)]	**r'**	**r'**	**r'**
Track-type I			0.154	0.070	0.,142
Track-type II			0.719	0.453	0.986
Track-type III			0.431	0.454	0.552
Track-type IV			0.415	-	0.415
Average Track quality			0.214	0.133	0.229
Third parties excl. level crossings			0.087	0.029	0.019
Other accidents			**r**	**r**	**r**
Rail passengers	198	613	0.022	0.087	0.178
Railway staff	129	662	0.010	0.083	0.084

Source: a) ETSC 1997; b) Includes all 'other' persons; c) Hansson-Lindberg 1992

Table 7 Examples of risk values by vehicle type and road type in some member states. Injury rates per 10^9 vehicle kilometre for occupants and non-occupants - not adjusted for underreporting!

	Car		Van		Lorry		Bus		Motorcycle	
	r	**r'**	**r**	**r'**	**r**	**r'**	**r**	**r'**	**r**	**r'**
DK	156.5	111.5	140.0	246.3	72.5	309.3			1720.	273.3
D	705.5	233.8			209.8	320.7	1303.	771.9	5591.	249.0
FIN	173.2	41.8	132.4	110.3	52.3	161.9	118.3	154.8	1843.	188.3
S	251.2	80.5			172.6	330.2	264.9	560.8	1334.	207.1
UK	536.1	267.6	255.3	416.7	106.6	313.6	1779.	869.1	4728.	717.6
CH	418.7	136.0			345.1	540.3			1978.	1641.

Source: Persson and Ödegaard (1995)

Table 8 Accident risks per 10^6 vehicle kilometre on interurban roads used in SNRA prediction model, Sweden (personal injury and damage only accidents, not adjusted for underreporting).

Road Section	**Speed** limit (km/h)	<5.7	5.7-6.6	6.7-7.9	**Road width (m)** 8.0-10.0	10.1-11.5	>11.5	**Accident** conseq.(SF)[8]
Two lane	70	0.60	0.55	0.50	0.48	0.45	0.43	0.53
	90	0.40	0.37	0.33	0.32	0.30	0.28	0.63
	110	0.32	0.29	0.27	0.25	0.24	0.23	0.72
Four lane	50	0.72	all widths					0.43
	70	0.46						0.53
	90	0.32						0.63
	110	0.27						0.72
Motorway	50	0.23	all widths					0.35
	70	0.23						0.40
	90	0.23						0.45
	110	0.23						0.50

Excluding game accidents. No correction for underreporting in risk numbers. Swedish National Road Administration correct for underreporting in the accident cost function.

Table 9 Values on statistical life in Member States, Summary from the European Commission COST 313 project (1990 values).

Fatalities	Loss of Prod. Cap. (gross) GLP 000 ecu	Loss of Prod.capacity (net) NLP 000 ecu	Loss of human consump. VLC 000 ecu	Loss of human value PHV 000 ecu	Medical and other cost HCC+ADM 000 ecu	Total Cost per person Total Cost 000 ecu	Severe Injury Total Cost	Slight Injury Total Cost
A	589,54	117,91	471,63	795,88	3,10	1388,52	52,61	4,41
B	330,11	66,02	264,09	14,79	3,92	398,82	47,19	1,092
CH	816,20	123,24	692,96	1344,60	4,76	2165,56	95,39	5,44,6
D	670,05	134,01	535,81	904,56	0,73	1575,34	66,95	3,4
DK	240,76	48,15	192,61	418,71	4,59	628,05	13	1,064
E	112,83	22,56	90,27	57,77	0,39	170.99	9,53	0,393
F	216,01	43,20	172,81	164,36	2,35	234,79	32,32	2,114
FIN	548,31	109,66	438,65	864,28	1,83	1414,42	31,14	2,423
L	344,48	68,90	275,58	465,05		809,52	70,25	1,164
N	251,62	50,32	201,30	339,69		591,31	108,51	5,42
NL	105,55	21,11	84,44	142,49		248,03	45,89	4,91
P	224,54	44,90	179,64	203,124		527,66	17,52	0,133
S	436,69	87,34	349,35	516,89	2,53	956,11	131,12	6,057
UK	272,73	54,54	218,19	657,98	0,56	931,27	96,96	7,774
average	347,31	69,46	277,85	478,71	1,30	827,32	56,96	3,559
Severely injured	16,49	16,49		34,42	5,05	-	-	-
Light injured	0,955	0,955		2,228	0,376	-	-	-

Table 10 Accident values in Swedish road investment planning (ECU price level 1997 and percentage).

Cost component	Fatality		Severe Injured		Slight Injured	
Willingness to pay for safety	**1,484**	91.1%	**234**	**79.9%**	**10**	**60.7%**
Net lost production	111	6.8%	29	10.0%	1.6	9.3%
Hospital care	4.0	0.2%	22	7.5%	1.2	7.1%
Administration	6.6	0.4%	1.3	0.5%	0.6	3.6%
Property damage	24	1.5%	6.4	2.2%	3.3	19.3%
Value of statistical life and injury	**1,630**	**100%**	**293**	**100%**	**17**	**100%**

Source, Swedish National Road Administration Note: 1 ECU = 8.7 SEK.

8 The average cost of an accident is a function of the accident consequence (SF; i.e. number of casualties per accident). For 1997 the cost function (in thousand SEK) was *Total accident cost* (a+c) = 90 + 860 * SF + 2939 * SF^2. The cost is adjusted for underreporting.

Table 11. Accident values and its components, Sweden 1997 (1000 ECU and percentage of official value of statistical life and injury, a+c).

Ex ante and ex post cost components	Fatality		Severe Injured		Light Injured	
Stated WTP	*1484*		*234*		*10*	
Cost of death and injury based on WTP for safety of the household for persons exposed to risk; **a**	1514	93%	244	83%	14	83%
direct material cost for the victim's household; **a'**	29	2%	10	3%	4	22%
indirect material cost for the victim's household (lost consumption), **a"**	209	13%	2	1%	0	0%
Costs of death and injury based on WTP for safety of relatives and friends of the person exposed to risk; **b**	594	36%	94	32%	4	24%
Accident cost for the rest of the society; **c**	117	7%	49	17%	3	17%
Official value of statistical life and injury; **a+c**	1630	100%	293	100%	17	100%
Total value of statistical life and injury, including **b**; **a+b+c**.	2224	136%	386	132%	21	124%

Note: 1 ECU = 8.7 SEK.

Table 12: Marginal accident cost on interurban roads, Sweden (ECU/100vkm, based on official values 1997 except for b9).

Ex ante and ex post cost components	ECU/100vkm	%
Cost of death and injury based on WTP for safety of the person exposed to risk, **ar**	4.60	65%
Direct material accident cost for the victim's household, **a'r**	0.32	4.5%
Indirect material accident cost for the victim's household (lost consumption), **a"r**	0.18	2.5%
Costs of death and injury based on WTP for safety of relatives and friends of the person exposed to risk, b**r**	1.71	24%
Accident cost for the rest of the society, **cr**	0.78	11%
Total marginal cost **(a+b+c)r**[10]	7.09	100%

Table 13: Accident externality charges on cars in the central city of a representative big European city assuming only voluntary traffic insurance (ECU per 100 car kilometre).

Traffic volume Q	Inrasystem accidents		Intersystemaccidents	Total accident externality charge
(AADT)	cr	$(a+b+c)r_L E^L_{rQ}$	$(a+b+c)r_{ML}(1+E^{ML}_{RQ})$	
500	0.7	1.6	16.3	18.5
5,000	0.8	1.9	5.3	7.9
10,000	0.9	2.1	3.7	6.7
25,000	1.0	2.4	2.4	5.8
40,000	1.1	2.6	1.9	5.6

Note: E^L_{rQ}=0.2 and E^{ML}_{rQ}=-0.5.

Table 14 Accident externality charges on vulnerable road users in the central city (ECU per 100 vulnerable road user crossings).

Volume of pedestrian			Total accident externality charge
Crossings per day (M)	cR	$(a+b+c)RE_{RQ}$	excluding br
500	2.5	-6.8	-4.3
1,800[11]	1.7	-4.8	-3.0
5,000	1.3	-3.6	-2.3
10,000	1.1	-2.9	-1.9
20,000	0.9	-2.4	-1.5

Note: E_{RM}=-0.3; Q=20,000 AADT

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9 A b-component of 0.4*a has been assumed

10 62% of the marginal cost is related to severe injuries, 24% to fatalities and 14% to light injuries.

11 The M value on which *table 4* is based.

Table 15 Insurance Limits (1000ECU) compared to the Value of Statistical Life in Some Member States.

	Insurance Limits			**VOSL**
	Property Damage	**Personal Damage**	**Total Limit**	
A	n.a.	n.a.	n.a.	1389
B	unlimited	unlimited	unlimited	399
D	236	591	**827**	1575
DK	1836	9185	11021	628
E	20	74	**94**	171
F	521	868	1389	235
FIN	3300	unlimited	n.a.	1414
GR	17	84	101	0
I	235	548	**782**	810
IRL	126	unlimited	unlimited	0
LUX	unlimited	unlimited	unlimited	0
N	n.a.	n.a.	n.a.	591
NL	1047	1047	2094	248
P	?	80	**80**	528
S	n.a.	n.a.	31960	956
UK	426	unlimited	unlimited	931

Table16 Comparison of the most generous award for fatalities of two different persons and the value of statistical life (1000ECU)

	Death of family father	Death of young woman	VOSL
B	465	8	398
D	472	2	1575
DK	116	1	628
E	240	96	170
F	438	22	234
GR	278	21	0
I	664	300	809
IRL	659	11	0
LUX	501	9	0
NL	320	3	248
P	328	6	527
UK	444	2	931

Table17 Comparison of the most generous award for different degrees of invalidity for two different persons and the value of statistical life (1000ECU).

0	Inv. 100% of family father	Inv. 100% young woman	Inv. 70% family father	Inv. 70% young woman	VOSL
B	1394	1340	642	529	398
D	961	616	911	616	1575
DK	158	129	158	129	628
E	400	240	400	240	170
F	1008	805	1008	805	234
GR	871	861	444	335	0
I	678	455	678	455	809
IRL	868	757	868	757	0
LUX	648	537	648	537	0
NL	714	714	714	714	248
P	413	515	413	515	527
UK	1436	1387	804	646	931

Annex 1.

The number of opportunities for road accidents is obviously related to the volume of traffic. Fortunately, only a very small proportion of these opportunities actually results in an accident. The ‘simple’ theoretical conclusion suggests that single vehicle accidents should vary in proportion to the number of vehicles on the road and that the number of collisions between two vehicles should be *proportional to the square* of the number of vehicles. However, as the probability of an opportunity producing an accident may be related both to the traffic volume and to other factors, we can not expect a close relationship between the frequency of accidents and the volume of traffic.

A comprehensive summary of earlier research of the relationship between accidents and traffic volume can be found in Satterthwaite (1981). A wide spectrum of estimated risk elasticities appears from surveying the literature but in general the accident risk is more or less independent of the traffic volume, possible slowly decreasing, for most *interurban road types (links)*, which means that the risk elasticity is approximately zero ($\mathbf{E_{rQ}}$=0). This suggestion is supported by among others Vitaliano and Held (1991) and Winslott (1998).

Considering different *accident types* and *accident consequences*, a more complicated pattern emerges. Evidences presented by Satterthwaite (1981), Ceder and Livneh (1982), Ceder (1982) and Jovanis and Chang (1986) and lately Winslott (1998) all suggests that collision accidents increase with the number of vehicles while single accident decreases. The relationship between traffic volume and total number of accidents is hence *U-shaped*. As traffic density increases, the speed goes down, and the accidents become less severe. It can thus be assumed that the more serious consequences increase digressively with increased volume while the property damage will increase progressively (Elvik 1994). When economic values are assigned to the different injury types the *average accident cost* could be expected to fall with increased traffic volume. This result has been found empirical by Fridström et al (1991) and (1993) on regional data. However, Winslott (1998) could not find any relationship between average accident cost and traffic flow on most Swedish road types.

In *Urban areas* the elasticity seems to be higher than on interurban roads. Satterthwaite (1981) review a number of studies related to accidents and traffic volume at *intersections* implying risk elasticity ($\mathbf{E_{rQ}}$) between 0 and 0.4. Maycock and Hall (1984), Swedish National Road Administration (1993) and UK Department of Transport (1994) find and utilises similar results.

The survey of literature suggests that the elasticity is not constant over the whole interval of traffic flow. Dickson et.al (1998), Vitalino and Held (1991) respectively Ceder and Livneh (1982)[12] found an increasing elasticity with increasing traffic flow for all accident types respectively for multi-vehicle accidents.

Maycock and Hall (1984) as well as Brüde, Larsson (1993) have estimated models of accident risk for *unprotected road* users at roundabouts respectively intersections. The total number of accidents with pedestrian’s (**Z**) increases in both vehicle flow (**Q**) and pedestrian crossing flow. The risk, defined as number of accidents with unprotected road users per passing motor vehicle (**r’=Z/Q**), decreases with increasing number of motor vehicles. The risk elasticity in relation to motor vehicles is thus negative. Both studies suggest a risk elasticity ($\mathbf{E_{r'Q}}$) around –0.5. Ekman (1996) does not support this conclusion and finds in a non-parametric study that the risk is more or less independent of the motor vehicle flow.

[12] Three out of four observations where the risk does not increase sharply with traffic flow are characterised by low upper bound of traffic flow (p24).

Annex 2 - Source: PETS Workpackage 1.3.

Table A.1 Fatality and injury risks per 10^9 vehicle kilometre by vehicle user, Sweden

	Occupants risk			Non-occupants risk Other motor vehicle users			Non-occupants risk Unprotected		
	r	**R**	**r**	**r’**	**r’**	**r’**	**r’**	**r’**	**r’**
	Fatalities	Severe Injuries	Slight injuries	Fatalities	Severe injuries	Slight injuries	Fatalities	Severe injuries	Slight injuries
Car	**7.7**	**113**	**474**	[0.3]	[7.1]	[17]	2.4	42	103
Truck	**3.9**	**60**	**208**	**15**	**126**	**488**	6.4	49	77
Bus	**3.4**	**70**	**295**	**18**	**193**	**831**	13	144	291
MC	**54**	**1030**	**2059**	0	0	0	4.3	111	254

Average 1991 - 1993, adjusted for underreporting 2.4 for both severe and slight injuries; unprotected = pedestrians, bicycle and moped. Bold numbers used in the examples of Annex 7:6.
Source: Own estimate[13.]

[13]Source: SCB Trafikskador 1991, 1992 and 1993. Tab 15. each year. Assumes that in accidents between vehicles the injured /killed persons are in the lighter vehicle. For accidents between bus and lorry the causalities are split 50/50 and for accidents between lorries and passenger cars the number of causalities are split 5% in the lorry and 95% in the car. Single accidents include game accidents. Underreporting of injuries; 2,4.

<u>The link between values used for road investment planning and the relevant values for pricing.</u>

The border line between the material losses and the willingness-to-pay (WTP) is uncertain. A common assumption is that the individual when making his/her decision on the “risk market“, or hypothetical risk market ,assess a value on the risk which includes value of own lost consumption (VLC). The consumption is in principle together with the net lost value of production equal to the gross lost production (GLP). The remaining component is called “pure human value“ (PHV). The total value on the (net) material losses (netMML) is a sum of the net lost value of production (NLP), cost of health services (HCC), cost of the administration (ADM) and the value of property damages (PDV). The material losses can be estimated from hospital, insurance and policy record.. Therefore, the value can be expressed as:

(1) Value on statistical life = WTP + NLP + HCC + ADM + PDV.
Where NLP = GLP – VLC

Table A.3 Accident values and its components, Sweden (1000 ECU price level 1997).

	VOSL USED IN SWEDISH ROAD INVESTMENT PLANNING (1000ECU)				**A-COMPONENTS (% and 1000ECU)**								**C-COMPONENTS (1000 ECU)**			
		Fatal.	**Sev.Inj**	**Sl.Inj.**		**Fatal.**	**Sev.Inj**	**Sl.Inj.**		**Fatal.**	**Sev.Inj**	**Sl.Inj.**		**Fatal.**	**Sev.Inj**	**Sl.Inj.**
WTP	Willingness to pay	1484	234	10	WTP	100%	100%	100%	**a (excl a')**	**1484**	**234**	**10**				
PHV	*"pure human value"*	*1066*	*231*	*10*		-	-	-		-	-	-		-	-	-
VLC	*lost consumption*	*419*	*3*	*0*		-	-	-		-	-	-		-	-	-
NLP	Net lost production	111	29	2	NLP	*0%*	*0%*	*0%*	*NLP*	*0*	*0*	*0*	NLP	*111*	*29*	*2*
HLC	Hospital care	4	22	1	HLC	*13%*	*13%*	*13%*	*HLC*	*1*	*3*	*0*	HLC	*4*	*19*	*1*
ADM	Administration	7	1	1	ADM	*85%*	*85%*	*85%*	*ADM*	*6*	*1*	*1*	ADM	*1*	*0*	*0*
PDV	Property damage	24	6	3	PDV	*95%*	*95%*	*95%*	*PDV*	*23*	*6*	*3*	PDV	*1*	*0*	*0*
netMML	sum of NLP+HLC+ADM+PDV	146	59	7					**a'-comp**	**29**	**10**	**4**	**c- component**	**117**	**49**	**3**
VOSL	**Value of statistical life**	**1630**	**293**	**17**					**SUM a-comp.**	**1514**	**244**	**14**				

The material losses constitute 10% of the cost of fatalities and up to 40% of the cost of slight injuries. In Sweden it has been estimated (Swedish National Road Administration 1997) that the individual pays 15% of the *hospital care*. Approximately 85% of the *administrative cost* is paid by the Insurance companies. The rest of the administrative costs cover police and the legal system. Of the *property damage* cost 77% is covered by the insurance company, 18% by the user directly and 5% by the road authority. We may assume that the user through the premium pays the cost attributed to the insurance system. The user therefore pays 85% of the administrative cost and 95% of the property damage. The whole part of the *net lost production* can be assumed to be a loss for the rest of the society. A large part of this net lost production is in fact tax income on the persons gross income. To summarise, as the user is paying a part of the material losses approximately 80% of the material losses in fatal and severe accidents and 40% in slight accidents has to be covered by *the rest of the society*.

Table A.4 Examples on Estimation of optimal accident externality charges (ECU per 100km).

													Total Charge
Passenger Car	**r**	**ar**	**br**	**cr**	$\mathbf{E_{rQ}}$	**(ar+br+cr)*** $\mathbf{E_{rQ}}$	**r'**	**ar'**	**br'**	**cr'**	$\mathbf{E_{RQ}}$	**(ar'+br'+cr')*** $\mathbf{E_{RQ}}$	**excl br**
Fatality	7,7	1,17	0,46	0,09	0,00	0,00	0	0,00	0,00	0,00	0,5	0,00	0,09
Severe	113	2,76	1,06	0,55	0,00	0,00	0	0,00	0,00	0,00	0,5	0,00	0,55
Slight	474	0,68	0,20	0,14	0,00	0,00	0	0,00	0,00	0,00	0,5	0,00	0,14
SUM		4,60	1,71	0,78		0,00		0,00	0,00	0,00		0,00	**0,78**
HGV	**r**	**ar**	**br**	**cr**	$\mathbf{E_{rQ}}$	**(ar+br+cr)*** $\mathbf{E_{rQ}}$	**r'**	**ar'**	**br'**	**cr'**	$\mathbf{E_{RQ}}$	**(ar'+br'+cr')*** $\mathbf{E_{RQ}}$	**excl br**
Fatality	3,9	0,59	0,23	0,05	0,00	0,00	14,6	2,21	0,87	0,17	0,5	1,62	1,67
Severe	60,4	1,47	0,57	0,30	0,00	0,00	126,1	3,08	1,18	0,62	0,5	2,44	2,73
Slight	208	0,30	0,09	0,06	0,00	0,00	487,8	0,70	0,20	0,14	0,5	0,52	0,58
SUM		2,36	0,88	0,40		0,00		5,98	2,25	0,93		4,58	**4,98**
Bus	**r**	**ar**	**br**	**cr**	$\mathbf{E_{rQ}}$	**(ar+br+cr)*** $\mathbf{E_{rQ}}$	**r'**	**ar'**	**br'**	**cr'**	$\mathbf{E_{RQ}}$	**(ar'+br'+cr')*** $\mathbf{E_{RQ}}$	**excl br**
Fatality	3,4	0,51	0,20	0,04	0,00	0,00	18,5	2,80	1,10	0,22	0,5	2,06	2,10
Severe	70	1,71	0,65	0,34	0,00	0,00	193,1	4,71	1,81	0,94	0,5	3,73	4,07
Slight	295	0,42	0,12	0,09	0,00	0,00	831,1	1,19	0,35	0,24	0,5	0,89	0,98
SUM		2,64	0,98	0,47		0,00		8,70	3,25	1,40		6,68	**7,14**
MC	**r**	**ar**	**br**	**cr**	$\mathbf{E_{rQ}}$	**(ar+br+cr)*** $\mathbf{E_{rQ}}$	**r'**	**ar'**	**br'**	**cr'**	$\mathbf{E_{RQ}}$	**(ar'+br'+cr')*** $\mathbf{E_{RQ}}$	**excl br**
Fatality	54	8,17	3,21	0,63	0,00	0,00	0	0,00	0,00	0,00	0	0,00	0,63
Severe	1030	25,12	9,64	5,03	0,00	0,00	0	0,00	0,00	0,00	0	0,00	5,03
Slight	2059	2,94	0,86	0,60	0,00	0,00	0	0,00	0,00	0,00	0	0,00	0,60
SUM		36,24	13,70	6,27		0,00		0,00	0,00	0,00		0,00	**6,27**

Note: Risks based on table A.3.4 excluding unprotected users to mirror an interurban road situation; values from table A.3.7.

Table A.4 continues

													Total Charge
Rail (track I)	**r**	**ar**	**br**	**cr**	**ErQ**	**(ar+br+cr)* ErQ**	**r'**	**ar'**	**br'**	**cr'**	**ERQ**	**(ar'+br'+cr')* ERQ**	**excl br**
Fatality	32	4,84	1,90	0,37	0,00	0,00	241	36,48	14,31	2,81	0,5	26,80	27,17
Severe	170	4,15	1,59	0,83	0,00	0,00	99	2,41	0,93	0,48	0,5	1,91	2,74
Slight	262	0,37	0,11	0,08	0,00	0,00	161	0,23	0,07	0,05	0,5	0,17	0,25
SUM		9,36	3,60	1,28		0,00		39,13	15,30	3,34		28,89	**30,17**
Air	**r**	**ar**	**br**	**cr**	**ErQ**	**(ar+br+cr)* ErQ**	**r'**	**ar'**	**br'**	**cr'**	**ERQ**	**(ar'+br'+cr')* ERQ**	**excl br**
Fatality	40	6,06	2,38	0,47	0,00	0,00	0	0,00	0,00	0,00	0,5	0,00	0,47
Severe	40	0,98	0,37	0,20	0,00	0,00	0	0,00	0,00	0,00	0,5	0,00	0,20
Slight	40	0,06	0,02	0,01	0,00	0,00	0	0,00	0,00	0,00	0,5	0,00	0,01
SUM		7,09	2,77	0,67		0,00		0,00	0,00	0,00		0,00	**0,67**