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UNIfication of accounts and marginal costs for Transport Efficiency

Deliverable 9:

Marginal accident costs – case studies

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Executive Summary

The consequence of a traffic accident can be horrendous and we know that people indicate a high willingness-to-pay to reduce the risk of being the victim of a traffic accident. The cost of traffic accidents in Europe is huge. A part of the traffic accident problem can be explained by the fact that the user, in his decision, does not consider all costs related to an accident - a part of the accident cost is external to the user.

However, the huge cost does not directly imply that the *marginal external accident cost* is high. Two important principles are included; first, the term *external* suggest that we are only interested in the cost not already borne by the user and, secondly, the term *marginal* suggest that we examine the change in cost at the margin when the user takes a decision. We consider here the decision to make a trip in all modes; the external marginal accident cost is related to distance (kilometre).

We summarise a number of case studies on the marginal external accident cost. The result is, however, nothing more than an indication of the marginal external accident cost and a base for more studies. Congestion pricing has been discussed for decades in numerous articles and books; the theory on marginal external accident cost is new and has been developed during the last few years. The amount of literature to support our studies is very limited.

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

We conclude that the most important element in the cost of an accident is the risk value, or value of statistical life. We use studies based on the willingness-to-pay approach to recommend an average European value of statistical life of 1.5 Million €. The value will depend on the purchase power and thus be different between Member States.

The accident risks vary widely between Member States and, of course, between modes of transport. While accident statistics may be good in many cases, although underreporting has to be considered separately, the possibility of finding information on exposure (e.g. kilometre driven) is in general *very* poor. The problem of finding a measure of exposure also means that the possibility to estimate accident functions, and consequently to be able to say something about the relationship between accident risk and traffic volume (elasticity), is limited. Nevertheless, we have been able to undertake three original cases studies where we have examined this relationship. In general, we find that the risk does not increase strongly with traffic volume; on the contrary, it seems to decline. We have also made original estimates on the proportion of cost borne by the examined user; in general, the proportion declines with the weight of the vehicle.

Previous studies on the accident cost and its internalisation have often presented the average accident cost. The approach taken in this report is to find the *marginal external* accident cost. We have assumed that the user understands his risk and consequently already bears the value related to his own risk of being a victim. This

assumption, in addition to the low risk elasticity values we find, explains why the cost is lower than previously thought.

The approach taken here means that we try to find the accident cost that is relevant to internalise in the user's trip decision. However, such a charge will not affect the behaviour while driving. It is possible that the behaviour is a much more important trigger of accidents than the trip decisions - this highlights the importance of a broad traffic safety policy. Such a broader approach would result in a differentiated strategy consisting of a mix of pricing and of non-pricing measures. However, non-pricing measures should also be evaluated in an economic framework to ensure an efficient traffic safety policy in Europe.

1 Introduction

Accidents are a severe problem in all modes of transport. The consequence of a traffic accident can be horrendous and we know that people indicate a high willingness-to-pay to reduce the risk of being the victim of a traffic accident. The cost of the traffic accidents in Europe during one year is huge. A part of the traffic accident problem can be explained by the fact that the user, in his decision, does not consider all costs related to an accident - a part of the accident cost is external to the user.

However, the huge total annual accident cost does not directly imply that the *marginal external accident cost* is high. Two important principles are included; first, the term *external* suggests that we are only interested in the cost not already borne by the user and, secondly, the term *marginal* suggests that we examine the change in cost at the margin when the user takes a decision. In the following, we consider the decision to make a trip, i.e. the external marginal accident cost, is related to distance (kilometre).

Let us assume that the marginal external accident cost is estimated and introduced as a distance based charge. What should be included in the charge? *First*, we have the question of whether we need to remind the user of his own accident cost. If not, a large part of the accident cost is already internalised in the user's decision, and it is not necessary to remind him of this cost once again. It is suggested here that we should adopt the same principle as in congestion pricing[1] - the user is aware of the risk and 'cost' to be a victim. *Secondly*, we have the question of whether the cost will change with an additional trip or an additional kilometre driven. If the number of accidents will not change due to the trip decision, there is no need to charge the user (for accidents that he does not create). However, often the number of accidents will increase, which means that we have a marginal effect. The increase in the number of accidents may be in proportion to the increase in traffic, which means that the accident risk, expressed as accidents per vehicle kilometre, is constant. However, the risk may also decline or increase. The actual change in risk will have a strong impact on the marginal external accident cost.

1.1 Study Context and Purpose of this Deliverable

This study summarises a number of case studies on the marginal external accident cost. It should be clear that the number of case studies is very limited compared to the questions raised. *The result from this report is thus nothing more than an indication on the external marginal accident cost in European transport and a base for more studies.*

Why is the result only an indication? While congestion pricing has been discussed for decades in numerous articles and books, the theory on marginal external accident cost is new and has been developed during the last few years. The amount of literature to support our studies is very limited. Instead of giving the final answer, these studies give a first indication of the answer.

[1] The user is aware of the average time cost.

1.2 The Structure of this Report

Section 2 below presents the general theory of marginal external accident cost. We conclude that a relevant theory of the external marginal accident cost exists. The result from the theory should be the groundwork for a distance-based charge, which will ensure an optimal traffic volume. However, it is also concluded that traffic safety policy is not only, or even mainly, about optimal traffic volumes.

In the following, section 3, we summaries UNITE conclusions vis-à-vis risk values. It should be noted that the risk values used here are based on factor costs[2]. The six case studies are introduced in section 4. Three of the studies, **Switzerland**, **Stockholm/Lisbon** and **Inland waterways**, were focused on the problem of implementing the methodology developed in the guidelines. Three were focused on specific questions. The **railway** case study focused on the question how the cost will be allocated between different user groups, road users vis-à-vis rail operators. The **heavy goods vehicle** study concentrated on the relationship between vehicle weight and external marginal cost while the **maritime** study was aimed at answering the question how well the legal system ensure ex post internalisation in the case of maritime accidents. The case studies are included as an annex to this report.

In section 5, we make a synthesis of the findings of the case studies and draw conclusions. The case studies have different focus and the result, the marginal external accident cost, cannot be compared between the studies. The synthesis of the case studies is drawn on two levels, data availability, and key results. Based on this discussion we make some conclusions and recommendations for the generalisation. The report ends with a discussion on further research (section 6).

2 Marginal cost based pricing

Let us assume that a car driver, train operator or ship captain is i) aware of the accident risk related to his trip and ii) that he will bear all costs[3] in the case of an accident. Under these circumstances, he will be aware of the expected accident cost that will arise due to his trip decision. This cost, together with vehicle operating costs, time costs and charges for other external effects, will be weighted against the expected revenue or benefit of the trip. The individual decision maker will consider all the socio-economic consequences in his private decision. Under these circumstances, also other safety related decisions will be socioeconomic efficient.

If the driver doesn't bear all accident costs, an externality will emerge. The private decision will not be based on information on all consequences that the decision will trigger. With a charge for the trip, the appropriate cost information will be given to the driver.

[2] To make the price level comparable to the price level the consumer meets, indirect taxation has to be added - approximately 20%.
[3] With costs we mean both 'hard' material cost and 'soft' valuations, so called risk values (see section 3).

We assume that the charge shall be paid *ex ante*, i.e. before the trip has started and before an accident occurs. *This charge should be based on the expected accident cost the driver/operator does not already bear, and that arises as a consequences of his trip decision.* The charge, based on what is called marginal cost, will be dependent on two parts, i) the accident cost the decision maker does not bear and ii) how this cost is influenced by his trip decision.

This charge will only directly affect the trip decision, and not the choice of technology or behavior. Such an influence can be achieved with other charges directly related to these decisions, or the charge on the trip can be differentiated to take these other choices into account.

In the first section below (2.1), we make an intuitive discussion on the principle while the basic theory is developed in section 2.2. The next section (2.3) shortly presents an important topic, risk-avoiding behaviour; the risk we observe is only one part of the problem, the users may have huge costs to protect themselves against an increased risk. Section 2.4 extends the theoretical concept further and introduces compensations and fines. Finally, section 2.5 discusses other policy instruments.

2.1 Characteristics

The external marginal accident cost has two distinct characteristics:

1. A division between internal and external cost
2. A congestion like effect

If the total accident cost during one year is divided by the annual traffic volume, the average accident cost is of course the result. Sometimes this has been labelled as the accident cost that should be charged to the user. However, if this is to be equal to the relevant marginal external accident cost, two assumption have to be fulfilled; all accident cost is external and the risk is constant. Neither of these are fulfilled according to our case studies. We develop these two issues further below.

2.1.1 Internal/external

The question of internal and external accident cost can be broken into two parts; i) does the user consider his own risk and ii) does the user consider the risk of others? Our straightforward assumption is *yes* on the first question and *no* on the second question.

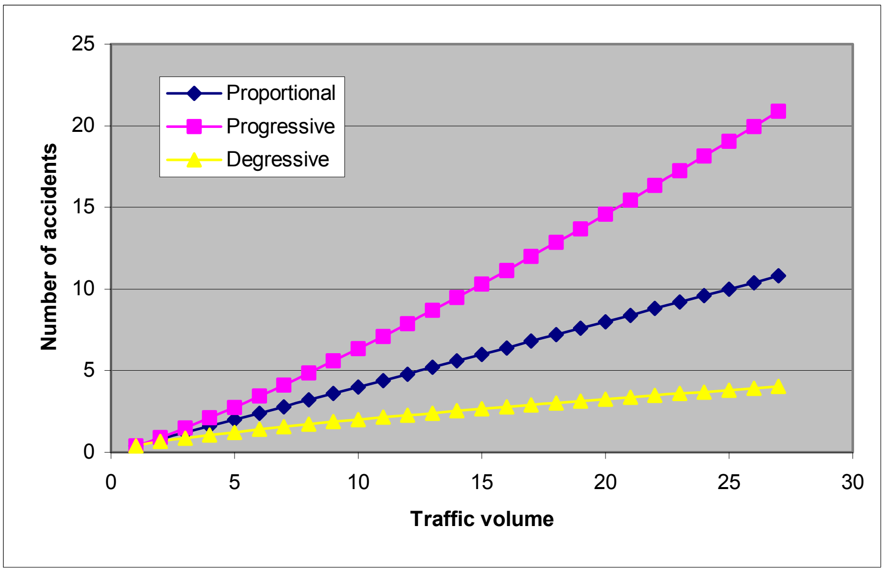
When a value-of-statistical-life is estimated we usually ask users about their trade-off between accident risk and money. We give them information on a hypothetical risk reduction and ask them to consider what they would be willing to pay for this reduction. Their reply is used to derive the value-of-statistical-life. Consequently, if the users understand their own risk, related to their decision, the value-of-statistical-life will be internal.

If they do not understand the risk related to their decision we have a pure information failure. It has often been shown that individuals overestimate small risk and underestimate large risks – "In general, rare causes of death [are] overestimated and common causes of death [are] underestimated"[4]. This has as a corollary that they underestimate risk changes[5]. However, recent results suggest that with a more detailed definition of the risk, the timing of the risk[7] or using risk defined for relevant age groups[8], the difference between actual and perceived risk diminish or disappear. However, exactly how individuals assess the *marginal* risk related to a change in driven distance or a new trip is unclear. We have here based our analysis on the assumption that they understand the risk change. This is not a trivial assumption[9].

2.1.2 Congestion effect

It is well know that when the traffic volume increases on a road the speed goes down and the average travel time increases. But what about the accident risk? As the number of vehicles increases the number of accidents will most probably increase; we have not seen any evidence on the opposite effect. However, exactly how the number of accidents increases is important; will the number of accident increase in proportion to the increase in traffic volume, or will the increase be progressive or degressive?

Figure 1: Change in number of accidents as the traffic increases

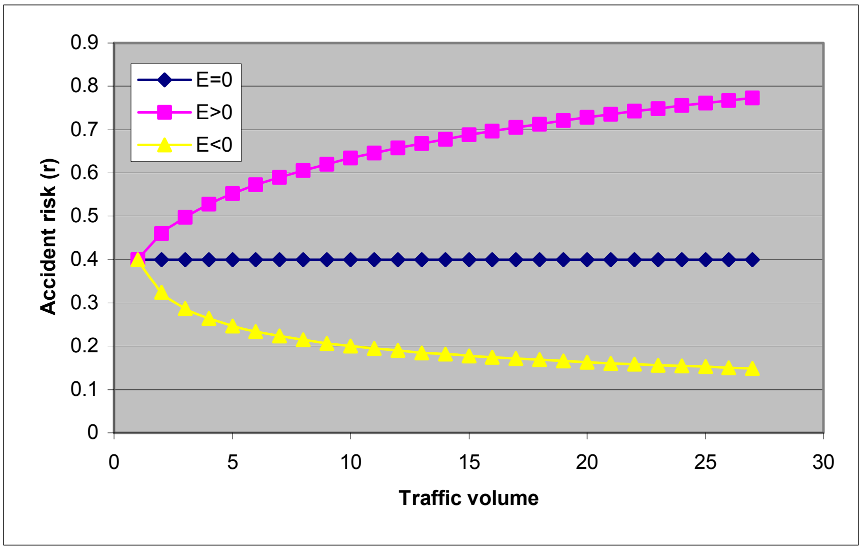


If the number of accidents increases in proportion to the traffic volume the risk, i.e. the number of accidents per vehicle or vehicle kilometer, will be constant (see figure

4 Slovic, Fischhoff, and Lichtenstein 1982, p 467)
5 See Viscusi (1998) for a short discussion on this topic.
6 See Viscusi (1998)
7 Viscusi et.al. (1997).
8 Benjamin et al (2001)
9 Our assumption is close to the risk homeostasis theory (Wilde 1981, 1982) where the user acts as a utility maximizer and tries to keep his risk in equilibrium with his target risk. The zero risk model (Näätänen and Summala 1974, 1976) suggests that in most circumstances the traffic risk is perceived to be equal to zero.

2). A term we have labeled the risk elasticity (E), i.e. the percentage change in risk when the traffic increases by one percent, will take the value nil. If the increase is degressive the accident risk will decline and the elasticity will be negative. This means that an additional user reduces the risk for an accident for all other users. We can think of a situation where pedestrians cross the road; if additional pedestrians adds into the flow of people, the risk for the others to be hit by a car may decline. Finally, if the number of accidents increases progressively the risk will increase. An additional vehicle will impose an increased threat to all other vehicles and the external effect will be larger, the elasticity will be positive.

Figure 2: Change in accident risk as the traffic increases



All of the cases studies where risk elasticities are estimated (case study 4.1, 4.3 and 4.4) found that the risk was not constant. Indeed, all of them suggested that the risk is declining with more vehicles.

2.2 Theory of external marginal accident cost

In the following section, we present a more theoretical explanation of the marginal external accident cost.

The total annual cost of accidents, where vehicle type j has been involved, can be written as equation (1) where ***A*** is the number of accidents and *(a+b+c)* the cost components. With involved we mean, for multi-vehicle collision accidents, that the vehicle has been one of the parts in the accident, irrespectively who is hurt or who was at fault. We can briefly define ***a*** as the 'value of statistical life' (VOSL), ***b*** ditto for relatives and friends and ***c*** as costs, mainly material, for the rest of the society (see section 3). The marginal cost with respect to the traffic volume (***Q***) for a vehicle of category *j* can be written as equation (2). Finally, we derive the external marginal cost as equation (3), where ***PMC*** is the private marginal cost already internalised.

$$TC_j = A(a + b + c) \qquad \textbf{(1)}$$

$$\mathrm{MC}_{j} = \frac{\partial A}{dQ}(a+b+c) \quad \textbf{(2)}$$

$$\mathrm{MC}_{j}^{e} = MC - PMC_{j} \quad \textbf{(3)}$$

Under the assumption that the user perceives the average accident cost imposed on the users of vehicle category *j* as already internalised in his trip decision, the external marginal cost can be written as equation (4), following Lindberg (2001). The total cost (equation (1) above) has been divided into total accident cost imposed on other categories of users (TC_k) and the average cost of the users own category (*ACj*)[10]. The marginal external cost will comprise all costs imposed (i) on other user of the same category, (ii) on road users of other categories, and (iii) on society at large, which is shown in the equation below.

$$\mathrm{MC}_{\mathrm{j}}^{\mathrm{e}} = Q\frac{\partial AC_{j}}{dQ} + \frac{\partial TC_{k}}{\partial Q} + \theta rc \quad \textbf{(4)}$$

We have introduced the risk (***r***) of category *j* to be involved in a multi-vehicle accident as (5) and established ***θ*** as the share of the total accident cost per collision that falls on category *j*. The risk, ***r*** may be affected by an increase in the volume of traffic of category *j*. This effect is expressed as a risk-elasticity (***E***), equation (6).

$$\mathrm{r} = \frac{\mathrm{X}}{\mathrm{Q}} \quad \textbf{(5)}$$

$$\mathrm{E} = \frac{\partial \mathrm{r}}{\partial \mathrm{Q}}\frac{Q}{r} \quad \textbf{(6)}$$

Finally, we express the external marginal cost simply as:

$$\mathrm{MC}_{\mathrm{j}}^{\mathrm{e}} = r(a+b+c)\left[1-\theta+E\right]+\theta rc \quad \textbf{(7)}$$

We expect the external marginal cost to be high if:

- *the accident risk **r** is high*
- *the cost per accident is high **(a+b+c)**;*
- *most of the costs fall on other user groups **(θ≈0)**;*
- *the risk increases when the traffic increases **(E>0)**;*
- *or a large part of the accident cost is paid by the society at large (**c**).*

[10] $AC_{j} = r(a+b+c)\theta$; $TC_{k} = A(a+b+c)(1-\theta)$

This conclusion appears intuitively appealing and adds credibility to our theoretical expression of the external marginal accident cost.

However, the model it is not bound to give a positive external marginal cost. For some user categories, especially if they bear a substantial part of the accident cost ($\theta \approx 1$) and the risk decreases steeply ($E << 0$), the external accident cost will not be positive – it will be a subvention. More pedestrians into an area with mixed car/pedestrian traffic will probably reduce the pedestrian risk. All existing pedestrians will be better off if one more goes out for a stroll – the existing pedestrians should bribe new people to join them. If we instead assume that users do not understand their risk change they will not bear any accident cost ($\theta = 0$) and the external cost will increase.

Most of our empirical work suggests indeed that the risk decreases with traffic volume ($E < 0$). The reduction in the accident risk is so large in some cases that it offsets the external cost related to other categories. This highlights one of the problems of the presented approach – risk-avoiding behaviour.

2.3 Risk-avoiding behaviour

The marginal cost above is estimated based on the change in risk. This change in risk can be influenced by traffic safety behaviour, which the increased number of vehicles has forced the user to take. The cost of this behaviour is an externality.

In the following we divide the users into two groups, the first group (A) is injured and the second (B) is the other part in the accident. We assume that the level of safety (**s**) on a given trip is associated with a cost (**g**), which increases as the level of safety increases. The total annual cost (**TC**) for accidents and traffic safety can then be written as equation (8).

$$\mathrm{TC} = A(a+b+c) + Q_A g(s_A) + Q_B g(s_B) \qquad \textbf{(8)}$$

We allow only for risk-avoiding behaviour that increases the 'internal' safety, i.e. the user's own safety[11]. A user that expects to be a victim (user A; e.g. unprotected road users) will adjust behaviour (s_A) to protect himself from an accident. To the marginal accident cost, the cost of all victims' risk-avoiding behaviour has to be added. The total external cost for category B, the unharmed user ($\theta = 0$) will be:

$$\mathrm{MC}_{\mathrm{B}}^{\mathrm{e}} = r_B (a+b+c)\left[1+E_B\right] + Q_A \frac{dg}{ds_A}\frac{ds_A}{dQ_B} \qquad \textbf{(9)}$$

The last term in equation (9) is the cost of user group A's risk-avoiding behaviour triggered by an increased number of trips of category B. A part of the risk avoiding behaviour, lower speed, can be traced to the congestion cost and handled as such. Another part can be found in infrastructure cost, where a higher number of, for

[11] In the literature (Johansson (1996) it also exists a discussion on a possible positive externality in relation to this risk avoiding behaviour if it is not only internal safety that is affected (see PETS (1998) for a summary).

example flights, increases the necessary number of safety staff and the dimension on the rescue capacity at the airport.

When we try to include risk-avoiding behaviour in the external accident cost, we pass the boundary between cost categories and have to consider part of the congestion and infrastructure cost. However, in the limited number of UNITE case studies it has not been possible to focus on this aspect and we have to assume that these costs are covered in other parts of the external marginal cost.

2.4 Liability

The theory presented in section 2.2 does not explicitly discuss liability. As above we assume that the first group (A) is injured and the second (B) is the other part in the accident. Without any liability, the injured user (A) will bear all costs and the other part (B) will not bear any cost. The external marginal cost for each group is then:

$$\mathrm{MC}_{\mathrm{A}}^{\mathrm{e}} = r_A(a+b+c)[1+E_A] - r_A(a+b) = r_A(a+b+c)[E_A] + r_A c \qquad \textbf{(10)}$$

$$\mathrm{MC}_{\mathrm{B}}^{\mathrm{e}} = r_B(a+b+c)[1+E_B] \qquad \textbf{(11)}$$

The final expression of section 2.2 (equation 7) is, of course, a weighted sum of these two expressions, where θ expresses the probability of being the injured user.

Under a **negligence rule,** a user in group B, will not bear any cost as long as he behaves legally. If he breaks the law, he will be responsible for some of the costs as compensation (**d**) to user A or as a fine (**M**). These costs will be included in his private marginal cost and the external cost will decrease. At the same time, the compensation (**d**) will reduce the expected cost of an injured user in group A; consequently the external marginal cost of group A will increase. While this conclusion at first looks disturbing, it should be noted that the criminal user B will have a higher *Generalised cost,* than the legal user B. The criminal user has to pay fine, compensation and external marginal cost.

Legal user B => $\mathrm{MC}_{\mathrm{B}}^{\mathrm{e}} = r_B(a+b+c)[1+E_B]$ **(12)**

Criminal user B => $\mathrm{MC}_{\mathrm{B}}^{\mathrm{e}} = r_B(a+b+c)[1+E_B] - r_B(d+M)$ **(13)**

Not compensated user A => $\mathrm{MC}_{\mathrm{A}}^{\mathrm{e}} = r_A(a+b+c)[E_A] + r_A c$ **(14)**

Compensated user A => $\mathrm{MC}_{\mathrm{A}}^{\mathrm{e}} = r_A(a+b+c)[E_A] + r_A(c+d)$ **(15)**

With **strict liability** for user B, he will always pay the cost in the form of compensation (*d*) or a fine (*M*) in the case of an accident – in principle he is always ‘criminal’ as in equation 13 above.

Assume that both A and B are car users and that we cannot *ex ante* identify the criminal user; we have to assume that the probability of being in either group is 50/50. Consequently, while the marginal cost of group B is reduced, it is increased for group A through the compensation (*d*); the effect on the joint marginal cost for all car users disappears and the external marginal cost can be written once again as equation (7). However, a fine (*M*) will affect the result. This theory assumes that the user perceives the compensation and fine as a part of his cost ex ante.

With a large group of users, we know that some of the accidents are caused by bad luck and some by illegal behaviour. The first type of accidents can be handled with our basic theory (section 2.2), which is based on a weighted sum of equation 10 (=14) and equation 11 (=12), i.e. compensation and fines are ignored. The second type can be handled with the extended theory discussed here. However, if we cannot identify *ex ante* the criminal user and the compensated user within the large group, the effect of compensation will cancel out and we can rely on our basic theory. If we can identify the criminal user *ex ante* and treat them as a sub-group, we should naturally use the theory developed here. However, we need also to examine the risk and risk elasticity for this sub-group.

Another important case is if the victim (user A) is guilty of the accident, for example a pedestrian that crosses the street illegally and is hit by a car. Depending on the legal situation the car driver should *ex ante* be charged as equation (12) or (13) and the pedestrian probably as (14). Subsequently, the innocent car driver shall pay a charge *ex ante*. Is this an ethical problem? It may be. However, if it is too expensive to ensure that the pedestrian A behaves legally, it may be optimal to reduce the number of trips of the injurer B. While this conclusion sounds disturbing, it is less obvious with another example. If it is too expensive to ensure that children behave legal around the playground, it is more efficient to reduce the level of car traffic on the adjacent streets.

The Swiss case study elaborates further on the problem of liability in estimates of the external marginal accident cost.

2.5 Other policy instruments

The number of trips and the behaviour, while taking these trips, creates the traffic safety problem. Internalisation of the external marginal cost, that we have discussed, ensures an optimal number of trips. In addition, if the marginal cost is estimated for different road types or road/rail crossing protection devices, a differentiated charge will also influence the route choice. However, an *ex ante* charge will never influence the behaviour during the trip.

The external marginal accident cost estimated in this deliverable turns out to be small compared to the results from other studies, which often are based on a cost allocation approach. When the total cost is allocated to different users, and charged *ex ante*, the whole burden of externality will fall on the user's trip decision. He will probably make too few trips, but with the same behaviour as before.

The lower external marginal cost, emerging from some of the studies in this deliverable, highlights the importance of a broad traffic safety policy. Such a broader approach would result in a differentiated strategy consisting of a mix of pricing and of non-pricing measures. The main key factors identified are:

- Traffic volume
- Composition of traffic volume (share of heavy goods vehicles)
- Speed of vehicles
- Characteristics of victims and drivers (Sex, age, number of years driving)
- Road conditions
- Weather
- Time of day (daylight)
- Consumption of alcohol
- Safety regulations.

Traffic safety policy is not only, or even mainly, about optimal traffic volumes; more important is probably a safe behaviour while driving – this will not be influenced by a charge based on the external marginal accident cost measured related to driven distance. But a more sophisticated system may either observe the actual behaviour of the driver and can differentiate the charge appropriately or be differentiated according to some of the factors above (e.g. vehicle regulations)[12].

3 Value of Statistical Life[13]

There is today a reasonably widespread agreement that monetary values of risk reductions in the transport sector should be defined so they reflect individual preferences of the affected population.

The willingness to pay (WTP) or willingness to accept compensation (WTA) can be estimated by asking a sample of the affected population about the amount they would be willing to pay or accept as compensation for changes in the level of safety. This method is often referred to as the 'contingent valuation' (CV) method. A number of studies apply the CV method to estimate the WTP. The use of the Contingent valuation method has become the standard method when the WTP for increased safety in the transport sector shall be estimated. From the WTP a 'value of statistical life' (VOSL) can be derived.

$$VOSL = WTP/\text{change in risk} \qquad \textbf{(16)}$$

However, lately questions on the reliability of the results have been raised. Serious problems with embedding, scope and framing effects have been found. Embedding and scope effects refer to the tendency of respondents to report the same WTP for a larger safety improvement as for a smaller improvement. If the responses are only weakly dependent on the magnitude of the risk reduction, almost any VOSL can be derived from the studies.

[12] Such a differentiation will mainly be based on the vehicles external safety standard, i.e. how it is constructed to reduce the risk for other road users.
[13] Based on the UNITE valuation note.

Nevertheless, we believe that the CV-method is the right approach and that estimates that are more reliable can be found if these problems are taken into account in the study design. In fact, some studies are already now conducted with this problem in mind. Instead of summing studies with uncertain quality and estimate an average, UNITE base the recommendations on a few well-conducted studies.

Based on a limited number of well-designed studies, UNITE has proposed a European Standard Risk Value, 1.5 million € per fatality measured as a Consumer value. The value is in line with other recent estimates but at the lower end of previous estimates. To calculate the full value of a fatality the cost of net lost production, medical and ambulance cost should be added, which is approximately 10% of the risk value. To express it as a Factor cost it should be reduced with the proportion of indirect taxation (around 20%).

Following the latest development of studies of VOSL, which includes risk-risk studies, the relative value between different degrees of injuries can also be derived. Earlier recommendations include the ECMT (1998), which estimates the Risk Value for severe injuries at 0.13 and for light injuries at 0.01 of the Risk Value of fatalities. Our conclusion is that the evidences do not suggest that the ECMT values need to be updated. However, our survey also suggests that it would be appropriate to divide the severe injury group into two sub-groups with permanent and temporary injuries. If values for the subgroup of severe injuries are to be used, we recommend using the factors from Persson et al (2000). When adapted to the ECMT factors for severe injury the factor for permanent injury becomes 0.32 and for temporary 0.09.

Finally, we believe it is clear that relatives and friends of a user have a positive willingness to pay to reduce the user's risk. However, due to the uncertainty in the assessment of the user's own value, discussed above, we refrain from including this component in our estimates. If it would have been included we anticipate that the external marginal cost would increase with around 40%.

Each case study uses the values relevant for that mode and country, but in principle the values follows the recommendation;

- User's own risk value (a) – around 1.5 M€
- Relatives and friends (b) – ignored
- Material costs (c) – approximately 10% of users own risk value.

4 Summary of the Case studies

Six case studies have been carried out in the field of marginal external accident cost. Three of the studies, in Switzerland, Stockholm/Lisbon and Inland waterways, where focused on the problem of implementing the methodology developed in the guidelines (Lindberg (2000)) and summarised in section 2 above. Three were focused on specific questions. The railway case study focused on the question how the cost will be allocated between different user groups, road users vis-à-vis rail operators. The HGV study concentrated on the relationship between vehicle weight and marginal external cost while the maritime study was aimed at answering the question how well the legal system ensure ex post internalisation in the case of maritime accidents.

Table 4-1 Case studies

Case study	Mode	Summarised in section	Presented in appendix
Switzerland	Road and rail	4.1	1
Stockholm/Lisbon	Road	4.2	2
Railway	Rail	4.3	3
HGV	Road	4.4	4
Maritime	Maritime	4.5	5
Inland waterway	Inland waterway	4.6	6

As noted in the introduction; *the result from this report is (thus) nothing more than an indication on the external marginal accident cost in European transport and a base for more studies.*

4.1 Switzerland

In the framework of this case study specific risk rates according to vehicle categories and road types have been derived for Switzerland. A similar in-depth study for railways was not possible due to lack of data. The number of non-reported accidents and accident victims has been taken into account. These estimations show that the total number of accident victims is about four times higher than the number of officially recorded accidents.

For the calculation of accident risk elasticities the case study carried out several comprehensive empirical estimates for different road types. The calculations are based on information about the number of accidents per hour and transport volume per hour for 114 road sections in Switzerland in the years 1996 - 2000. Altogether, the results show an under proportional increase in both accidents and accident victims with increasing transport volume. The results are of a similar order of magnitude as estimates found in the literature.

Based on these findings the case study determined the external marginal accident costs for road transport. It shows that the size of the marginal costs depends crucially on the assumption concerning the internalisation of the accident risk. In the Swiss data the responsibility of the accident is attributed to one of the involved drivers. It means, for example, that for a car-car collision accident it is possibly to define one responsible driver and consequently also to define, if appropriate, responsible victim (the driver) and non-responsible victims (which include all passengers and the other driver). In the case of a car-pedestrian accident the pedestrian may be the non-responsible victim.

The study offers a number of alternative expressions of the marginal external accident cost. In one assumption the average risk is internalised. However, it should be observed that the internalised risk here is the risk of causing an accident with both responsible and non-responsible victims (i.e. pedestrian victims will be included here). The proportion cost born by the user (θ) is equal to unity. Considering this average accident risk to be internalised, the result – due to the under proportional increase in the number of accidents – are negative marginal costs.

The more realistic assumption, although not uncomplicated, is that the responsible victim has internalised his risk[14]. This means that the proportion of the cost born by the user (θ) will be smaller than unity. Consequently, assuming a causation perspective in which the causer of the accident normally bears only his consequences of the accident, but not (or just partly) the costs of the non-responsible victims, the external marginal costs turn out to be in the range between € 0.002 (motorway) and 0.048 (roads inside settlement area) per vkm. Only this cost is presented in the table below.

For rail transport, the case study has only estimated average but not marginal external accident costs. The rates amount to € 0.04 / train-km (risk fully internalised) and to € 0.30 / train-km (risk of non-responsible victims not internalised) respectively.

The case study includes a considerable amount of high value original data and estimates. In addition, it expresses clearly some of the problems around the assumption regarding the proportion of internal/external cost we can see in the table below.

Table 4-2: Marginal external accident costs of road transport in Switzerland with average risk of causer internalised, in € / vehicle kilometre, 1998

	Average risk of causer internalised
All road types	**0.012**
Car	0.012
Coach	0.132
Urban Public Transport	0.025
Light goods vehicles	0.014
Heavy goods vehicles	0.018
Moped, motorcycle	0.080
Motorway	**0.002**
Car	0.003
Coach	0.009
Urban Public Transport	-
Light goods vehicles	0.003
Heavy goods vehicles	0.003
Moped, motorcycle	0.002
Outside settlement areas	**0.014**
Car	0.016
Coach	0.208
Urban Public Transport	0.039
Light goods vehicles	0.021
Heavy goods vehicles	0.027
Moped, motorcycle	0.055
Inside settlement areas	**0.048**
Car	0.042
Coach	0.774
Urban Public Transport	0.047
Light goods vehicles	0.053
Heavy goods vehicles	0.107
Moped, motorcycle	0.309

[14] The expression a'_D in the case study 8a (page 26) can be seen as similar to (1-θ) in equation 7 (page 6) of this report. However, as the responsible victim is assumed to only be the driver, θ tends to be small compared to situations where the risk of passengers also are internalised.

4.2 Stockholm – Lisbon

The paper has examined the different elements in the expression of external accident cost in Portugal and in Sweden. In addition, a detailed study has been carried out for Stockholm where elements are compared to general Swedish urban areas and non-urban areas. The elements that are discussed are the valuation ($a+c$), the accident risk (r), the proportion internal cost (θ), and finally the risk elasticity (E).

The accident valuation is similar in both Sweden and Portugal. The difference can be explained by the difference in purchase power between the countries. This result is not surprising as the dominant risk value has the same origin, the common UNITE value, adjusted for purchase power. The ratio between the Portuguese and Swedish value is 0.73. The assumption on the part of cost born by the victim is very similar in the two countries. *The marginal external accident cost will thus differ according to the purchase power.*

The accident risk, or the risk for a fatality, shows a very high difference between the countries. The Portuguese risk per vehicle kilometre is 4.5 times higher than the Swedish risk for a fatal car accident. Also the risk for bus accidents, LDV and HGV accidents are higher. However, the risk for a fatal HGV accident is only 3 times higher. *To generalise the external marginal accident cost, it is necessary to consider country specific risk estimates.*

The structure of the probability of being a victim in an accident is, amazingly, very similar in Sweden and Portugal. *Our preliminary conclusion is that the proportion of internal/external cost can be generalised between countries.*

It is difficult to judge the possibility to generalise the risk elasticity, as the number of available estimates is so few. More studies have to be carried out on the magnitude of the risk elasticity.

The difference between areas in Sweden is smaller. The valuation is often assumed the same, and we have not examined if higher income would generate a higher accident valuation locally. As we move from all roads to urban areas and to Stockholm, the fatality risk declines. However, the accident risk, or risk for a personal injury accident, may be constant. This means that the consequences of the average accident will be less severe and consequently the average accident cost will be lower.

The main problem regarding estimation of accident risk shall be examined is the availability of exposure information. Rough estimates can be found for whole countries or for urban and non-urban areas in Sweden. For a single municipality the information is not readily available. A detailed study on victims and injurers in Stockholm compared to urban areas in general in Sweden, and to accidents on all roads suggests a surprisingly close relationship between Stockholm and other urban areas.

The paper concludes that valuations will differ with purchasing power between countries and that the accident risk is very country specific. The proportion of internal cost shows a very similar structure in both countries, in urban areas and in a large city, Stockholm. It is possible that the proportion of internal/external cost is stable and can be generalised. Differences in the resulting external marginal accident cost between countries and areas will in essence depend on the valuation and the accident risk and possibly also the risk elasticity.

4.3 Railways

Since the pioneering separation of the Swedish railway monopoly in 1988, into a Track Authority (*Banverket*) and a Railway company (*SJ*), the operator(s) have been charged for the use of the infrastructure. The charge shall in principle be based on the marginal costs of infrastructure damage, including damage on aerial lines, marginal accident and environmental costs. While proposals on new charges over the years adhere to the principle of marginal costs, no proper theory for the accident component has been developed and consequently, no proper marginal cost analysis has been carried out. The case study discusses a theory of external accident cost and analyses the external marginal cost at rail/road level crossing.

The case study has concluded that there are no welfare economic reasons to abolish the level crossing accidents in a calculation of the relevant accident charge. We have estimated an accident function based on the discrete choice model. We have observations on all (8600) Swedish road/rail level crossings where the tracks have been used in 1998. However, we have only information for road traffic on a limited number of crossings (977). The effect of both road and rail traffic are significant and the protection devices have the expected sign. The accident probability will decline if full or half barriers are installed. The proxy used for train speed or car speed was not successful. The model that includes the full dataset employs road type as a proxy for road traffic volume. The same conclusion can be drawn vis-à-vis barriers and, as expected, the probability is higher for crossings with main and county roads than for streets and other roads. The lowest probability is found at minor private roads. This reflects the expected road traffic volume.

The marginal cost, estimated based on the probabilities in the full dataset, is on average around 0.034 €/passage. For barriers the marginal cost is 0.062 €/passage and for open crossings with light or S:t Andrew cross 0.108 €/passage. For unprotected crossings, the marginal cost is 0.007 €/passage. The low cost on the unprotected crossings reflects of course the fact that the traffic on the passing roads are very limited on these crossings.

Table 4-3: Marginal cost at road/rail level crossings

Protection type	Costs per passage
Barriers	0.062 €/passage
Open crossings with flash light or S:t Andrew cross	0.108 €/passage
Unprotected crossing	0.007 €/passage
All crossings	0.034 €/passage

We cannot distinguish the marginal cost for freight and passenger train separately, although we expect slower freight trains to have a lower marginal cost.

There is a strong case to re-introduce the road/rail level crossing charge. With our analysis, this can be done individually for each track segment. If the charge is differentiated according to protection device new incentives will be created in the railway safety system. If the number of dangerous crossings can be reduced, the charge will go down. This will give incentives to train operators to co-finance road/rail level crossing protection devices.

The study is based on a large dataset. However, the quality of the result is restrained by the limited information on road traffic flow, car and train speed. This should be improved in the future.

4.4 Heavy Goods Vehicles

Marginal cost of HGVs has previously been dominated by the cost of road wear and tear. This cost increases exponentially with axle weight, the so-called 'forth-power law'. Consequently, road taxes and charges based on marginal cost theory increases generally strongly with axle weight. As the accident cost component becomes more important, the structure of the accident component becomes crucial; does the external accident cost increase with axle weight and reinforce the current structure on taxes or charges or does it decrease with axle weight, i.e. cancelling out the axle dependence of the tax structure. Thanks to two unique databases, one on accidents and one on driven distances, we try to estimate the marginal external accident cost for a number of different weight classes of HGVs.

The study focuses on driven distance by individual vehicles, which is a problem. This is different from the traffic volume on a single road. We may expect that vehicles driven longer distances drive more on interurban roads, have a more experienced driver and may be better maintained. While we may expect that a higher share of HGVs on a single road increase the risk, we may expect longer distances driven to decrease the risk. This is because if higher mileages are correlated with the use of less risky roads, the effect of mileage on risk will be understated. Our analysis may therefore understate the risk resulting from an equi-proportionate increase in traffic on all roads.

The case study has two basic data sources, information on almost 90 000 individual accidents during 1999 from the Swedish National Road Administration (*Vägverket*) and information on the distance driven during 1999 for 78 000 HGVs above 3.5 tonne from the Swedish Vehicle Inspection Authority (*Bilprovningen*). With the unique accident number, we have linked the motor vehicle database with the other databases. The complete HGV database consists of 3 940 accidents including 83 fatalities, 254 severe injuries, and 1 035 slight injuries. This is 5.8% of all the (reported) accidents in Sweden during 1999. In general, HGV accidents seem to be more severe than the average road accident (14% of the fatalities) even if they include less passengers and unprotected users (bicyclist, moped users (1.2%) or pedestrians (2.6%)).

The case study has estimated an external marginal cost of 8.4 €/1000 vkm for an average HGV above 12 tonne (see table 5-2 for more results). This is far below other estimates of the external accident cost. Basically, this is a result of the low elasticity we have estimated. The number of accidents increases as the number of driven kilometre by HGV increases, but the number of accidents do not increase in proportion to the increased number of driven kilometres. This means that the accident risk decreases.

We have found a positive relationship between the accident probability and axle weight. This relationship reinforce the 'forth power law', used for estimates of marginal infrastructure cost, even if the accident relationship is not as progressive as the marginal infrastructure cost.

We have in this paper not estimated any model to explain the average accident cost or the proportion of internal cost. However, there are indications that the average accident cost may increase with axle weight, and the proportion internal cost decreases with axle weight. This would strengthen the relationship between axle weight and marginal external accident cost.

4.5 Maritime shipping

Reliable estimates on the accident risk in maritime transport are rare. Two reasons can be found, first, maritime transport is a truly international mode and for almost every single trip a number of different territorial waters are passed which make the statistics difficult to collect. Secondly, the traditional measure of exposure, vehicle kilometre, is difficult to find for sea transport. The paper has not been able to improve the estimates on maritime risk.

The paper examines detailed accident reports from the Swedish Maritime administration for all accidents with Swedish ship on Swedish water during 1998. It is suggested that the fatality risk at sea are surprisingly high at a first glance. Per Swedish ship, the risk is 1.9 fatalities compared to 0.1 per vehicle in road transport. The fatality risk per passenger kilometre for ferry traffic could nevertheless be around half of the risk in road transport.

A majority of the accidents can be classified as single accidents (90%). Many of the accidents in the statistics are not transport related. Around 70% of the fatalities and personal injuries occurred in 'non-transport' related accidents, such as illness or accidents in the kitchen. If these accidents are deducted from the risk estimate presented above, the risk will fall in the maritime sector.

In Sweden, 14 collision accidents happened during 1998 which involved at least one Swedish commercial ship. No person was killed or injured in these accidents.

Very little in the material suggests that the accident risk should be dependent on the traffic volume or distance. A plausible hypothesis is that the 'congestion' type of externality, i.e. the fact that the cost changes with traffic volume, may be ignored in maritime accidents in Sweden.

The second type of externality, the proportion of internal and external costs, depends on who is the victim, and if he is compensated or not by the injurer. A number of international conventions regulate the level of compensation. It is thus found that, for the most catastrophic accidents, the cost of accidents is much higher than the total limit. In addition, the limit per passenger is far below the accident cost if the willingness-to-pay based component is included. The limitation means that the compensation, and consequently the internalised cost, is around 5% for a fatal accident and 30% for a severe injury. The conclusion is that the shipowner does not internalise all accident costs in the case of catastrophic accidents. The total limit for compensation to own passengers is 34.5 million €. That means that 'full' compensation to a passenger (64 399 €) can be paid to 536 passengers. The ship with most passengers involved in an accident during 1998 had 1 554 passengers (fire). A large ferry, Silja Serenade, may carry 2 852 passengers. If an accident means injuries to passengers on other ships, the total limit is set according to gross tonnage. The largest passenger ship involved in an accident 1998 had a weight of 38 772 GT which means a total limit of 13 million € or 8 427 € per passenger. A large ferry may have a tonnage of 58 000 GT which means a total limit is 25 million € or 8 787 € per passenger.

The resulting external cost related to personal injuries is low and can be estimated to around 0.4% of the current Swedish fairway charge. Even if we employ a limit on the compensation, the external cost is relatively low and amounts to 5% of the current fairway charge. The paper has assumed that the fairway charge should internalise the externality due to maritime accidents, but excluded the cost of illness and fire accidents.

An externality may occur in accidents between ships. However, collision accidents between ships constitute only about 10% of the total number of accidents. No person was injured or killed in such accidents during 1998. An externality can take place, but that depends on the actual compensation of the cost of hull damage of the involved ships.

In summary, for the year 1998 no significant externality occurred in Maritime transport which would suggest any dramatic shift in the fairway charges. The paper does not include the cost of oil spills in the analysis. Neither has it considered the risk for catastrophic accidents. It can nevertheless be concluded that due to the limitation of compensation, the degree of externality will increase with the size of the accident.

4.6 Inland waterway

The study area comprises the areas along the lower and middle Rhine, from the seaport of Rotterdam to the inland port of Mannheim with a total distance of 590 km. In the year 1998, 378 accidents were reported. Approximately 2 of every 1000 ships travelling along the Rhine segment meets with an accident. These accidents are usually very light with some damage to the ships; no fatalities were recorded on the stretch. Of the total number of accidents, 57% took place in ports and the remaining 43% along the inland waterway stretch. Over half of the accidents, 57%, are single ship accidents: for instance, the shipper runs his ship aground.

The total cost of inland waterway accidents was 27.9 million €. These include costs of damage to ships (84%), the costs of damage to infrastructure (8%), costs resulting from human injury or death (8%). Cost of environmental damage or operational damage has not been included.

An attempt has been made to analyse ship accident statistics over the period 1993-1997 and to make an estimation of the increase in accident risk with additional ship movements. However, many safety measures were taken during this period whereas ship movements increased, which makes a comparison unreliable. There is still a lot of spare capacity on the Rhine and there is therefore no reason to assume that congestion will cause marginal cost to rise. It is assumed that the accident risk is almost constant (E=0.01).

Based on the assumption that the ship owner pays all the damage to the ship and, through insurance premiums, half of the cost for injuries and fatalities, the ship owner internalises 91% of the total accident cost. Marginal external costs related to one additional ship movement on the Rhine case study stretch are estimated to amount to approximately € 16 per movement or 0.0019 € per ship tonne kilometre.

Statistics on actual inland waterways accident costs have proven to be less readily available than expected, whereas the accident occurrence information is very detailed.

5 Synthesis

The case studies have different focus and the final result, the marginal external accident cost, cannot be compared between the studies. The UNITE project could not both cover the width of the problem, and go into depth with numerous studies for the same mode and vehicle category. With our case studies we examine the possibility to employ the theory on different modes of transport.

The synthesis of the case studies is presented on two levels, data availability and key results (section 5.1). Based on this discussion we make some recommendations for the generalisation (5.2).

5.1 Conclusions from the Case studies

5.1.1 Data availability

We need information on the accident risk (r) and its relationship with traffic volume (the elasticity E), the cost per accident ($a+b+c$) and how this cost is allocated between user groups (θ). It turns out that none of these information requirements are trivial to fulfil.

Accident statistics are available for all modes studied. The statistics are based on reported accidents, underreporting has to be considered separately. For some modes the statistics are very detailed but difficult to generalise, this is true for maritime, inland waterway and railway accidents. So-called ‘damage only’ accidents are the type of accidents that are most difficult to find information about. Information on traffic volumes is more difficult to find than expected. It is easiest for the road sector, but the differentiation between road type and vehicle type is less reliably. The problem to find reliably information on traffic volume for railways was unexpected, while we expected the problem for maritime and inland waterways. The problem with reliably information on traffic volume made it difficult to estimate risks and even more difficult to estimate risk elastcicties.

We have based our research on generalised unit costs for different degree of severity of the casualties. These values are based on other research and often codified as official values used in road investment planning. Nevertheless, uncertainty remains around the magnitude of these values but we have used what we judge as the most recent well-founded values. For road accidents, the huge number of accidents makes it easier to generalise a cost model. Unit values for casualties are the base for road accident costs and average unit values for material cost is also often available. For the other modes, every accident is unique and it is very difficult to employ a generalised model. In addition, the material accident cost is seldom easily available, and thus often ignored in these estimates.

Only rather advanced databases could present the information in matrix form, with information on victim and injurer. This information is necessary to be able to estimate the proportion cost born by each user category. For maritime, railways and inland waterways, the number of accidents is limited and it is possible to construct matrices separately. Information on the actual compensation paid and received is difficult to find.

5.1.2 Key results

The table below summarises the key results from the case studies (**Column 1**) for different modes (**Column 2**). **Column 3** defines the measure of exposure. **Column 3** presents the accident risk. The accident risk is defined different for different case studies. In some cases, the focus is on personal injury accidents (case study A, B, C and D) while others include all types of accidents. The risk is often expressed per vehicle kilometre (unit). For some studies, the risk is expressed per tonne kilometre, which is not very convenient for pricing policy but a consequence of the data availability. The Swedish railway study presents the risk and result per train that pass different types of crossings.

Table 5-1 Summary of key variables

(1) Case Study	(2) Mode	(3) Unit	(4) Risk (Accident per million unit)	(5) Cost per accident (k€)	(6) Internal part (%)	(7) Elasticity	(8) Average Cost (€ per unit)	(9) Marginal external cost (€ per unit)
A	**Switzerland**							
	All road	Vehicle km	1.270	-	0.68[C]	-0.54	0.025	0.012
	Motorway	=	0.201	-		-0.50	0.005	0.002
	Other	=	1.184	-		-0.62	0.030	0.014
	Urban	=	2.362	-		-0.25	0.099	0.048
	Railways pass	Pass. km	0.0017	-	0	-	(0.04/0.30)	-
	Freight	Tonne km	0.0006	-	0	-		
B	**Stockholm-Lisbon [E)]**		[D)]					
	Sweden	Vehicle km	8.4	-	0.76	-	-	-
	Lisbon	=	38.1	-	0.65	-	-	-
	Urban Sweden	=	5.9	-	0.59	-	-	-
C	**Railways - Sweden**							
	All Level crossings	Passage	0.271[B)]	971.0	0[A)]	-0.87	0.26	0.034 [B)]
	Barriers	=	0.225	=	=	-0.72	0.22	0.062
	Open cross.	=	0.725	=	=	-0.85	0.70	0.108
	Unprotected	=	0.085	=	=	-0.92	0.066	0.007
	HGV							[F)]
D	Sweden average >12t	Vehicle km	0.869	58.3	0.09	-0.76	-	0.0084
	12t – 14.9t (2)	=	1.002	36.2	0.15	-0.90	-	(-0.00081)
	15t – 18.9 t (3)	=	0.896	77.0	0.07	-0.86	-	0.0062
	19t – 22.9 t (4)	=	0.724	45.9	0.09	-0.71	-	0.0074
	23t – 26.9t (5)	=	0.977	55.0	0.12	-0.74	-	0.0081
	27t – 30.9t (6)	=	0.914	57.6	0.07	-0.61	-	0.016
	Above 31 t (7)	=	1.030	99.3	0.03	-0.74	-	0.032
E	**Maritime**							
	Swedish ship on Swedish water	Registred ships	0.026	n.a.	n.a.	n.a.	-	73 – 10 000 anually
	Inland waterway							
F	Rhine	Ship tonne km	0.273	73.9	0.91	*0*	0.020	0.0019
	Rhine	Ship movement	0.0022	=	=	=	162	16

[A)] Only personal injuries in road/rail level accidents were included.
[B)] Personal injury accident
[C)] Responsible injured/All injured
[D)] Fatality risk
[E)] For passenger car
[F)] Model 3

The cost per accident differs widely for different case studies as expected (**Column 5**). The highest cost is found in road/rail level crossings accidents. The car user is often seriously injured or killed in these accidents. The cost per casualties for some of the case studies are presented in the table below.

Table 5-2 Cost per casualties in the case studies (k€)

	Sweden	*Portugal*	*The Netherlands*
Fatality	1 327	965	1 806
Severe injury	201	170	316
Light injury	15	12	16

The shares of costs that fall on the examined user differ widely between the studies but are correlated with the modes (**Column 6**). The information is calculated as *the accident cost borne (as victim) by the examined user group, divided by the total accident cost where the examined user group has been involved*. Compensation between groups is often ignored. Inland waterways internalise 91% of the accident cost. The ship owner pays the majority of the cost, because most of the accident consequences are material damages. Maritime transport also internalises most of the cost. In both these groups, most accidents are single accidents with a limited amount of system external cost. Road vehicle users in general have an internal part of 68% in Switzerland. For the heavy goods vehicles in Sweden this share is down to 9%, but differs between different weight classes. Finally, the rail mode does not internalise any costs related to road/rail accidents. This is however, an outcome of the study design in the Swedish study.

The most surprising result from our case studies is the risk elasticities as summarised in **Column 7**. As the number of vehicles increases the number of possible interactions increases with the square. This suggests that the risk should increase with traffic volume. Accident models employed by infrastructure authorities do often assume that the risk is constant when the traffic flow increases; this implies a risk elasticity of zero. However, our results suggest that the risk decreases with traffic volume. Admittedly, this has been found in other studies, but not such a strong decrease. In an overview of six international studies, Chambron (2000) finds a positive, but in general less than proportional increase in injury accidents. This is also true for fatal accidents. Dickerson, Peirson and Vickerman (2000) find that the accident elasticity varies significantly with the traffic flow. They argue that the accident externality is close to zero for low to moderate traffic flows, while it increases substantially at high traffic flows. Vitaliano and Held (1991) show in their estimation that the relationship between accidents and flows is nearly proportional and thus the risk elasticity is close to zero. This is also found by Fridstrøm et al (1995).

The HGV study (Case Study D) focuses on driven distance by individual vehicles, which is a problem. This is different from the traffic volume on a single road. We may expect that vehicles driven longer distances drive more on interurban roads, have a more experienced driver and may be better maintained. While we may expect that a higher share of HGVs on a single road increases the risk, we may expect longer distances driven to decrease the risk. Our analysis is thus relevant for a charge based on a non-positioned kilometre charging system.

Column 8 presents the average cost, where available, and **Column 9** the marginal external accident cost. The estimated low risk elasticity has its consequence for the magnitude of the marginal external accident cost - our estimated marginal external accident cost is low compared to other studies.

It should be recalled that we have used a theory of the true *marginal external accident cost* which may differ from results presented in other studies. We have assumed that the 'charged' user is aware of his own risk and related cost *of being a victim*, i.e. a large part of the cost is already internalised. We have only studied the accident cost. In addition to this cost, and possibly as a mirror of our low elasticities, users have a cost for *risk avoiding behaviour* that are not included in this study. We have ignored the cost for *relatives and friends* (*b*) based on the argument that we are uncertain on the basic own risk value; to add another unsure component would increase the uncertainty in our results.

5.2 Generalisation

We discuss generalisation in four parts. The possibility to generalise the theory and method (5.2.1), to generalise functions (5.2.2), values (5.2.3) or even final estimates on external marginal costs (5.2.4).

5.2.1 Method

The method and theory presented here, condensed in equation (7), is suitable for all modes in all member states. We cannot foresee any more general form of the external marginal accident cost. However, some further development would be useful and discussed in section 6 below.

5.2.2 Functions

The basic function to discuss is the accident function. The form of this function is captured in the risk and the risk elasticity.

The case studies do not give a clear recommendation; we may *hope* that the risk elasticity can be generalised and used in other Member States. The elasticity captures *the form* of the accident function. However, we have only carried out a limited number of studies and some of our results are lower than expected. More case studies should be carried out before we are prepared to suggest a set of transferable and reliable elasticities.

The accident risk will define *the level* of the accident function. Estimates of accident risk are often available in each member state. In the case studies, we have seen that the risk varies strongly between different Member States. The UNITE accounts presents the average accident cost, which is the product of the risk and the cost per accident. This information fits very well into our approach (see section 5.2.5 below). However, for some modes we have seen that it is difficult to estimate the risk due to lack of data. A priority has to be to improve the data availability.

The cost share that falls on a user category (θ) could possibly be generalised to other Member States. A clear pattern emerges from our case studies. However, if the UNITE accounts are properly designed, this information should be possible to find within country accounts (see section 5.2.5).

5.2.3 Values

The cost per accident differs widely between different modes and is dependent on the accident definition. It is not recommended to generalise these values. In addition, if the risk is available, unit casualty values can be used to derive the unique accident cost. We have seen that for some modes, it is difficult to generalise the concept of an accident and the cost is not easily available.

Unit values should not be generalised directly. In the UNITE project a set of recommendations have been presented which allow adjustments to a Member State of a common European set of values.

5.2.4 Estimates

We do not recommend generalising the final estimates on the external accident cost. We know that the accident risk differs widely between different Member States and that the unit values are linked to purchase power. We do expect the external marginal accident to mirror these differences.

5.2.5 The link to the accounts

The matrix below depicts the monitoring scheme for a limited number of categories for total accident cost in relation to road transport accidents as proposed for the UNITE accounts. The column to the left shows the victims by different types of actors/vehicles involved in road accidents, and the row on the top shows the different types of accidents, in which the actors/vehicles may be involved.

Table 5-3 Total accident cost matrix, Sweden 1997 – 1999 (Million €).

Involved element/ Victim	ALL	Single accidents	Two party accidents			
			Pedestrian/ Cyclist	Car	Heavy vehicles	Motorcycle
ALL	**6265**	**2253**	**180**	**2975**	**821**	**35**
Pedestrian/Cyclist	**1871**	293	156	**1173**	228	20
Car	**3715**	**1604**	**14**	**1570**	**517**	**10**
Heavy vehicles	**292**	163	2	**72**	56	0
Motorcycle	**387**	193	8	**160**	20	5

Source: Lindberg (2001). Includes a b-value. Adjusted for underreporting.

As an example, we use information from Sweden. The total cost of accidents where car users are involved is 5120 M€. This includes the cost where car users are victim (3715 M€) and where car users are involved (2975 M€) less the cost for car-car collision accident (1570 M€) which otherwise would have been included twice. Dividing this total cost with the total number of car vehicle kilometres (58390 Mvkm) will give us the value of the first component $r(a+b+c)$ in the marginal cost expression. The cost share that falls on car users follows also from this general table and is θ=0.73 (3715/5120). The elasticity has to be found from other studies, let us assume E=–0.10 here. A similar table as above has been collected for the system external cost (c) separately, which gives us the final component in the external marginal cost expression 7 on page 6, this is also expressed per vehicle kilometre (rc).

Table 5-4: The external marginal cost calculated from the information in the accounts.

MC=r(a+b+c)(1-θ+E)+θ(rc)	r(a+b+c)	θ	E	rc
0.02 €/vkm	0.088 €/vkm	0.73	-0.10	0.01 €/vkm

However, this practical use of the accounts to estimate the external marginal cost requires that the accounts are made in the matrix form described above. This is not always the case as the information demanded to create accident matrix are rather complex.

6 Further research

Within this deliverable we have presented a theory of external marginal accident cost (see also Lindberg 2001). This is a 'new' approach based on welfare economic theory. It clears the ground for a more proper discussion on the magnitude of externalities. However, at the same time it raises a number of questions that have to be answered. One of the questions is how liability should be included; the other is how risk-avoiding behaviour should be included without complicating estimates on congestion externality. Yet, the most important insight is the necessity to take a broader view on traffic safety policy; to internalise the marginal external cost in relation to the trip decision will only be a partial answer to the best traffic safety policy. The approach taken in this work paves the ground for such broader views based on welfare economic theory.

Already the introduction to the report highlighted the need for more studies on the external marginal accident cost. From this summary of case studies, a number of key areas can be specified.

First, the theory is general and can be utilised in all modes of transport. However, the question of liability is still not satisfactory expressed in the case studies. Further explorations from the transport economic discipline into the area of law and economics are necessary.

Secondly, the assumption on the amount of internalised cost is critical, but rests on a very uncertain base. A number of empirical studies have to be carried out in this field. In addition, but separately from the main discussion in this report, the value of statistical life needs more studies before we can be certain on the magnitude.

Thirdly, it is clear that accident functions need to be further analysed. The approach taken in many of these studies have been limited in scope and very often only consider one dimension (e.g. the individual vehicle distance by HGVs).

Fourthly, risk-avoiding behaviour may constitute a significant cost component that is ignored in the approach taken.

Finally, studies on the external marginal accident cost should also include other types of behaviour than trip decision. A proper designed economic instrument could probably both improve the individual user's travel decision and his behaviour while making this trip. However, traffic safety policy is not only economic instruments. A proper mix of efficient regulations and charges is necessary.

Glossary of Terms

Term	
Accident Elasticity	Percentage changes in the number of accidents in response to a one percent increase or decrease in the traffic volume. The accident elasticity = 1 + risk elasticity
Accident insurance	Voluntary or mandated insurance against the risks of accidents (property and health). The premia serve to (partly) internalise external costs.
Heterogenous traffic	Traffic with different types of vehicles or users (pedestrian/car, HGV/car etc). Accidents between these different vehicles/users are called intersystem accidents.
Homogenous traffic	Traffic with the same type of vehicles. Accidents between these vehicles are called intrasystem accidents.
Injurer	In a collision accident the injurer are the user that are not hurt in the accident. The injurer does not have to be guilty of the accident.
Marginal accident cost (MC)	When a user enters the traffic he will expose himself to an accident risk. In addition he increases or decreases the risk for other users. When economic values are assigned to these changes in risk they express the marginal accident cost.
Marginal external accident cost	The user perceives already a part of the Marginal accident cost as a Private Marginal Cost (PMC). The difference between the Marginal accident cost and the PMC is the unpaid Marginal external accident cost.
Negligence rule	The faulty part bear all costs and if none is at fault the victim bear the cost.
Private Marginal Cost (PMC)	The cost the user perceives as an extra cost due to his decision to take one more trip.
Revealed preference	Valuation technique wherein consumers'choices are revealed in the marketplace (e.g. by the purchase of a good).
Risk avoiding behaviour	When a user perceives that the risk increases he changes his behaviour and search for safer alternatives. This means that the observed change in risk due to increased traffic may be an underestimation of the cost; in addition to the cost of accidents the users also have cost of protection.
Risk Elasticity	Percentage changes in the accident risk in response to a one percent increase or decrease in the traffic volume.
Risk value	A term often used instead of VOSL to emphasise the origin of the value; i.e. a statement about the WTP for risk-reduction. This term is also applicable to non-fatal accidents.
Stated preference	Valuation technique wherein monetary estimates are derived from hypothetical statements by individuals about their preferences. The typical method used is a questionnaire approach (e.g. contingent valuation method).
Strict liability	The user under strict liability will bear all cost irrespectively of his and the other parts behaviour. A number of variations exist where the other parts behaviour may reduce the liability.
System externalities (accidents)	The expected accident cost to the rest of the society when the user exposes himself to risk by entering into the traffic flow- mainly medical and hospital costs
Traffic category externalities (accidents)	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.
Traffic volume externalities (accidents)	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; and finally
Value of statistical life (VOSL)	An unit often used to express individuals willingness-to-pay (WTP) for safety. The individual state (or reveal) a WTP for a small reduction in risk (dz) for a fatal accident; he is never asked the question about the value of life per se. If this risk change is summed over (n) individuals so that statistical the risk reduction will save one life we can also sum their WTP; this sum of the WTP then becomes the Value of statistical life (VOSL). $VOSL = WTP*n = WTP/dz \quad \text{if } n*dz = 1$
Victim	The user that are hurt in an accident
Willingness-to-pay (WTP)	The direct or indirect response to questionnaire about individuals willingness-to-pay for a good. For example the WTP for higher safety.

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